COMMERCIAL FISHERIES REVIEW

August 1954 Washington 25, D.C. Vol. 16, No. 8

FREEZING FISH AT SEA -- NEW ENGLAND

Part 8 - Some Factors Affecting the Salt (Sodium Chloride) Content of Haddock During Brine-Freezing and Water-Thawing

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ABSTRACT

A study of the penetration of salt into fish during brine-freezing was made in connection with the U. S. Fish and Wildlife Service's study of the commercial feasibility of freezing fish at sea aboard the experimental trawler Delaware. Penetration of salt was found to be influenced by the temperature, concentration, and composition of the sodium chloride brine; by the length of time the fish were immersed in the brine; and by whether the fish were gutted or ungutted. Salt penetration occurring under routine operations was found to be a minor factor, and salt was shown to be leached from the fish during water thawing. Salt content of the meat directly under the skin was shown, after water thawing, to be below the taste threshold (0.5 percent) for salt in fish.

INTRODUCTION

In the course of a continuing study of the feasibility of freezing fish at sea, the Boston laboratory of the U. S. Fish and Wildlife Service has investigated immersion freezing (Magnusson, Pottinger, and Hartshorne 1952) of the fish aboard the experimental trawler Delaware. The frozen fish are water-thawed prior to commercial processing into fillets. Results to date with round (uneviscerated) fish indicate that this method of freezing is commercially feasible. A recent and thorough review of the study has been reported by Puncochar and Pottinger (1953).

In the formative stages of the freezing-at-sea project, there was some question as to whether the freezing by immersion in cold sodium-chloride brines might be objectionable from the standpoint of possible excessive penetration of the salt into the meat of the fish. Studies by various investigators (Plank, Ehrenbaum, and Reuter 1916; Almy and Field 1921; and Stiles 1922) have indicated that with proper procedures the amount of salt penetrating into the meat can be controlled. Preliminary work along these lines at the Boston laboratory confirmed these findings. Later, this

Fig. 1 - Experimental freezing tank.

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laboratory initiated a detailed study of the various factors governing the penetration of salt into fish during the immersion-freezing process. The study was to serve as a guide in the development of suitable procedures for the immersion-freezing of certain varieties of groundfish native to the Northwestern Atlantic Ocean.

The following major factors governing the penetration of salt into the meat during immersion-freezing of fish were selected from the studies conducted at the Boston laboratory and will be reported on here:

1. The effect of brine temperature.
2. The effect of brine concentration.
3. The effect of immersion time.
4. The effect of brine composition.
5. The effect of evisceration of fish prior to freezing.
6. Salt penetration during unsupervised semicommercial operations.
7. The leaching of penetrated salt during the water-thawing process.

The penetrated salt content in brine-frozen fish and in brine-frozen and water-thawed fish will be discussed in terms of taste thresholds and tolerances for salt in fish.

EXPERIMENTAL

A study of the published literature on the penetration of salt into fish during immersion-freezing in sodium-chloride brines indicated that sample control was of paramount importance for reproducibility of results. Replicate values of salt content, in some cases, varied by as much as 200 to 300 percent (Almy and Field 1921). Preliminary work at this laboratory, which showed variations in replicate values of some 40 to 50 percent, confirmed the necessity for sample control. On the basis of this preliminary work and to fulfill the requirements for which the study was initiated, a reproducibility of ± 20 percent was deemed necessary.

A precise and reproducible method of sampling the frozen fish was developed to meet these requirements. In the preparation of samples for determination of salt content, the heads and tails of the individual brine-frozen haddock were removed with a meat saw. The skin, relatively easily removed by hand from the frozen fish, was discarded. The exposed meat, from pectoral fin to tail and between the lateral lines and dorsal line to a depth of one-quarter inch, was very carefully cut from the still semifrozen fish. A second quarter-inch layer, identical to the first, was then removed from the exposed interior meat. Figure 2 by means of a cross-sectional drawing of a fish illustrates this procedure.

Six strips of meat, of the same depth level, from three fish were grouped to form one sample. The sample was then ground in a meat grinder, mixed thoroughly by hand, and reground. Two portions of the ground meat, of about 10 grams each, were removed for analyses. The salt content of three such samples, in good quantitative agreement in the majority of cases, was averaged to give a relatively stable, reproducible figure for salt penetration. Total salt content was determined on samples prepared from all the meat above the lateral lines as illustrated in figure 2. Salt determinations were made by the modified Volhard titration procedure of the Association of Official Agricultural Chemists (1950).

