The Processing of Dried Salted Fish

By

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Sun drying Gaspé cure.

BULLETIN No. 112

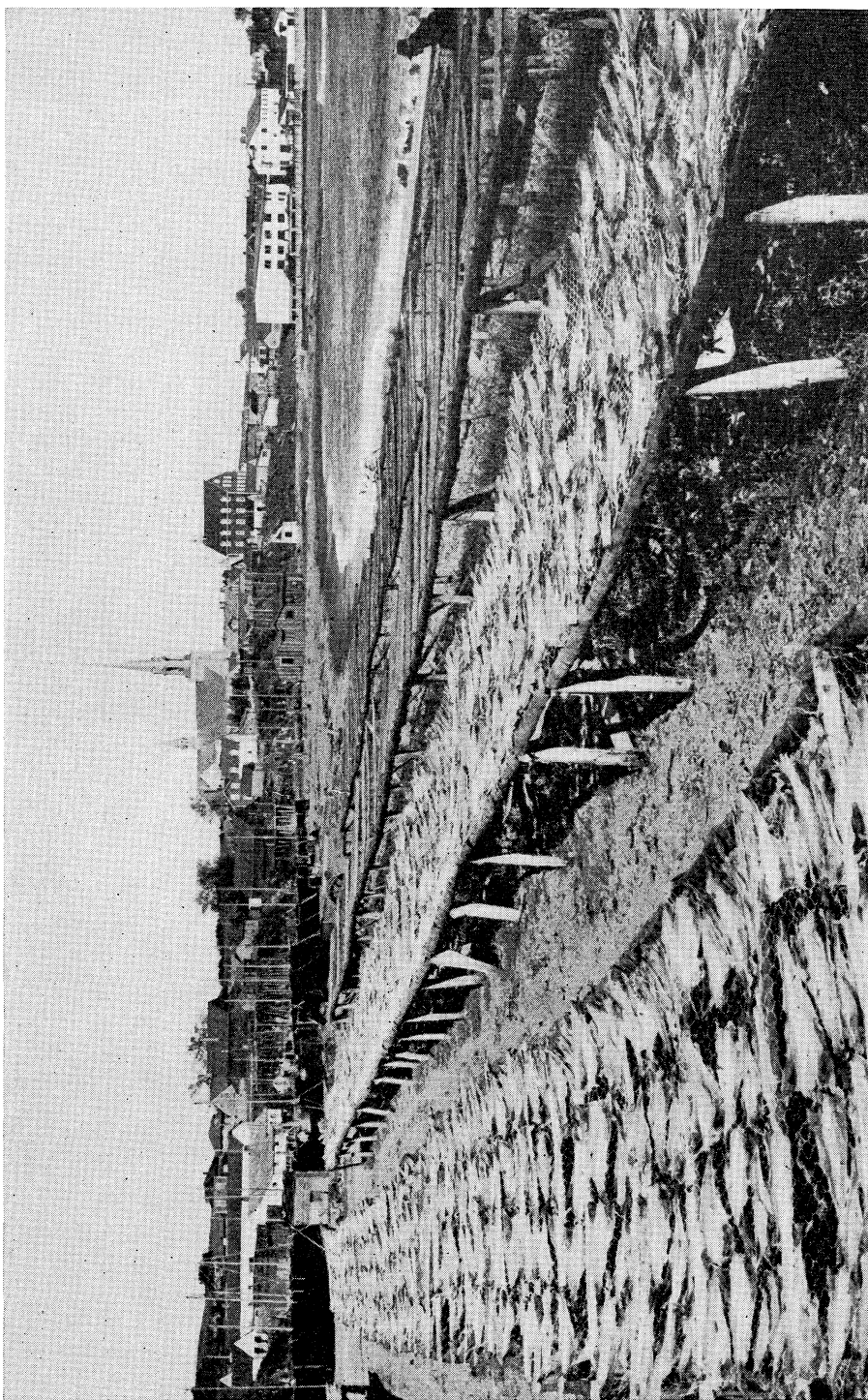# The Processing of Dried Salted Fish

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Bulletins of the Fisheries Research Board of Canada are published from time to time to present popular and scientific information concerning fishes and some other aquatic animals; their environment and the biology of their stocks; means of capture; and the handling, processing and utilizing of fish and fishery products.

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FOREWORD

The English edition of this Board's Bulletin No. IX (Methods of Handling Fish. 1. The Processing of Dried Fish. By A. G. Huntsman) has been out of print for a considerable time. From its first issue in 1927 that bulletin was popular and a reprinting has been under consideration for some time. However, during the period since it was issued our knowledge of the chemistry and bacteriology of the preservation of fish by salt has been extended and the drying of fish is now largely carried out indoors in well-designed tunnels under the control of the operator. For these reasons, while that portion of the original bulletin concerned with the dressing of fish has been left intact, the present bulletin has been extended to include sections concerned primarily with the bacteriology and the chemistry of fish salting, and artificial drying.

This bulletin has been written by members of the staffs of the Fisheries Research Board of Canada's Technological Stations at Halifax, N.S., Grande Rivière, P.Q., and the Technological Unit at St. John's, Nfld. The following staff members have contributed to it: S. A. Beatty, H. Fougère, C. H. Castell, H. P. Dussault, W. J. Dyer, M. A. Foley, W. A. MacCallum, and A. L. Wood.

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CHAPTER I

THE CARE OF FISH AT SEA

The salt fish industry of the Atlantic Provinces is under very serious economic pressure. Better facilities for the transport of fish to the processing plants and for transport of the finished packaged goods to the market have enabled much of the raw material that heretofore was marketed only as dried fish to be processed instead as fresh and frozen fillets or fish blocks. Competition from European processors is keen and the amount of salted fish produced by consumer countries has increased since the end of World War II. If the Canadian Atlantic salt fish industry is to prosper, perhaps even if it is to survive, this must be as the result of most careful attention to the cost of production and to the maintenance of high quality.

Fish can be ruined before it is landed even from shore boats returning to port daily. Ordinarily, spoilage in meats and fish is caused by bacteria. But bacteria seldom spoil fish in shore boats because they do not have time to grow to sufficient numbers.

In late fall, winter, and in the spring, the fish landed from the shore boats is usually of excellent quality. But in summer and early fall the fish landed daily may be poorer in quality than those iced several days in a trawler hold.

This poorer quality is always the result of warm weather and it is of three kinds.

