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The Investigation of Drip and Juice available for Drip in Frozen Fish

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The purpose of this article is the examination of Cod frozen, stored, and defrosted in different ways, with a view to obtaining information leading to the elimination of Drip and to some explanation of the fundamental changes in the fish due to freezing.

Because of the many relevant factors a complete research was impossible in the time available. For this reason a review of the conditions known to affect Drip and the juice available for drip is proffered to indicate those factors investigated and those concurrently constant. These conditions are:

(1) Pre-freezing treatment:

- (a)- History of the fish.
- (b)- Temperature conditions in the fish following death.
- (c)- Time interval between death and freezing.

(2) Rate and Mode of freezing:

(3) Post-freezing treatment:

- (a)- Temperature changes in the frozen state, such as storage time and conditions.
- (b)- Rate and mode of thawing.
- (c)- Temperature and pressure variations during pressing.

The experimental treatment in this report is confined to (2) and (3) necessitating constant pre-freezing history.

Pre-freezing treatment

Due to the fact that in most cases, the fish used had been caught by an associate, the history of the fish prior to freezing was known so that measures could be taken to ensure constant conditions in the experimental fish.

Temperature conditions were of negligible importance in the case where fish were immediately frozen or pressed and elsewhere the fish was kept on ice at 33° Fahrenheit for twenty-four hours until required for freezing.

Unless the fish was pressed immediately the time interval between death and freezing was twenty-four hours.

Rate and Mode of Freezing

Three different general types of freezing were considered with their individual range of temperature. They may be classified as Brine, Air, and Reagent freezing.

Brine freezing was carried out in a specially constructed wooden container in which a fairly rapid and efficient circulation was possible through the action of a centrifugal pump of low pressure and large volume power. The addition of ice made it possible to attain temperatures as low as -3°F. with regularity. Lower temperatures could be produced by supplementing the brine with Calcium Chloride. In this way a brine temperature range of from -7 to plus 32°F. was available for experimental purposes.

Air freezing was accomplished with the aid of the sharp freezer of the National Fish Co. and for extremely slow freezing the cold box at hand was utilized.

Reagent freezing is a general term for the use of such cooling media as Benzene, Liquid Air, Carbon Dioxide-Ether mixtures, and Carbon Dioxide snow. Of this type of freezing only the latter two examples were investigated.

With the exception of this last general method it was customary to fillet the fish and then pack them in tin folders which had been coated with Paraffin. This arrangement served to maintain a uniform thickness of fish as well as to prevent infiltration of brine. Preliminary investigations indicated that, at a depth of one-half inch from the surface the difference in the rate of freezing when compared to that at the surface was negligible. For this reason the experimental sections were cut to approximately one inch in thickness. Furthermore thinner sections were impracticable due to the size of the bulb of the thermometer which was placed in the center of the mass of fish in order to construct a cooling curve.

The size of the Dewar flask used in freezing with Carbon-Dioxide - Ether mixtures necessitated dividing the fish into two smaller sections, the equivalent of those used for brine and air freezing, each of which was frozen separately.

For purposes of these experiments the fish was considered frozen when the temperature of the centre of the fish mass had lowered to twenty-five degrees Fahrenheit. Observations taken from the cooling curves indicated that at this point on the curve the tangent to the curve tended to parallel the temperature axis and this the latent heat of fusion of ices in the fish muscle had been practically accounted for. Where a cooling curve was impossible, such as in the case of Carbon-Dioxide-Ether mixtures the cessation of bubbling in the medium was used as the criterion for complete freezing.

Post-Freezing treatment

The fish sections were conveyed to the storage room of the North Atlantic immediately following freezing, where they were glazed from time to time to prevent drying and where they were either exposed to the fluctuations of the room temperature or kept in an incubator at a temperature constantly above the maximum temperature attained by the room. The temperature of the room varied from zero to 10°F. whereas that of the incubator was twelve degrees.