Unless the conditions of the experiment required otherwise, all brines used in the study contained 23 percent (by weight) sodium chloride. Such a solution is of the eutectic concentration, affording the lowest freezing point (-6° F.) that is possible

with sodium-chloride solutions. The total salt content of trawl-caught gutted haddock, stored in ice, was found to range from 0.13 to 0.17 percent.

BRINE TEMPERATURE AND CONCENTRATION: To study the effects of brine temperature, of brine concentration, and of length of immersion periods on salt penetration, a portable immersion freezer developed at this laboratory was used (Oldershaw, Holston, and Pottinger 1953). The relatively small quantities of brine (150 pounds) used in the freezer and the ease with which the temperature of the brine could be controlled facilitated study of the different factors governing salt penetration. Round haddock of known history were frozen in brine at -6°, 0°, 5°, 10°, and 15° F., at sodium-chloride concentrations of 15 and 23 percent. They were held in the brine for periods of time up to 24 hours.

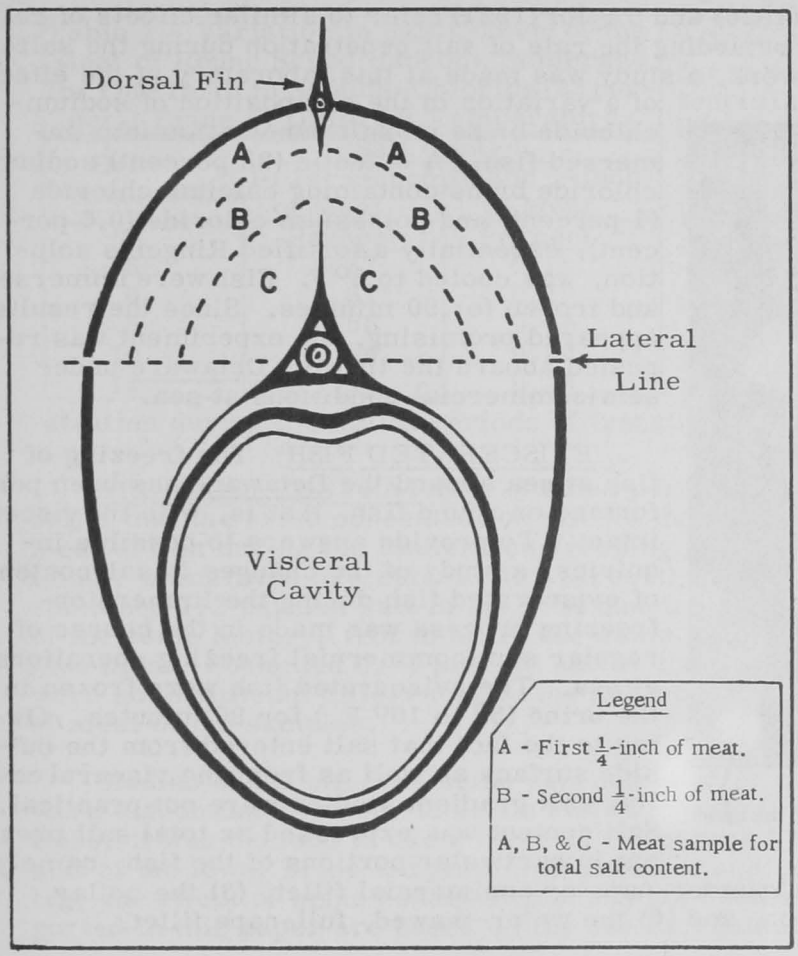

Fig. 2 - Cross-section of haddock showing portions of meat removed for salt analyses.

IMMERSION PERIOD: The observed continuation of salt penetration into the fish throughout an immersion period of 24 hours appeared to conflict with reports from the West Coast (private communication) concerning the prolonged immersion of salmon and tuna in cold (5° F.) sodium-chloride brines without undue penetration of salt into the fish. An experiment was therefore conducted to test the degree and rate of penetration of salt into fish during a two-week immersion in cold brine. Fresh (less than 24 hours dead), carefully iced, undamaged, round haddock were chosen for the experiment. They were rinsed to remove slime and debris, and were individually tagged for sample identification. The fish were separated into groups of three, and each group was weighed. The fish were then immersed in a cold (5° F.) sodium-chloride (23 percent) brine. The brine was agitated by a sump pump, and the temperature was controlled by a thermostat. The usual variation in temperature was about ±1° F., with two short periods when the temperature dropped to about +2° F. A group of three fish was removed at the end of the first, second, fourth, sixth, eighth, tenth, and twelfth day.