1. *Fish may become soft without being sour or spoiling in the normal manner.* When split, the flesh tends to flake apart or may appear quite soft and mushy, resulting in a rough uneven surface after drying. This occurs most frequently during the warmer days of July and August and tends to disappear with the coming of cooler September weather.

Not too much is known about why this happens. Skippers of the trawlers believe that fish are soft in warm weather while they are still alive; and fish from some banks are believed to be softer than those from others. But it is known that temperature is one important factor in this type of softening. Fish landed daily from shore boats without ice is often softer than well-iced fish 7 or 8 days in a trawler. While shore-caught fish may not need the careful icing of trawler fish, a little ice, especially during the warm summer weather, makes a marked difference to the firmness of the fish landed.

If fish are very soft they can be discarded at splitting. But sometimes fish that seem all right when dressed, open up during handling and produce a very rough surface during drying.

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2. *The condition known as "putty fish" may arise.* There have been quite serious losses, particularly in the Gulf of St. Lawrence area, from this condition. It is the result of both heat and bacteria. Fish that get too warm become soft and tend to break open when they are dressed. Later, during the splitting and washing, bacteria get into these cracks. When the fish is salted, many of these cracks are pressed together leaving the bacteria inside the fish, and the salt outside. If these bacteria grow fast enough, they may spoil the fish before the salt strikes in to stop their growth. It takes from one to two full days in warm weather for the salt to penetrate the thicker parts of the fish, and usually only large fish become puttied.

Putty fish may also be the result of improper distribution of salt on the fish while they are being salted down. For an even distribution, the thickest portion of the fish requires the most salt. If too little is placed on the thick parts and if the fish are pressed tightly together, the flesh in this area will for some time have less salt than in the thinner portions of the fish. Sometimes the flesh here will spoil before the salt has completely penetrated, resulting in soft putty-like areas.

The prevention of putty fish is simple. Fish should be kept cool until split; they should then be washed in cool water and salted in a well-ventilated shed. Above all, extra care should be taken to place plenty of salt between the thicker portions of the fish to keep them from sticking together before they have become fully struck.

3. *The third cause of quality loss frequently encountered in shore fish is indirectly brought about by heat.* When the fish are alive they digest their food by means of digestive juices which flow from the walls of the stomach and intestines, and particularly from the cluster of short finger-like glands that form a ring around the front end of the stomach. These juices are not able to digest the flesh or organs of the fish itself while it is alive, but after death they act on them just as on the food in the stomach. And the warmer the fish, the faster these digestive juices work. They are the cause of "belly burn" in herring and mackerel, and of liver stains on the napes of cod.

This type of quality loss can be avoided. The fish should be gutted very shortly after death. If this is not possible they should be iced until they are gutted. In certain areas the trawls are underrun, and much of this fish is belly-burned in warm weather before it is brought into the boat. It is doubtful if underrunning catches as much fish as do flying sets. Certainly in warm weather the quality of the fish is not as good.

CHAPTER II

DRESSING

The actual dressing operation has not changed substantially since the publication of Bulletin IX some 30 years ago and the directions in that bulletin are so clear and concise that they are reproduced here:

"Bleeding

"Blood in the cured fish is objectionable from two standpoints. It darkens the fish wherever it remains, and so interferes more or less with getting the whiteness that is so desirable. It is also more prone to decomposition than is the flesh, and may so give an objectionable flavour to parts of the fish, where it occurs, that would otherwise be quite good.

"To bleed the fish, cut the throat immediately after the fish are taken from the water, before they begin to stiffen, and the blood ceases to run. It is a good plan to throw water over the fish after they are landed and before splitting, as this will remove much of the blood and slime that accumulates on the fish when it lies in the boats.

"Throating and ripping

"Hold the jaws of the fish closed with the left hand, and rest the back of its neck on the edge of the tub or table, thus opening the gills and exposing the throat. *With a sharp knife cut the throat across just behind the gills, and continue the cut to clear the gills from the body. Introduce the knife between and under the lug bones, and rip the belly from this point straight to the vent but not beyond.*

"When the rip goes behind the vent, the tendency is to carry the knife up the side at the last. This produces the so-called "sliver" condition, part of the flesh alongside the fin being left attached when the splitting is done, instead of going with the side to which it belongs. This causes a waste of part of the flesh and is to be avoided.

"Gutting

"Open the belly with one hand, and with the other remove the liver and put it into a tub. Then loosen the guts and pull them out.

"Beheading and trimming

"Make a cut just behind the gills up each side to the back. Then break the head from the body by pressing down on both with the back of the neck on the edge of the tub or table. Or better, place the fish back down and cut off the head with a heavy knife or cleaver.

"Splitting

"For this operation the regular splitting knife that can readily be bought in the trade, or the French splitting knife, should be used. The French splitting knife is curved two ways and is especially adapted to the splitting of large fish. It is important that the splitting knife should be in excellent condition in order to avoid giving the flesh a ragged appearance."

(See Fig. 1 of the present bulletin.)

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"Place the fish on the table or splitting board with the back against a cleat fastened to the board and with the tail to the right.

"With the belly of the fish toward you seize the upper nape or lug with the left hand. With the rip carried only to the vent make the first cut from the vent close along the left side of the vent fin a little past the end of the belly cavity.
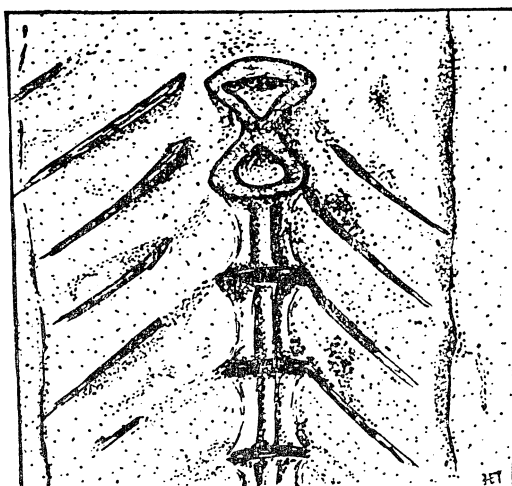

FIGURE 1. Appearance of backbone when properly cut.

"Insert the knife at the neck of the fish on the upper side of the bone, and make a clean cut to the tail, keeping close to the bone, so as to separate the flesh of the left side cleanly from the backbone all the way to the tail. The cut should not go so far through the flesh toward the back as to make the fish thin at that point when spread out.