When desired for pressing the sections were allowed to thaw in air at room temperature, about sixty-seven degrees F., for three hours, at the end of which time the fish was quite limp and flexible. This length of time was arbitrarily adopted for convenience in arranging the experimental program. Consequently this procedure was investigated at a later date. The determination of the effect of different rates of defrosting was made by using water baths kept at constant temperatures. When temperature of the centre of the fish mass had risen to 34°F. the section was considered defrosted because at this temperature the curve for thawing had definitely deviated from the flat portion.

Other arbitrary procedures were the pressing the fish by subjecting to a pressure of fifteen pounds to the square inch and a temperature of 35°F. Variations in the pressure and temperature conditions of the apparatus were investigated in a later section of the work.

Apparatus

The apparatus, as drawn in the diagram, consists of four main units:

(1) An expression system made up of a water-tight brass cylinder and an outlet therefrom.

(2) A lever system by which the pressure was adjusted.

(3) A weighing system consisting of a balance and a flask for collecting juice.

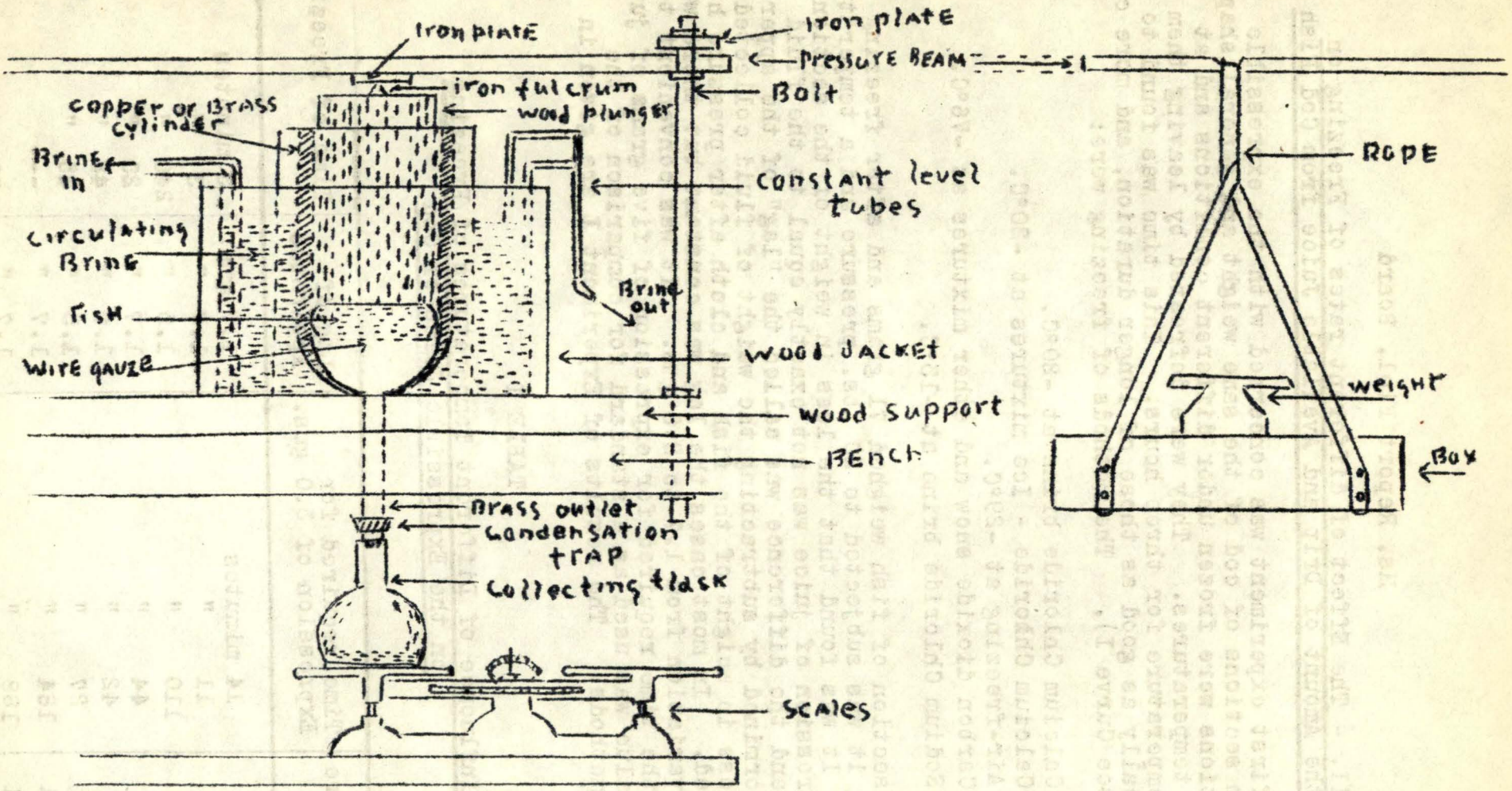
(4) A cooling system by which the temperature was regulated.