Upon removal from the brine, the fish comprising a particular group were washed and weighed. Each fish was cut in cross-section at the point of maximum girth and examined for evidence of thawing due to excessive salt penetration. The extent of thawing, evidenced by a dark ring of meat surrounding white, hard-frozen meat, was measured. The fish were then wrapped in kraft paper to retard desiccation and stored in a cold (-20° F. ambient temperature) box. Subsequently, determinations

of penetrated salt, of total salt, and of moisture changes in the meat due to salt penetration were made.

BRINE COMPOSITION: Hober (1945) reports the results of many investigations of the "solubilizing" of animal membranes by pure sodium-chloride solutions and also the prevention of such action by the addition of small quantities of calcium and magnesium salts. Tressler (1920) and Taylor (1921) refer to similar effects of calcium and magnesium salts in retarding the rate of salt penetration during the salting of fish. In line with this work, a study was made at this laboratory of the effect of a variation in the composition of sodium-chloride brine on salt penetration into immersed fish. A eutectic (23 percent) sodium-chloride brine containing calcium chloride (1 percent) and potassium chloride (0.6 percent), essentially a fortified Ringer's solution, was cooled to 5° F. Fish were immersed and frozen for 90 minutes. Since the results appeared promising, the experiment was repeated aboard the trawler Delaware under semicommercial conditions at sea.

Fig. 3 - Hoisting defrosted round fish from the thawing tank.

EVISCERATED FISH: The freezing of fish at sea aboard the Delaware has been performed on round fish, that is, with the viscera intact. To provide answers to possible inquiries, a study of the changes in salt content of eviscerated fish during the immersion-freezing process was made in the course of regular semicommercial freezing operations at sea. The eviscerated fish were frozen in the brine (5° to 10° F.) for 90 minutes. Owing to the fact that salt entered from the outside surface as well as from the visceral cavity, salt gradient studies were not practical. Salt content was expressed as total salt present in particular portions of the fish, namely: (1) the full-nape fillet, (2) the quarter-nape or commercial fillet, (3) the collar, (4) the nape, (5) the tail portion, and (6) the water-thawed, full-nape fillet.

SALT CONTENT OF COMMERCIALLY BRINE-FROZEN AND OF BRINE-FROZEN AND WATER-THAWED FISH: Several large random samples of haddock and of scrod haddock frozen at sea with only superficial supervision, were removed from various lots of frozen fish before and after routine water-thawing processing. The large haddock and the scrod haddock had been immersed in the cold (5° to 8° F.) eutectic brine for 180 minutes and for 90 minutes, respectively. These immersion periods have been found to fit conveniently into the normal routine of operations aboard the trawler. The conditions of the water thawing, insofar as was practical for large quantities of fish, were standardized. Temperature of the thawing water was maintained at 60° F. The water was agitated by means of a motor-driven propeller. The scrod were immersed in the thawing water for 120 minutes and the haddock for 200 minutes. The thawed samples were immediately refrozen in a plate freezer (-20° F., ambient temperature) to insure that salt remaining in the meat did not diffuse throughout the fish. Salt gradient studies were performed on 6 samples of 3 fish each, of both the brine-frozen (before water thawing) and brine-frozen and water-thawed scrod haddock and haddock.

RESULTS AND DISCUSSION

BRINE TEMPERATURE: The effect of brine temperature upon salt penetration into fish during an immersion-freezing process is shown in table 1. A graded increase in salt content in the first quarter-inch of meat, with increase of brine temperature, is observed. The increase in salt content of the second quarter-inch of meat in all cases is slight and is well below the taste threshold (0.5 to 0.6 percent--unpublished data) for salt in fish. The increase in salt content in the first quarter-inch of meat evidences serious differences only when considered in relation to freezing rates at the differing brine temperatures. Fish immersed for one hour at -6° F. are wholly frozen and absorb further salt very slowly. Those immersed for one hour at higher brine temperatures are not frozen and continue to absorb salt at a relatively high rate. It is apparent that the brine temperature, to minimize the rate of salt penetration during the initial periods of freezing, should be held as low as is feasible.