"Cut the backbone through three joints behind the vent by a motion downwards and towards you, leaving the cut end of the bone appearing like a figure '8'. The point where the backbone is cut through should be just far enough back to avoid leaving a blood spot.

"Grasp the free end of the bone with the left hand, and strip it up cleanly with the knife from the flesh of the right side. When this is done properly, the white spinal cord is laid bare uninjured along the full length of the cut. If at any point the cut is too deep as shown by injury to the cord, the interlocking spines above the bone are apt to be so damaged that the fish will later break at that point. A cut should be made into the part of the backbone that remains in the tail in order to remove any blood there."

Where the volume of fish to be split is large, it is possible to employ machines that remove the head and split the fish, but the Canadian experience with these machines has not been sufficiently extensive to determine their overall efficiency and economics.

"Washing from the knife

" 'Washing from the knife' is done immediately after splitting.

"Wash the fish very thoroughly with clean water, removing the blood, which adheres to the flesh during splitting, and take particular care at the neck and at the cut end of the backbone. Remove the slime from the skin, cleaning the skin well along the back fins.

"A good supply of running water is desirable, but if still water is used, it should be changed frequently to prevent its getting so dirty as to fail to clean the fish properly."

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We have had many queries over the years as to whether sea water or fresh water is better for fish. Both have been used successfully and it does not seem to make much difference whether the water is salt or fresh, as long it is clean. But the water should be cold. In summer, dock water—particularly in the Gulf of St. Lawrence—can be very warm and possibly contaminated. On the other hand, wells supply water at 50°F. or lower over much of this area even during warm summer weather. One should use the coolest water available. Also the wash water should be kept running to keep it cool and clean.

"Whitenaping

"The belly is lined with a dark inner skin, which does not come away in gutting and splitting, but is to be seen on the napes of the split fish. If it is removed, the dried fish have a better, whiter appearance."

"To whitenape the fish, strip or rub this black inner skin off."
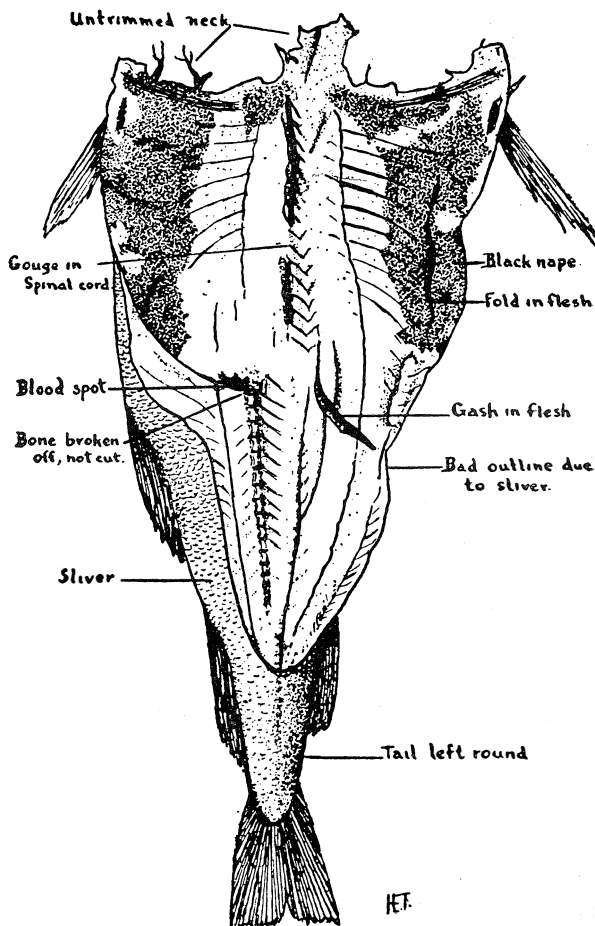
(See Fig. 2 of this present bulletin.)

FIGURE 2. Things to avoid in preparing dried fish.

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CHAPTER III

ABOUT SALT

Practically all our commercial salt (sodium chloride, or common salt) originates from the evaporation of sea water from present or ancient seas. The leaching of the land has gradually caused the sea to acquire about one-third of a pound of dissolved salts of various kinds in each gallon of water. Besides their chief constituent, common salt, these salts also include calcium salts, magnesium salts, potassium salts, carbonates, sulphates, bromides, iodides, and even traces of gold and silver. But a good fishery salt must contain very little of only a few of these other constituents. Fishery salt is of three kinds, depending on how it is obtained—solar salt, mined salt, and evaporated salt.

Solar Salt

Solar salt is obtained from the evaporation of sea water by the sun, in areas where the rainfall is low enough to allow long, uninterrupted periods of evaporation. These regions are usually dry for only part of the year, the dry season being followed by a rainy season.

In the manufacture of solar salt, the sea water is run into a settling pond either by pumps or at high tide, and the non-dissolved impurities (including clay) are allowed to settle out. As the sun dries up the water, the more insoluble of the dissolved constituents are forced out of solution and go to the bottom. The first ones to come down are limestone (calcium carbonate) and gypsum (calcium sulphate). When most of these have settled out, the brine is run into other settling ponds where the common salt starts to form. By the time most of this salt has crystallized out, the brine has become so concentrated that even the more soluble of the other constituents remaining in it also start to crystallize out. At this point the concentrated brine is run off and the common salt that was deposited is raked up and piled.

It is clear that the amount of impurities in a solar salt depends on the care with which it is made. But all solar salts contain some gypsum, and usually other calcium salts and often some other sulphates.

What difference do these impurities make? Too much gypsum in a salt may form a rough deposit like cement on the fish. A little gypsum has some advantage. A salt with about $\frac{1}{2}$ to 1% gypsum produces a whiter fish than does pure sodium chloride. Calcium and magnesium impurities generally tend to slow up the striking, and the freshening out of the fish before cooking. Magnesium impurities may give a more bitter taste than does pure salt. Iron and copper compounds, or traces of the metals themselves, are particularly bad because

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they stain the fish a dirty brown or yellow.   For these reasons the purer the salt, the better; and the only impurity that seems to have any merit at all is gypsum.