For ready expression of juice the section of fish was enclosed in linen and placed on a circular piece of wire gauze which fitted tightly into the cylinder. This arrangement prevented clogging of the outlet. Rapid drainage was made possible by constructing the base of the cylinder at an angle of 45° concavity. Retention of fluid in the walls of the container was practically impossible due to the fact that the cylinder was constructed of brass.

Pressure was brought to bear on the section of fish by means of a seven foot long hardwood plank acting as a lever on a solid hardwood cylinder which fitted into the brass cylinder. The wooden cylinder did not fit snugly but when a screen of wire gauze was placed around it the plunger slid easily and snugly into the brass cylinder. In this way jamming due to heating and accumulation of moisture was prevented. Absorption of fluid into the wooden plunger was minimized by coating it with paraffin wax. The pressure was regulated by adding weights to a box which hung down from the extreme end of the lever-plank. At the point of contact between the lever-plank and the wooden plunger the first was fitted with a ground piece of cast iron into which fitted a knife-edge piece of cast iron of the second.

Thus when weights were added to the box and the lever-plank was placed upon the knife-edge of the plunger the section of fish was squeezed and the juice flowed freely through the gauze support into the outlet. The juice was collected in a narrow necked Florence flask which rested on one pan of a balance.

In order to maintain a temperature as constant as possible the cylinder was kept in a medium of constantly stirred water. This water entered the water-jacket made up of an internal sheet of galvanized iron and an external jacket of wood about two inches in thickness. The water left by way of a constant level outlet.



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II. - The Effect of different rates of Freezing on the Amount of Drip and Available Juice from Cod Fish

The first experiment was concerned with the expressible juice from sections of cod of the same weight and general shape. These sections were frozen under different conditions and at different temperatures. They were defrosted by leaving them at room temperature for three hours. This time was found to be practically as good as those of longer duration, and more convenient (see Curve I). The methods of freezing were:

(1) Calcium Chloride brine at -20°C.
(2) Calcium Chloride - Ice mixtures at -20°C.
(3) Air-freezing at -29°C.
(4) Carbon dioxide snow and ether mixtures at -76°C.
(5) Sodium Chloride brine at -13°C.

Each section of fish weighed 71 grams and after freezing and defrosting it was subjected to 20 lbs. pressure and a temperature of 34°F. It was found that the loss in weight of the section due to expression of juice was not exactly equal to the fluid collected and the difference was called the "lag" of the apparatus. It was determined by subtracting the weight of fluid collected from the loss in weight of the fish and cloth after pressure had been applied. In most cases the lag was constant but there was a general variation from 1.7 to 2.5 gms. It was convenient to determine the time required for expression of five grams of juice and this value was used as a standard for comparison of the different methods. The results of Experiment I are given in Table I.