Table 1 - Variation in Salt Content of the Meat of Round Scrod Haddock Immersed for One Hour in Sodium-Chloride (23 percent) Brine at Different Temperatures

Brine Temperature	Salt Content	
	In 1st ¼-inch of Meat	In 2nd ¼-inch of Meat
°F.	Percent	Percent
-6	0.37	0.15
0	0.51	0.19
5	0.55	0.24
10	0.64	0.23
15	1.15	0.24

BRINE CONCENTRATION: Studies performed in this laboratory confirmed the belief that the brine concentration affects the rate at which salt penetrates into the meat of fish during the immersion-freezing process. Scrod haddock, after a 60-minute immersion in a eutectic (23 percent) sodium-chloride brine held at 15° F., contained 1.2 percent salt in the first quarter-inch of meat. Other scrod haddock, of the same history, frozen under the same conditions in a 15-percent sodium-chloride brine, contained 0.72 percent salt in the corresponding level of meat. There were no significant differences in the salt contents of the second quarter-inch levels of meat of the samples.

Studies of the effect of brine concentration on the penetration of salt into fish were discontinued when, to attain faster freezing rates for semicommercial operations, it was decided to use a eutectic (23 percent) sodium-chloride brine. As a result of the lower brine temperatures possible and the correspondingly faster freezing, the effect of brine concentration has not been a problem. All other results reported in this paper are based on the use of a eutectic brine.

IMMERSION TIME: The effect of the length of the immersion period (up to 24 hours) for fish in brines of different temperatures is shown in table 2. During the first portion of the immersion period there is a relatively high rate of penetration of salt. The rate of penetration tapers off as the immersion period is increased to such an extent that penetration during the second two hours of a four-hour immersion period is approximately only 1/3 of that occurring in the first two hours. The initial higher rate continues for a longer period of time in fish frozen in the brines of higher

Table 2 - Variation in Salt Content of Meat of Round Scrod Haddock Immersed in Sodium-Chloride (23 percent) Brine for Differing Times and at Differing Temperatures

Immersion Time	Salt Content					
	5° F.		10° F.		15° F.	
	1st ¼-inch of Meat	2nd ¼-inch of Meat	1st ¼-inch of Meat	2nd ¼-inch of Meat	1st ¼-inch of Meat	2nd ¼-inch of Meat
Hours	Percent	Percent	Percent	Percent	Percent	Percent
1	0.55	0.24	0.64	0.23	1.15	0.24
2	0.91	0.31	1.10	0.26	1.27	0.26
4	1.22	0.20	1.29	0.24	1.49	0.21
24	2.09	0.84	3.02	0.93	5.15	3.01

temperatures. The relatively slow penetration occurring after the freezing of the outer layers of fish has been called "secondary penetration." It appears to persist throughout the immersion period. After 24 hours' immersion, the further increase in salt content due to "secondary penetration" is marked. It is greatly reduced, but not eliminated, by maintenance of lower brine temperatures. With the exception of the samples immersed for 24 hours, the increased salt content of the fish is again shown to be concentrated in the first quarter-inch of meat. After immersion for 24 hours, there is a noticeable increase in the salt content of the second quarter-inch of meat.

The results of the tests of salt penetration into fish immersed in cold (5° F.) brine for prolonged periods (up to 12 days) are shown in tables 3 and 4. Table 3 shows the thawing (due to increased salt content) which reached a readily measurable depth after 48 hours and reached a depth of 9/32 of an inch after the fish were immersed for 12 days. The corresponding increase in total salt content of the fish from 1.01 percent after being immersed in the brine for 1 day to 10.1 percent after 12 days' immersion is also shown. The high weight change occurring in the 10-day immersion group is not yet explainable. These figures, together with the initial weights of the various groups, are added to indicate the reason for the high total salt contents observed for the 6- and 10-day immersion groups. Thawing due to salt penetration was first noticeable as a very slight softening of the skin of the fish. As salt continued to penetrate into the frozen meat, thawing occurred at greater depths. Shrinkage, due apparently to loss of water from the fish, began after 48 hours and eventually became so great as to cause outlines of the muscular striations to appear on the skin. After four days the tail section became pliable; this condition spread slowly to about one-third the length of the fish at the time the test was terminated. Upon examination of the cut cross-sectional surfaces, two sharply demarked areas were observed. Centers were hard frozen and white, but surrounding the hard-frozen areas were bands of soft, highly discolored, unfrozen meat.

Table 3 - Effect of Prolonged Immersion of Round Scrod Haddock in Sodium-Chloride (23 percent) Brine at 5° F.