Solar salt is easily recognized if one knows how it is made.   A pure crystal of sodium chloride is a cube, or a squared shape.   Ordinary table salt consists of tiny cubes that can be recognized under a magnifying glass.   In a salt pond, the water dries from the surface, and so the salt starts to crystallize there.   It always starts out as a cube.   But it does not sink at once.   It settles slightly to

FIGURE 3.   Broken piece of one of the complex salt crystals.

form a dimple on the surface.   Then new crystals start forming along all four edges of the top face.   As they grow and the complex crystal gets heavier, new crystals again form along the top edges.   The result is the formation of an irregular, hollow, upside-down pyramid of salt still floating on the surface of the brine.   When the crystal becomes heavy enough or is upset by waves, it settles to the bottom.   Figure 3 shows a broken piece of one of these complex

crystals. These crystals are entirely too big to use and usually are crushed to pieces between 1/10 and 1/4 inch across. Solar salt can always be recognized as pieces of these pyramidal crystals. They show up as particles with a straight grain or as pieces with square corners and a straight grain to each side. Mined salt looks like pieces of broken quartz or white glass, and evaporated salt is always finer.

Mined Salt

Underground deposits of salt are fairly common. These also originated from sea water, in a region where the climate was, or still is, dry. A bay or arm of the sea with a narrow shallow entrance eventually filled up with salt because as the level of the water in it fell through evaporation, more flowed in from time to time from outside, and the narrow shallow mouth did not permit mixing of the stronger salty water inside with the more dilute sea water outside; eventually the increasingly more salty water inside became concentrated enough so that limestone and gypsum settled out, then the salt began to crystallize out. If there happened to be alternate rainy and dry seasons as was usually the case, a new small layer of gypsum was laid down each year. Also, a layer of earth or clay was usually deposited along with the gypsum and limestone. When the bay filled up and earth covered it, a potential salt mine was formed. Similar deposits originate from the evaporation of inland salt lakes or small seas.

Salt mined by digging out these deposits, that is, mined salt, may be very impure or quite pure depending on the deposition of impurities when the deposit of salt was originally formed. The most common impurity is gypsum, but clays and other insoluble materials are usually present as well.

Evaporated Salt

A deposit of salt near the surface is usually mined. But if the deposit is deep, water is pumped down through drill holes and the concentrated brine which returns is evaporated with heat. This is how much of our table salt is made. Since the evaporation is carefully controlled, this evaporated salt can be very pure.

What Constitutes a Good Fishery Salt?

A good fishery salt must strike quickly. It must come out of the fish readily on freshening. It must contain little or no objectionable impurities, particularly compounds of magnesium, iron, and copper. It must contain no bacteria capable of living and growing in the presence of salt. It must be of suitable particle size. Fine salt has two bad faults: it tends to become caked or solid in moist weather, and it is more difficult to salt evenly with it than with coarse salt. On the other hand, coarse salt strikes more slowly and may mark the surface of the fish. Probably the most suitable salt results from the mixing of fine evaporated salt with an equal volume of coarse salt which contains particles up to about 1/4 inch diameter.

TABLE I.—Average analytical values of fishery salts used in Eastern Canada.

Constituent	Solar			Evaporated	Mined	Overall average
	North American	Medit- terranean	Average			
	%	%	%	%	%	%
Water...........................	2.94	2.21	2.54	2.21	2.27	2.40
Common salt (sodium chloride)............	96.5	98.0	97.3	98.3	98.0	97.7
Calcium chloride........................	0.82	0.09	0.42	0.03	0.06	0.24
Calcium sulphate (gypsum)...............	1.45	0.68	1.03	0.67	1.13	1.08
Magnesium chloride.....................	0.82	0.26	0.52	0.06	0.07	0.30
Magnesium sulphate.....................	0.27	0.30	0.29	0.005	0.04	0.17
Insoluble...............................	0.10	0.38	0.25	0.03	0.56	0.40

Table I gives the average results of analyses of commercial salts done in the Fisheries Research Board's Halifax Station laboratories. It shows the amounts of various impurities that were found in solar, mined, and evaporated salts used in the fishery of Eastern Canada. The calcium sulphate or gypsum content averaged about 1% for all of these salts.

Of late quite a volume of fishery salt has been made by pressing ordinary fine salt into blocks and then crushing the blocks to about 1/4-inch mesh. The resulting salt contains enough fine particles to enable rapid striking, and enough coarse salt to hold the fish apart until they are cured.

Often fishermen claim that certain salts are strong or weak. This actually doesn't mean very much. One salt is said to be stronger than another if a *volume* measure (e.g. a bushel) of one salts more fish than does the same measure of the other. In practice this means that a *bushel* of the first salt is heavier than one of the second. If the salt is bought by *weight* (e.g. ton), and the fish are salted *by weight*, the salts all have about the same strength.

Salts should always be bought by weight, and the fish should always be salted with a definite proportion by weight of salt. For example, mined salt or fine evaporated salt probably weighs more than 90 lb. per bushel; solar salt may weigh any amount between 70 and 90 lb.; coarse evaporated salt may weigh less than 70 lb., and sometimes less than 60 lb. These differences in weights per measure explain why one salt can cure thoroughly while the same proportion by volume of another salt allows the fish to spoil. Salting by weight is particularly important with light salt cures, such as the Gaspé cure. Slightly too little salt can result in spoiled fish, slightly too much in an inferior quality product.

Most salts contain negligible amounts of iron and copper or their compounds. However, every year salt fish is found which is stained yellow and brown on the surface. This is due to iron or copper contamination of the salt. Care must be taken to store salt under conditions where these metals cannot get into the salt.

CHAPTER IV

HOW SALT CURES FISH

EFFECT OF SALTING ON FISH

The flesh of groundfish, such as cod, contains about 80% water. When salt is added to the surface of a fish, some dissolves in this water. If the fish is examined shortly after salting, it will be found that the surface has become quite sticky. This is because the salt affects the protein in the flesh and makes it swell and absorb salt and water. Soon, however, sufficient salt has been absorbed by the surface layers so that the proteins pass the swelling stage. They now start to shrink and harden and begin to lose water with the result that a large part of the water in the flesh oozes out and forms a pickle around the fish.

The end result is an absorption of salt by the fish and, by the time it is fully struck, the loss of just under one-half of the original amount of water in the flesh.

Furthermore, salt affects the state of the flesh itself with the result that the finished product will have physical characteristics which will depend very much upon the quantity of salt the fish takes up, the temperature, and curing time.

Salt also stops or slows spoilage according to the quantity added.

These general facts constitute the basis of the art of salting. It is by knowing their limits that the art may be practiced successfully; although even with the guidance of well-defined methods, salting of fish requires experience.