TABLE I

Influence of Different Temperatures of Freezing on the Expressible Juice of Cod

Temperature	Time required for Expression of 5.0 gms.	Lag of Apparatus	Time of Freezing
-76°C.	14 minutes	1.7 gms.	3 minutes
-76°C.	11 "	1.7 "	3 "
-29°C.	110 "	1.5 "	240 "
-20°C.	44 "	1.7 "	20 "
-20°C.	42 "	1.6 "	48 "
-13°C.	27 "	1.5 "	35 "
Control	184 "	1.7 "	--
Control	188 "	1.7 "	--

Table I would suggest that there is no relationship between time of freezing and the rate of expression of juice. It also suggests that there is a zone of temperature above and below which the juice may be expressed less like that from fresh fish. However the amount of juice lost by the defrosting process was not taken into account. It is reasonable to suppose that that section losing a large proportion of juice by defrosting will have less available for expression and that the smaller the amount of fluid lost by defrosting the more will be available for expression.

Experiment II was done to investigate both the drip from defrosting and the juice expressible from sections of fish from different temperatures. The methods were:

(1) Carbon Dioxide snow-ether mixtures at -76°C.
(2) Air freezing at 8°F. or -13°C.
(3) Brine freezing at -3°F. or -19°C.

The pressure, temperature factors were the same as in Experiment I except that the standard was the time required for expression of 10 gms. of fluid.

The results of Experiment II are given in Table II.

TABLE II

Influence of different Temperatures of Freezing on the Expressible Juice and Drip from Cod

Temperature	Time Required for Expression of 10 gms.	Lag of Apparatus	Time of Freezing	3 Hours Drip
-76°C.	15 minutes	1.95	3 min.	1.3
-19°C.	30 "	2.2	14 "	6.6
-13°C.	36 "	2.3	360 "	15.3
-13°C.	20 "	2.1	240 "	10.0
Control	36 "	2.2	--	--
Control	42 "	2.35	--	--

The results in Table II show that whereas the rate of expression of juice from these different sections varies universely as the temperature, the amount of drip in three hours defrosting varies directly as the temperature.

Experiment III was performed under different conditions. The range of temperatures was extended. The fish sections were put in half-pound tins and sealed. The tins were then frozen in brine, and Carbon Dioxide Snow at the following temperatures: 15°, 2°, 0°, -105°F.
The cans were then defrosted at 20°F. for one hour. The new time for defrosting was found satisfactory for the new conditions. Drip was calculated by the difference in weight of each can before packing with fish and the weight of the can after removal of the defrosted fish section. The weight of each section of fish was 232 grams. These sections, when defrosted, were subjected to 20 lbs. pressure and a temperature of 34°F.

The results of Experiment III are given in Table III.

TABLE III

Effect of different Temperatures of Freezing on the Expressible Juice and Drip from Cod

Temperature (°F.)	Time Required for expression of 10 gms.	Lag of Apparatus	Time of Freezing Mixture	Drip in one hour
-105	30	1.05	60	3.7
0	33	2.30	60	7.1
+2	45	1.50	60	6.7
+15	13	1.95	90	6.6

The results of Experiment III indicate that when the time for freezing mixture is constant, the lower the temperature, the less the expressible juice, and the less the drip.

Experiment IV was done under the same conditions as Experiment III. The range of temperature was 15, 9, 3, 0, -2.5, -105°F. The results are given in Table IV. Weight of fish section = 120 gms.

TABLE IV

Temperature (°F.)	Time required for Expression of 5 gms.	Lag of Apparatus	Time of Freezing	Drip
15	46	2.1	40	1.50
9	42	1.75	35	1.15
3	42	1.60	35	1.20
0	40	2.30	30	1.20
-2.5	37	1.70	30	1.70
-105	34	2.00	17	1.85

The results of experiment III and IV suggest that when the time of freezing is less than 60 minutes there is little difference in brine freezing over the temperature ranges 15°F. to -105°F.

Experiments II, III, IV indicate that two factors play a part in determining the release of water from fish following freezing - the time and temperature of freezing. The temperature of freezing seems to be a factor depending on the time of freezing and is determinate in a zone of time of freezing at most from one to four hours. Beyond this zone the time of freezing is the primary factor. Experiment III suggests that in this zone there is an optimum temperature of about 0°F. at which the drip is not markedly more than at lower temperatures and at which the expressible juice is lost. Higher temperatures than 0°F. indicate that there is about the same drip but more readiness to lose the expressible juice.