Immersion Time	Initial Weight of Fish	Weight Loss	Depth of Thaw in Meat	Total Salt Content 1/
Days	Grams	Percent	Inches	Percent
1	2320	0.8	0	1.01
2	2330	1.7	1/32	2.22
4	2635	1.7	3/32	4.68
6	2215	3.1	5/32	7.40
8	2430	1.9	7/32	6.21
10	1845	2/8.1	9/32	10.6
12	2050	1.7	9/32	10.1

1/ Of all meat above the lateral lines of the fish.
2/ The high weight loss in this group of fish is as yet unexplained.

Table 4 - Variation in Moisture and Salt Content of Meat of Round Scrod Haddock Immersed in Cold (5° F.) Sodium Chloride (23 percent) Brine for Extended Periods

Immersion Time	Moisture Content		Salt Content	
	1st ¼-inch of Meat	2nd ¼-inch of Meat	1st ¼-inch of Meat	2nd ¼-inch of Meat
Days	Percent	Percent	Percent	Percent
2	76.8	80.6	4.48	1.39
4	74.5	77.7	5.81	3.57
6	73.6	75.5	7.51	5.64
10	71.8	70.8	10.3	8.98
12	69.4	69.7	12.3	10.7

Table 4 shows the increase in penetrated salt in the first and second quarter-inch levels of meat during the prolonged immersion test. The corresponding changes in the moisture content of the two levels of meat are also tabulated. After two days' immersion, when thawing was first observed, the salt content of the first and second quarter-inch levels were 4.5 and 1.4 percent, respectively. On the twelfth day of the tests the salt in the corresponding levels of the test fish had risen to 12.3 and 10.7 percent, respectively. The characteristic smoothing out of the salt gradient as thawing continues is borne out by the changes in moisture content in the two levels of the fish during the test. After two days the moisture content of the first and

second quarter-inch levels was 76.8 and 80.6 percent, respectively. After 12 days' immersion, the moisture content of the corresponding levels was 69.4 and 69.7 percent.

These studies indicate that the penetration of salt into nonfatty groundfish (haddock) of the northwest Atlantic continues throughout the period of immersion in brine. The work of Godsil (1940) and of Lang and Farber (1939) on salt penetration into tuna during prolonged immersion in cold brines indicates that such secondary penetration is very much slower in these fish. Godsil found that when tuna were immersed in brine at 20° F., 34 days' immersion was required before the salt struck through the first $1\frac{1}{4}$ inches of meat. Lang and Farber found only 7 to 8 percent salt in the first quarter-inch of meat of tuna after immersion in cold (5° F.) brine for almost two months. Subsequent to the performance of this laboratory's work, a progress report by Harrison and Roach (1953) on brine freezing of fish was received. These investigators found no change in the sodium-chloride content of the meat of two types of fatty fish (king salmon and chum salmon) during brine freezing, whereas grey cod, similar in composition to cod and haddock found in the Atlantic Ocean, showed a distinct increase in salt content. Thus, there appears to exist a distinct difference in the permability of the meat of brine-frozen fatty fish of the Pacific Ocean and that of the nonfatty groundfish of the Atlantic Ocean.

BRINE COMPOSITION: Table 5 shows the effect of a modified sodium-chloride brine upon salt penetration into the immersed fish. In the laboratory tests and under actual full-scale semicommercial operations at sea, the salt penetration in the first quarter-inch of meat of fish frozen in such a brine was reduced by from 25 to 33 percent below that of fish frozen in the usual eutectic sodium-chloride brine. No salt penetrated into the second quarter-inch of meat. These results seem to indicate that penetration is, in part, a diffusion process that may be minimized by the use of calcium salts in sodium-chloride brines.

Table 5 - Variation in Salt Content of Meat of Round Scrod Haddock Immersed for $1\frac{1}{2}$ Hours in Sodium-Chloride (23 percent) Brine (5° F.) or in a Modified[1/] Sodium-Chloride (23 percent) Brine

Replicate	Salt Content			
	Sodium-Chloride Brine		Modified Sodium-Chloride Brine	
	1st $\frac{1}{4}$-inch of Meat	2nd $\frac{1}{4}$-inch of Meat	1st $\frac{1}{4}$-inch of Meat	2nd $\frac{1}{4}$-inch of Meat
Number	Percent	Percent	Percent	Percent
Iced round fish frozen in the laboratory[2/]				
1	0.73	0.23	0.46	0.16
2	0.77	0.21	0.47	0.17
Frozen at sea under semicommercial conditions[2/]				
1	1.13	0.32	0.88	0.13
2	1.21	0.26	0.92	0.19

1/ Modified brine contains sodium chloride (23 percent), calcium chloride (1.0 percent), and potassium chloride (0.6 percent).
2/ The penetration of salt into iced fish frozen in the laboratory was, in all cases, less that that occurring under semicommercial conditions at sea.