SALT AS A PRESERVATIVE

Salt does not always kill the bacteria that can spoil the fish. The bacteria which contribute to spoilage in fresh fish cannot survive very long at salt concentrations much above 12% by weight of the green fish. On the other hand, some types of bacteria such as the halophiles (those that can grow in the presence of salt) require high concentrations of salt to live; and, contrary to other types, are made inactive or die out at low salt concentration.

Salt fish therefore is subject to spoilage at both extremes of salt concentration.

Furthermore, it must be pointed out that fish salted in the proportions of 6 to 16 lb. of salt per 100 lb. of split fish will not keep long in the green state. The smaller the quantity of salt used, the more quickly the fish will spoil.

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Table II gives an idea of the keeping time of kench salted fish, salted in proportions of 16 lb. of salt to 100 lb. of fish, indicating the storage temperature and the period of year during which the fish was caught. The season during which the fish was caught seems to have a bearing on the preserving effect of salt, but since salted fish is usually produced in the summer months, it is especially that season which concerns us. Therefore, as may be seen, kenched fish, salted with 16 lb. of salt per 100 lb. of undressed fish, will keep in summer for only some 11 to 14 days. Fish kept under pickle spoils much more slowly than kench salted fish.

TABLE II.—Keeping time of kench salted fish, salted in proportions of 16 lb. of salt to 100 lb. of fish.

Storage temperature	Keeping time	Period of year
°F.		
84	10 to 20 hours	August
70	12 to 18 hours	June
66	2 to 3 days	January
45	6 to 7 days	August
45	6 to 9 days	June
45	16 to 21 days	January
37	23 to 27 days	January
33	11 to 14 days	June
33	30 to 34 days	January

As a general rule, light salted fish, whether kench or pickle salted, should not be kept too long in storage. Usually 3 days is the limit for the low concentration of salt, and 8 days for the high, provided the temperature is not too high. The lower the temperature the better, and temperatures of 65°F. or above should be avoided as much as possible.

CHAPTER V

THE RELATION BETWEEN THE AMOUNT OF SALT USED ON FISH AND TYPE OF CURE

There are two typical salt fish cures on the Atlantic coast, the light salt cure, exemplified by the Gaspé cure, and the heavy salted product such as put up in the large Nova Scotia salt fish plants. The fish may be subjected to a whole range of salt concentration, particularly in Newfoundland, but the finished product generally resembles one or other of these cures.

The light salted fish when finished is very hard, amber in colour, with a smooth face showing little or no salt on the surface. It has a characteristic pleasant odour and flavour somewhat suggestive of cheddar cheese. The heavy salted fish is completely saturated with salt before drying. The surface is white, somewhat rough, and shows a distinct salt face.

Light salted fish is the more expensive to produce because it takes more fish for a finished quintal (112 lb.), more water must be removed in drying, and the possibility of spoilage is greater. On the other hand, it commands a higher price.

Intermediate cures between heavy and light salted resemble the heavy product and may cost almost as much to produce as light salted fish. Therefore it is very important that the action of salt on fish and its relation to these cures be thoroughly understood.

Cod flesh consists of about 80% water and almost 20% protein, a little fat, and a small amount of salts of various kinds. For purposes of our discussion, the fat and the salts can be neglected. If we mince a cod fillet and shake it up with a dilute salt solution, the proteins from the fillet dissolve in the brine, giving it a slightly cloudy appearance. If the fillet is minced fine enough, almost the whole of it dissolves in the brine. On heating, the cooked fish comes out of solution very similar to cooked egg white. That is, these proteins in the fish flesh can be made insoluble by heat, by light, and by other means in the same fashion as egg white.

If we do not mince the cod fillet but put it in brine, it may gain weight or lose weight depending on the concentration of the brine. If it is placed in a saturated brine, the fillet loses a great deal of weight. If this fillet that has been left in saturated brine for a few days is then put into dilute brine, for example 5%, then it will not gain weight. The proteins have been changed so that they are no longer affected by the salt. If we were to mince this fillet, we would find that the proteins will dissolve only slightly in dilute brine. They have

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been changed in much the same fashion as though they were heated. Scientists call this change "protein denaturation" and say that the proteins are denatured.

Let us suppose we pickle fish with 9 lb. of salt per 100 lb. of fish. If we leave it long enough, salt will be distributed evenly through the fish. But before this can take place, the fish will be spoiled because its acquired salt concentration is not high enough to stop the action of the bacteria. But while the fish is under salt, if the concentration of salt at the surface of the fish is substantially more than 10%, denaturation takes place. However, since the salt concentration at the surface is not much greater than 10%, denaturation is not very deep. When this fish is dried, the surface shows the typical smooth amber colour of light salted fish. But with more salt added to the fish, the proteins show more denaturation and the combination of rough denatured protein and salt crystals on the surface produces the "salt burn" typical of heavy salted dried cod fish.

The surface appearance of a medium salted fish is almost the same as that of a heavy salted fish because there is considerable protein denaturation at the surface of both, and both show a pronounced salt face. It is difficult to distinguish these except by analysis for salt.

CHAPTER VI

METHODS OF SALTING

There are two methods of salting: kenching and pickling. Both are applicable to all types of salted fish whether heavy salted or otherwise.

KENCHING

Kench salting is carried out as follows. Salt is spread on a floor or other surface that will receive the fish. The thickness of the salt layer depends on the type of cure. The split fresh fish are laid skin surface down and salt is spread over the cut surface. For a light cure, the salt is distributed only over the thick parts of the fish, little or none being put on napes or tail. For a heavy cure, the fish are salted over the whole surface but a much thicker layer is spread over the thick parts. When the second and succeeding layers of fish are put down they are piled tails towards the outside of the pile so that the pile slopes downward from the centre outwards. This permits the ready escape of pickle. Hollow kenching, where the fish are piled tails inward, holds the pickle in the pile.

Due to the pressure exerted by the layers of fish upon each other, the salted product is usually well pressed and compact.

Kench salting has its advantages on board schooners and in small sheds where space is restricted, otherwise there is little advantage in employing this method and there is a danger of an uneven salt distribution. For this reason, and especially when light salted fish is required, the kench method of salting is not recommended during the hot summer months.

PICKLE SALTING

Pickle salting consists in salting the fish in the same manner as in the kench method, but in tanks or tubs. The pickle formed remains in contact with the fish.

This method of salting produces a much thicker fish because the fish are buoyed up by the brine instead of being pressed by the weight of fish above, as in kenching. It usually is employed when heavy salted fish is to be converted into boneless strips or manufactured into other products. Light salted fish can be produced by this method with the assurance of a better salt distribution.