Experiment V was done as a check on Experiments III and IV. The conditions were kept the same in V as in III and IV. The range of temperature was 15°, 2°, -0°, -105°F. The time for freezing was 90', 60', 60', 10'. Following freezing the cans were placed in water at 20°F. for 1 hour. At the end of this time the sections appeared uniformly limp and they were adjudged defrosted. The time of freezing and defrosting was practically identical for each: the 10' time held for CO_2 - ether mixtures, but this section was kept exposed to the low temperature of -105°F. for fifty minutes extra. The weight of fish used in Experiment V was 73 gms. Table V indicates the results obtained from this experiment.

TABLE V

Temperature (°F.)	Amount of Juice Expressed in 10'	Lag of Apparatus	Drip (gms)
15	9 gms.	1.95	2.0
2	6.5 "	1.50	2.5
0	6.3 "	2.30	2.1
-105	5.5 "	1.65	1.1

The results of Experiment V show that when time of freezing and conditions of defrosting are kept constant, the expressible juice is decreased the lower the temperature of freezing. There is little difference in drip from defrosting except that for CO_2 - Ether mixtures. It is suggested again that there is little to be gained by freezing at temperatures below 0°F: (expressible juice is decreased only 8% by a decrease of 105°F.)

III (a) - Rate of Defrosting and Expressible Juice

To determine the importance of this factor a large fish was obtained from the National Fish Co. It was filleted, packed in cans, frozen in brine at 0°F. for 1 hour. Thermometer controls indicated that this length of time was sufficient for complete freezing. Four cans of fish were frozen this way. Defrosting was carried out as follows:

(a) Hot water at 100°F.
(b) Tap water at 68°F.
(c) Ice water at 50°F.
(d) Ice water at 32°F.

The drip was calculated from the difference in amount of fish in the frozen state from that when defrosted and blotted. Sections were pressed at 36°C. and 20 lbs. pressure.

Time	Temperature of Defrosting	Expressible Juice in 10'	Drip	Lag of Apparatus
½ hour	100°F.	10 gms.	2.7 gms	2.9 gms
1 hour	68°F.	6 gms.	1.25 "	2.0 "
2 hours	50°F.	7 gms.	2.9 "	1.9 "
8 hours	32°F.	9 gms.	1.4 "	2.25 "

The time of defrosting was estimated by the time required for the temperature to rise to 34°F.

It would seem probable that the time of defrosting has little if any bearing on the amount of expressible juice or drip. On the other hand the temperature of defrosting and the effects on drip show that an optimum temperature for defrosting is about 68°F.

III (b) - Time of defrosting and Expressible Juice

Conditions as in Experiment VI were maintained in this experiment. The sections were defrosted at 65°F. for different lengths of time.

(a) 3 hours 0'
(b) 4 " 13'
(c) 6 " 2'
(d) 8 " 28'
(e) 10 " 0'
(f) 11 " 49'

The results are given in Table VII. Expression at 32°F. and 20 lbs. pressure.

TABLE VII

Time (hrs)	Expressible Juice in 10'	Drip	Lag of Apparatus
3	8.5 gms.	5.4	2.1
4¼	11.0 "	7.0	1.7
6	12.0 "	6.3	2.75
8½	10.5 "	7.5	1.60
10	10.0 "	7.5	1.9
11¾	10.0 "	8.5	2.2

The fish used in this section gave more juice and drip than usual. It had been stored for a month at 12°F. Such a fish was frozen so that any differences might have been magnified by the greater loss of juice by expression and drip. Table VII suggests that the time of defrosting is of little importance and this bears out the results from Experiment VI.

IV - Storage:

(a) - Effect of Storage on Fish Frozen at different temperatures.

The fish were frozen at temperatures of 0°, 9°, -4°, -20°F, -105°F, -7°F. Storage at 12°F. was made possible through the courtesy of the National Fish Co. Defrosting was carried out for 3 hours at 67°F. Expression at 36°F. and 20 lbs. pressure. The storage was maintained for 27 days in each case. The results are given in Table VIII. 70 gms. of fish used for each temperature.