EVISCERATED FISH: The salt contents of the various portions of brine-frozen eviscerated fish are shown in figure 4. These studies indicate that, with the exception of the nape, the penetration of salt into these portions of fish is not excessive. At the most, it is within the range of greatest palatability for added salt in fish (umpublished data obtained at this laboratory). The quarter-nape or commercial fillet cut, which does not include the nape, contains, prior to water thawing, a total salt content of 0.72 percent. Such a salt content is well below that of the optimum salt level for palatability of brined fillets. From the standpoint of salt uptake it would appear that if adequate supervision of immersion time and brine temperature are exercised, eviscerated fish could be commercially frozen in brine.

SALT CONTENT OF COMMERCIALLY-FROZEN FISH: Large-scale analyses were performed on random samples of scrod haddock and haddock frozen at sea during different voyages of the experimental trawler Delaware. The results of those analyses for salt penetration during freezing are shown in table 6. In all cases the

penetration of salt was greater than that found in fish frozen under comparable conditions in the laboratory. Attempts are being made to determine the reason for this difference. Good agreement between samples is observed. The average salt content of 6 samples (each sample composed of 3 fish) of scrod and of haddock in the first quarter-inch are 1.1 and 1.4 percent, respectively. Variations in the individual samples are within 20 percent. The major penetration is confined to within the first quarter-inch, and that in the second quarter-inch is negligible. The tapering off of the rate of penetration is again evidenced since large haddock, immersed for twice the time of the scrod haddock, averaged only three-tenths of one percent more salt in the first quarter-inch of meat.

Table 6 - Variation in the Salt Content of Replicate Random Samples of Haddock and Scrod Haddock Frozen at Sea in Cold (5° to 8° F.) Sodium-Chloride (23 percent) Brine Under Semicommercial Conditions

Replicate Sample	Salt Content			
	Large Haddock 1/		Scrod Haddock 2/	
	1st ¼-inch of Meat	2nd ¼-inch of Meat	1st ¼-inch of Meat	2nd ¼-inch of Meat
Number	Percent	Percent	Percent	Percent
1	1.39	0.25	1.02	0.24
2	1.19	0.27	1.06	0.22
3	1.26	0.21	1.02	0.21
4	1.61	0.18	1.12	0.17
5	1.49	0.23	1.15	0.18
6	1.67	0.20	1.05	0.22
Average	1.4	0.22	1.11	0.21

1/ Large haddock were immersed in the brine for 180 minutes.
2/ Scrod haddock were immersed in the brine for 90 minutes.

LEACHING OF SALT DURING WATER THAWING: The random samples of brine-frozen and water-thawed scrod and large haddock had salt contents as shown in table 7. It is evident that a great proportion of the salt is leached from the meat during the thawing process. The slightly greater salt content of large haddock occasioned by the longer immersion periods necessary for freezing appears to be largely eliminated by leaching during the necessarily longer thawing period. In all samples, in the case of both scrod haddock and large haddock, the salt content has been reduced to a value only slightly greater than that of the normal unfrozen fish.

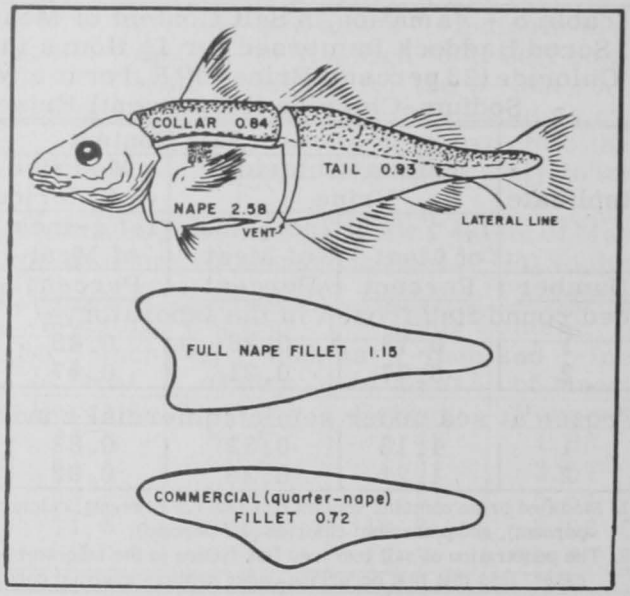

Fig. 4 - Variation in total salt (percent) content of various portions of eviscerated scrod haddock immersed in cold (5° F.) sodium-chloride (23 percent) brine for 90 minutes.