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KENCH METHOD

Heavy salted fish is that product which has absorbed its maximum quantity of salt. The brine within the tissue prior to drying is salt saturated. Usually 35 to 40 lb. of salt are added per 100 lb. of split fish, the top layer being heavily covered with salt. Normally the fish is struck through in about 10 to 20 days depending upon the size of the fish and to some extent the temperature. If the temperature is very low, as in late fall, the striking time will be longer.

After 10 to 20 days the fish is washed and water-horsed (an expression signifying "kept in pile to drain out excess brine"). Water-horsing not only helps the fish to drain but also presses the fish thinner. This pressing may result in a thinner less desirable fish, but it materially increases the drying rate.

PICKLE SALTING METHOD

Large scale operations require pickling tanks made of reinforced concrete. A convenient size of tank is 14 by 4 feet and 4 feet high, which will hold 10,000 lb. of fish.

When salt is placed on split fish, it begins to dissolve in the water on the surface of the fish and forms a brine. The salt then begins to diffuse into the 80% of water held by the protein in the fish. As more and more salt is taken up in the surface, the amount of salt becomes sufficiently high, about 10%, to start coagulating the protein. As soon as this occurs, the protein lets go some of the water held by it, and this comes out of the fish and forms pickle. The salt gradually penetrates the centre of the fish and more and more brine is formed.

Eventually, in about 14 days, the water still held by the fish has become practically saturated with salt and a considerable amount of pickle has formed.

With heavy salted fish the flesh now contains about 18% salt and the water content has been reduced from 80% to about 58%.
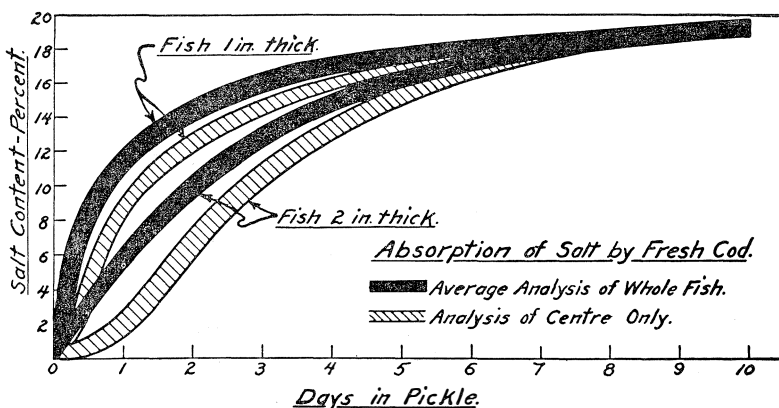

FIGURE 4. Absorption of salt by fresh cod.

With Gaspé cure (page 19), the salt concentration may be insufficient to denature the protein except at the surface and therefore much less water is lost from the fish, and the flesh remains translucent.

This passage of salt into the fish muscle is indicated in Fig. 4, which also shows the marked effect of the thickness of the fish on the rate of striking, and why thick fish are hard to cure in warm weather. Most bacteria that spoil fish are killed or fail to grow at 8 to 12% salt. Small fish acquire 8% salt even in the centre in one day, but the centre of large fish requires about 3 days to reach a salt concentration that stops spoilage bacteria. In Fig. 4 both thick and thin fish are shown to be almost struck in about 10 days.

Often fishermen used to say that the fish struck from the cut side only, and not through the skin. Many experiments have shown that salt passes into the fish through the skin at essentially the same rate as through the cut flesh side.

What then is the minimum quantity of salt which should be added to the fish in order to obtain a heavy salted pickle cured fish? A simple calculation will answer this question. For instance, a saturated salt solution, that is, a solution in which no more salt can be dissolved, contains 26 parts salt and 74 parts water by weight. On the other hand 100 lb. of split fish contains approximately 80 lb. of water. Therefore, 28 lb. of salt is the minimum theoretical amount of salt required to saturate the 80 lb. of water held by 100 lb. of split fish. In practice, however, a margin of safety should be applied and 35 lb. of salt per 100 lb. of split fish is a good proportion to ensure the production of heavy salted fish.

Another question often asked is: "How long should the fish remain in pickle and why?" Usually the fish is struck through within 7 to 10 days depending much upon the size and therefore the thickness of the fish. But experiments reveal that even after 10 days in pickle the fish cannot be manipulated with ease. Most important of all, the skin cannot be peeled off without tearing the flesh thus rendering skinning operations difficult and uneconomical. From the moment the salt is added to the fish and for a period of about 18 days a physical transformation takes place in the muscle that renders it firm and enables the skin to be peeled off more easily as time goes on.

Figure 5 represents this change for a period of 30 days, showing that the amount of protein dissolved (i.e. peptized) in the brine in the fish diminishes with time. The amount reaches a standstill after 18 to 20 days. These results indicate that heavily salted fish should remain in pickle for a period of at least 18 days.

Since the brine formed during salting comes out very rapidly during the first few days, it may not be saturated because the salt particles have not had time to dissolve completely.

This unsaturated brine is lighter than the saturated brine and tends to rise to the surface. It is therefore good practice to put extra salt on the top fish

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in the tanks to prevent these from spoiling.   A hydrometer especially designed for salt brines, hence called a salinometer, may be used for testing to make sure that the pickle remains saturated with salt.
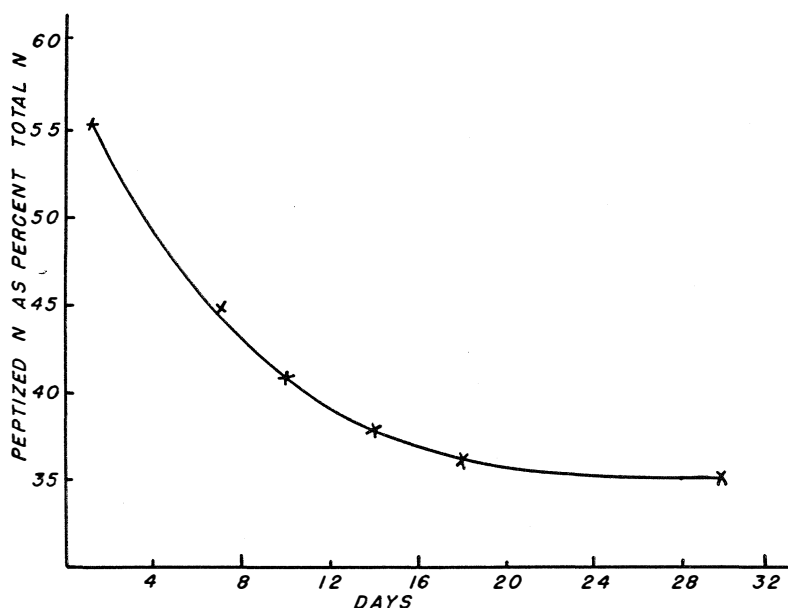

FIGURE 5.   Reduction of soluble protein in heavily salted codfish during storage at room temperature.