TABLE VIII

Temperature of freezing	Expressible Juice in 10'	Drip	Lag of Apparatus	E.J. + D
0°F. (a)	12.3	1.5	2.4	13.8
0° (b)	11.5	2.5	2.6	14.0
9°	8.5	5.4	2.1	13.9
-4° (a)	11.0	4.7	3.0	15.7
-4° (b)	10.0	3.7	1.85	13.7
-20° (a)	8.0	2.8	3.1	10.8
-20° (b)	9.0	3.4	3.0	12.4
-7°	12.0	1.8	1.7	13.8
-105°	7.0	6.7	2.8	13.7

(a) Kept at varying temperatures from +10° to +15°F.

(b) Kept in incubator at 12°F.

The first point to be deduced from Table VIII is the slight difference in effect when storage is carried out at a constant or varying temperature.

The second point to be deduced from Table VIII is taken from the column E.J. + D. which means expressible juice + Drip. It will be noticed that there is very little difference in the effect of storage on fish sections frozen at temperatures varying from 9°F. to -105°F.

IV - Storage

(b) Effect of time of Storage

70 gms. of fish were frozen at 0°F. in brine. The times of storage were 13, 27, 33 days. Expression was carried out at 38°F. and 20 lbs. pressure. Storage was maintained at a temperature from 0° - 14°F. or in an incubator at 12°F. The results are given in Table IX. Defrosted for 3 hrs. at 67°F.

TABLE IX

Time of Storage	Expressible Juice in 10'	Drip	Lag of Apparatus
13 days	7.5 gms.	1.3gm.	2.6 gms.
27 "	9.8 "	2.5 "	2.5 "
33 "	10.2 "	2.5 "	4.4 "

Results from Table IX show that storage for a month increases both the available juice for expression and drip by about 50% over that for storage of two weeks.

A section of the same fish pressed at the time of freezing showed an expression of 3 gms. in 10' and drip about 1.0 gms. Therefore the storage of 2 weeks increases the available juice for expression and drip by about 250% and for 1 month by about 300%.

V - Discussion

Moran (1) in his studies of freezing of gelatin observed that the structural formation of ice was controlled by freezing rate, absolute temperature, concentration of gelatin and pH. He found that below -20°C. the concentration of gelatin became constant and that at this point the gelatin contains 65.5% gelatin at pH =4.7. He concludes that the gelatin holds 53 % of its water by chemical attraction under these conditions.

Further observations on the irreversibility of freezing showed that the critical temperature for irreversible changes in egg yolk was -6°C. and for frog muscle was -2.5°C.

Callow (1) discussed the types of water in muscle. He considers two types: some of the water is found by chemical attraction and some by osmotic forces.

Plank (2) calculated the amount of water frozen at various temperatures by calorimetric measurements. He concludes that all the water content of muscle is not frozen until the temperature is reduced to -55°C. On the other hand about 91% is frozen at -20°C. or 0°F. and about 42% at 0°C. or 32°F.

These results confirm those obtained in the preceding experiments where 0°F. was found the temperature below which very little improvement, as determined by expression of juice and drip, was noted. Above 0°F. there was a distinct increase in available juice for expression and drip. At this temperature it is possible that the concentration of fish protein and other muscle contents becomes constant. This is of some value if true, for the uniformity of frozen fish products.

A brief review of results is:

(1) Freezing for one hour at 0°F. for 70 gms. of fish (Cod) is the optimum for efficiency and convenience.

(2) Defrosting at 67-68°F. for 3 hours for 70 gms. of fish is suggested.

(3) Storage increases available juice for expression and drip about 300% in a month. Varying temperature of storage is very little different in effect from constant temperature.

VI - References

(1) Moran, T.: Report of Food Investigation Board 1925,1926 p. 18, 39

(2) Callow, E.H. : Report of Food Investigation Board 1925 1926, p. 10

(3) Plank, R.: Zeit. Ges. Kälte-Ind, 1925,:32, 141.