Concurrent work by this laboratory on salt uptake by haddock fillets during commercial brining prior to freezing included studies on palatabilities of and tolerances for differing levels of concentration of salt in the fillet. The work will be made the subject of another report but can be applied to studies of brine penetration to relate the observed salt contents to known tolerances for salt. Figure 2 shows a cross section of haddock at the point of maximum girth. The portions of the fish removed for sampling are indicated by the letters A (the first quarter-inch of meat) and B (the second quarter-inch of meat). The lateral and dorsal lines limiting the sample width are indicated. Table 8 indicates the salt content to be expected in these portions of brine-frozen haddock and scrod haddock, and also the salt content after water thawing. Since tests at this laboratory indicate a salt content of from 0.9 to 1.2 percent in the fillet to be optimum for palatability, the salt content of the first and second quarter-inch levels of the commercially brine-frozen and also of the water-thawed fish is indicated

in terms of percentage of this optimum concentration. The salt content of the first quarter-inch of meat of fish, frozen for three hours, is seen to be slightly above the optimum. That of the scrod haddock is in the optimum range. In both cases the second quarter-inch of meat is bland and "flat" to taste. The salt content of the first quarter-inch of meat of both haddock and scrod haddock after adequate water thawing is reduced to a concentration below that discernible by the palate. The fillets prepared for such fish are bland and "flat" to the taste. It is probable that, contrary to reports of possibly excessive saltiness, fillets prepared from brine-frozen and subsequently water-thawed fish would require, to attain desirable saline palatability, dipping in light brines.

Table 7 - Variation in Salt Content in Meat of Replicate Random Samples of Haddock and Scrod Haddock Thawed (200 and 120 minutes, respectively) in Water at 60° F. After Being Brine-Frozen[1] at Sea

Replicate Sample	Salt Content			
	Large Haddock		Scrod Haddock	
	1st ¼-inch of Meat	2nd ¼-inch of Meat	1st ¼-inch of Meat	2nd ¼-inch of Meat
Number	Percent	Percent	Percent	Percent
1	0.41	0.19	0.36	0.20
2	0.38	0.20	0.36	0.18
3	0.38	0.25	0.33	0.22
4	0.36	0.18	0.25	0.21
5	0.35	0.19	0.34	0.24
6	0.68	0.17	0.29	0.18
Average	0.43	0.19	0.32	0.21

1/ Haddock and scrod haddock were frozen in brine at 5° to 8° F. for 180 and 90 minutes, respectively.

CONCLUSIONS

Salt penetration into the meat of fish during immersion freezing varies directly with the temperature of the brine. The increased penetration reaches serious proportions from the standpoint of palatability when the brine temperature is 15° F. or above. For this reason and because of the increased penetration observed under commercial-freezing conditions, it is recommended that temperature of a sodium-chloride (23 percent) brine be maintained at or preferably below 10° F. when freezing fish.

Immersion of the fish for periods of time longer than is required for freezing causes an unnecessarily excessive penetration of salt. The initial penetration is rapid until the outer layers of meat have been frozen. The rate of penetration then tapers off but continues slowly throughout the immersion period. This "secondary penetration" is greatly reduced but not eliminated by maintenance of the lowest feasible brine temperatures. Contrary to results observed by other investigators with brine-frozen fatty fish, prolonged immersion of haddock, a nonfatty groundfish, causes it to thaw as a result of excessive penetration of salt. The two closely interrelated factors of brine temperature and immersion time govern, in the main, the penetration of salt into the meat. For these reasons it is recommended that immersion times be restricted to four hours or less, if possible.