The salted fish is then removed from the tanks and water-horsed.   This type of fish is never slimy.   It may be kept in water-horse for 48 hours then re-piled to facilitate dripping.   After 4 to 5 days it is sufficiently drained of its excess brine for shipping or manufacturing.   Its water content at the time is approximately 58% and its salt content should be 20% calculated on the actual weight of the fish, but should never be below 42% on the dry weight basis.

A salt content below 42% dry weight may lead to the suspicion that the fish was not saturated with salt at any time during the salting process.   The theoretical maximum salt content is 50%, which is rarely attained. ·

Temperature always plays an important role in salting no matter what the type of product, be it pickle salted or otherwise.   The temperature of the surrounding air and therefore that of the fish should be kept as low as possible. Temperatures of 65°F. and above are dangerous.   Even if sufficient salt is added, the fish may turn out soft.

The following rules for making good pickle fish, if carried out conscientiously, will reduce trouble to a minimum.

1.   Never allow the fish to die on the hook.
2.   Bleed all fish.

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3. Keep fish cool and out of the sun. Don't walk over or bruise the fish. Land as soon as possible.
4. Use cool clean running water to wash after gutting and splitting.
5. Cover each fish with the proper amount of salt to prevent them from sticking together in the tanks, and keep the pickle up to strength.
6. Ventilate the fish shed to keep it as cool as possible.

LIGHT SALTED FISH (GASPÉ CURE)

One type of salt fish which has always created much interest because of its peculiarity is the light salted product of the Gaspé region, called Gaspé cure. It is difficult to know how this product originated although quite probably the French pioneers saw in the Gaspé region the possibilities of manufacturing a product having little salt and moisture, to facilitate transportation. At all events, the prevailing cool northwesterly winds of the St. Lawrence south shore offered these possibilities which for centuries have been exploited to advantage. This product has been highly prized in Italy, Spain, and Portugal for many decades.

Gaspé cure in the finished state is relatively hard, its moisture content being roughly 35%. Its salt content averages 18% on the dry weight basis. It is amber coloured and translucent.

CLIMATIC CONDITIONS

In the green state Gaspé cure codfish is a very perishable product which should be treated with the same care as that given fresh fish. Therefore, when contemplating the production of this type of cure, it is well to consider first of all the average climatic conditions prevalent in a chosen region, since temperature and relative humidity are the two main controlling factors. It is useless, therefore, to attempt operations of this type in a region where temperature and relative humidity are constantly high. Even in the Gaspé area the quality of the product is lower during July and August, when temperatures may rise to 75°F. and relative humidity to 80%. In other words, cool, dry weather with light winds presents ideal conditions for salting and drying.

SPLITTING

It is essential that only fish in a very good state of preservation should be used.

Furthermore, fish should not be kept too long in water after it is headed and gutted. Keeping fish in water should not be overdone as it must be remembered that water does not preserve fish. On the contrary, fish muscle takes up water, and besides softening the tissues and rendering splitting operations more difficult, the flesh is softened and rendered more susceptible to cracking when first exposed to drying. It is preferable after the fish is headed and gutted to

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lay it on a cement floor and sprinkle it with sufficient water to wash away slime and blood. It should then be immediately split, washed in weak brine, and stacked so it may drip for not more than 10 minutes, then salted without delay.
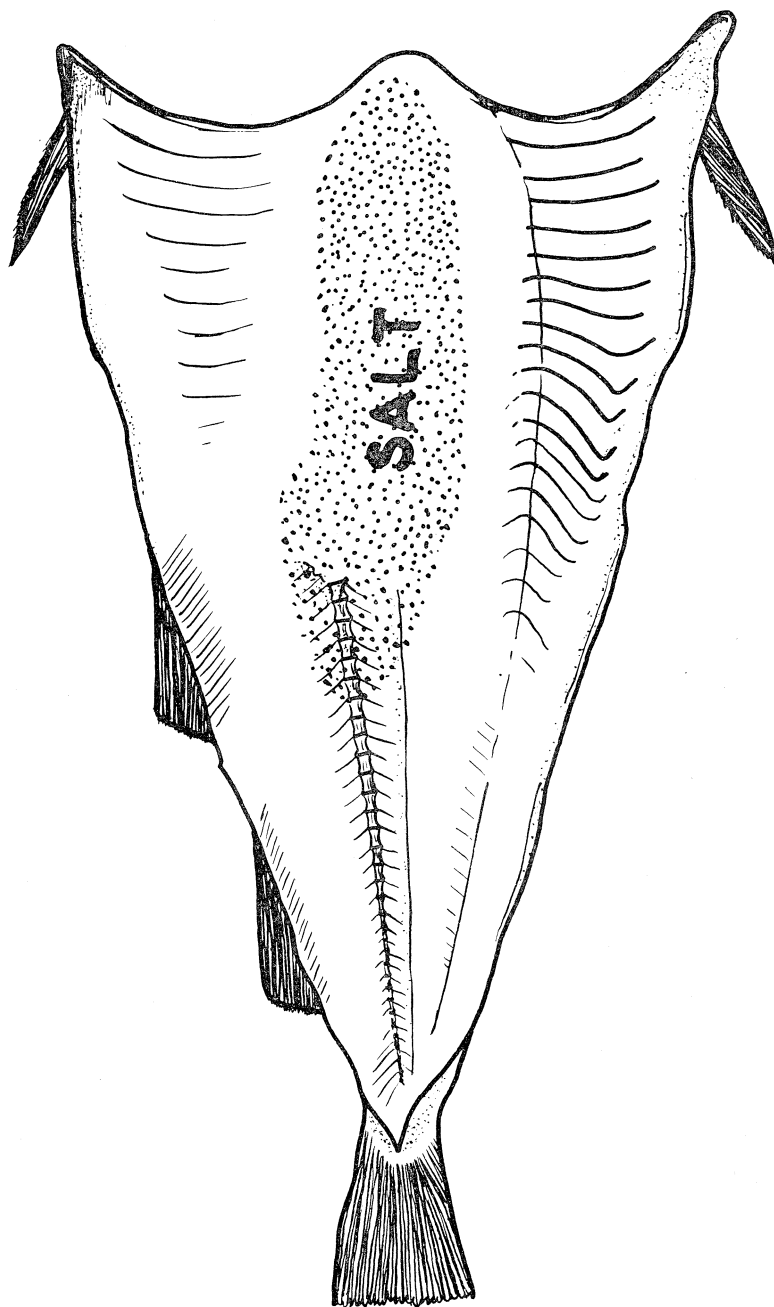

FIGURE 6. Application of salt to fish for making Gaspé cure.