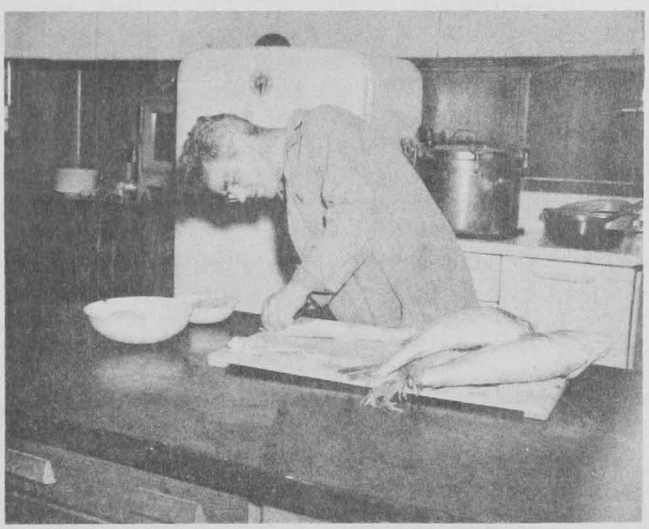

Fig. 5 - Testing the fillets in the laboratory.

An increase in brine concentration causes a proportional increase in the penetration of salt into fish during the freezing process. The Boston Laboratory, thus

far has standardized for semicommercial operations on a eutectic (23 percent) sodium-chloride brine. As a result of the lower freezing temperatures and faster freezing rates possible through use of such brines, the effect of brine concentration upon salt penetration has not been a problem.

The addition of small quantities of calcium (1 percent) and of potassium (0.6 percent) salts to a sodium-chloride brine retards the penetration of salt into the

Table 8 - Salt Content of Brine-Frozen and Water-Thawed Haddock and Scrod Haddock Expressed in Both Percentage and Percentage of Optimum Salt Content for Palatability[1/]

Sample	Salt Content			
	Brine-frozen		Brine-frozen and Water-thawed	
	Percent	Percent of Optimum Palatability	Percent	Percent of Optimum Palatability
Haddock:				
1st $\frac{1}{4}$-inch of Meat	1.4	127	0.43	39
2nd $\frac{1}{4}$-inch of Meat	0.22	20	0.19	17
Scrod haddock:				
1st $\frac{1}{4}$-inch of Meat	1.1	100	0.32	29
2nd $\frac{1}{4}$-inch of Meat	0.21	19	0.21	19

1/ The percentage of optimum palatability is based on the optimum salinity (1.1 percent) as found by experiment. Those values which are below 50 percent of optimum palatability are below the taste threshold for salt in fish.

fish frozen in such a brine. Salt content in the first quarter-inch of meat of fish frozen in the "modified" brine is 25 to 33 percent lower than in control fish frozen in the usual sodium-chloride brine.

The salt content of commercial fillets prepared from fish that were eviscerated prior to brine freezing is below the range of optimum palatability for salt (0.9 to 1.2 percent). Further, water-thawing of the fish prior to filleting reduces the salt content to a level below the taste threshold for salt (0.5 to 0.6 percent) in fish. Excessive salt penetration occurred only in the nape of the fish, a portion which is not normally incorporated into the commercial fillet.

The salt gradient analyses of random samples of fish, though drawn from lots frozen during different voyages of the Delaware, indicate that differences in the content of penetrated salt are not large under normal operating conditions. After water-thawing of the fish, the salt content is reduced to a level which is usually below the taste threshold for salt in fish.

The analyses further show that excessive penetration did not occur in routine freezing operations. The penetration of salt in scrod haddock and large haddock has been shown to be restricted almost wholly to the first quarter-inch of meat during freezing under semicommercial conditions. It has further been shown that the penetrated salt is leached during water-thawing to such an extent as to bring about a bland or "flat" taste to the final product.

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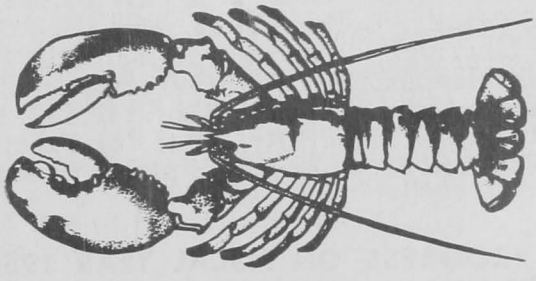
LOBSTER PEGS



The whittling of lobster pegs is a pastime that brings monetary returns for many residents along the western coast of Nova Scotia. Used to plug the claws of lobsters after they have been caught to prevent them from damaging each other, the pegs find a market both in Canada and the United States. West Pubnico is a typical peg-whittling community. Here young and old alike, knife in hand, shave pieces of wood to the desired size to while away their spare moments.

--Trade News, March 1954.