Any temperature between 50 and 65°F. will give excellent results, as the salt penetration is sufficiently rapid and the fish can remain in the brine for at least 3 days if necessary without ill effect.

The quantity of salt to be used per 100 lb. of split fish may vary between 8 and 10 lb. The ideal quantity, however, is 8 lb., since 10 lb. gives a product which is on the heavy salted side. Eight pounds may be used during the spring and early fall seasons when temperatures vary between 60 and 65°F., but 10 lb. must be added during the warm summer months of July and August.

This fish is usually salted in tubs averaging 30 inches in diameter and 30 inches in height. Molasses puncheons cut in two make tubs of suitable size for this purpose. The fish is laid in tiers, flesh side up, and the salt is added from about one inch from the butt down towards the tail, following the flesh part where the soundbone has been removed, and including a few of the remaining vertebrae, as illustrated in Fig. 6. This procedure is repeated until the tub is full. No salt should be added to the napes and tail. After 24 hours, the fish is weighted down with flat stones in order to keep it submerged in its brine. After a period of 48 hours, it is removed from the tub, washed in its own brine, water-horsed for 5 or 6 hours, and then dried. It must be emphasized that the period of 48 hours in brine is for fish salted with fine fishery mined salt.

CHAPTER VII

A QUANTITATIVE STUDY OF YIELDS

Three basic principles contribute to the framework of the economy of the salt fish industry: the raw material, the type of product or products which may be derived from it, and the cost of production.

RAW MATERIAL

The raw material for the production of salt fish in Eastern Canada varies widely according to area. In 1954, for instance, of the total salt fish produced 92% was cod, 3% hake, and 5% pollock. The Newfoundland production was entirely cod and it represented about 83% of the total Atlantic salt cod production. Pollock was produced largely in southwestern Nova Scotia, and hake in the southern Gulf of St. Lawrence area. The selling price varies not only according to species but also to type of cure. In all cases the margin of profit is small and to operate economically, waste must be avoided and full use must be made of by-products.

According to Macpherson ("The Dried Codfish Industry", Dept. of National Resources, St. John's, Nfld., 1935) the loss in weight when codfish from the sea are dressed ready for salting averages 38.5%. The same author makes reference to H. W. Bitting (U.S. Dept. of Agriculture, Bureau of Chemistry, Bulletin No. 133, 1911) whose data reveal that the loss in weight by dressing is 40%. Our own statistics show the loss to be 40.7%. Independent observations made in 1947 by a group of fisheries inspectors in the Gaspé region reveal that on June 27 the loss in weight was 40%, on July 3 it was 38%, and on July 14 it was 40%.

Although this percentage may vary slightly from one plant to another, it seems that 40% loss in weight from the round to the dressed stage could be accepted as a reliable average.

TYPE OF PRODUCT

Salt fish may contain any proportion of salt from a few percent to saturation (about 20%). The quantity of salt added to the fish is generally dictated by the type of product required.

Table III shows the types of cure which may be obtained by applying a given quantity of salt per 100 lb. of split fish.

In the light cures the quantity of salt added must be limited to 10 lb. per 100 lb. of fish. At 12 lb. there is danger of salt-burn.

TABLE III.—The salt and water contents, and change in weight, when 100 lb. of split fish is pickle-salted with given weights of salt.

Type of cure	Salt per 100 lb. of fish	Loss in weight	Moisture content	Salt content	Curing time at 65°F.
	lb.	%	%	%	days
Light..............	8	16	74	4.0	2
	10	18	72	6.0	2
Medium..............	12	20	70	8.0	3
	14	22	64	9.0	5
	16	26	63	10.0	8
Heavy..............	30	30	57.5	20.0	21

We therefore have three general types of salt fish:

1. *Light cure*—Immediately after salting, the muscle protein is not denatured. The surface has a distinct sheen. In the dry state, these fish are amber coloured, translucent, and hard. They are usually dried down to 35% moisture.

2. *Medium cure*—In the green state the salt content is such that the brine in the fish does not represent saturated conditions. When dry, however, the surface is characterized by salt-burn.

3. *Heavy cure*—In the green state the brine in the fish is saturated or nearly so. The flesh is distinctly white. When dry, the surface is characterized by salt-burn.

YIELD

From the foregoing, we know that the weight loss in dressing 100 lb. of round fish to split fish is on the average 40%. Let us assume that we wish to prepare a light cure by adding 8% salt to the split fish. The available quantity of fish is 100 lb. whole fish. This gives 60 lb. of split fish and the quantity of salt to be added will be 5 lb. According to Table III, the loss in weight caused by the action of the salt will be 16%. Therefore, 60 lb. of split fish salted with 5 lb. of salt will lose 9.6 or roughly 10 lb. after 2 days in pickle. Therefore, the salted fish in the green state will now weigh 50 lb. and the moisture content will be 74%. This 50 lb. must now be dried from a 74% initial moisture to a 35% final moisture content. The further loss in weight will therefore be 60%. The percentage loss in weight is found by means of a nomograph (Fig. 7) which is shown on page 7 of this Board's Atlantic Progress Report No. 47, (1949), or by the formula:

$$\frac{A-B}{100-B} \times 100 = \text{percentage loss in weight,}$$

where A = initial moisture content, B = final or required moisture content.

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Therefore, the 60 lb. of split fish salted with 5 lb. (8%) of salt and dried to 35% moisture will give 20 lb. of dry fish.

To summarize these results and also amplify still further:

100 lb. round = 60 lb. split = 50 lb. at 74% moisture.
= 20 lb. at 35% moisture.

166 lb. round = **100** lb. split = 84 lb. at 74% moisture.
= 34 lb. at 35% moisture.

497 lb. round = 298 lb. split = 250 lb. at 74% moisture.
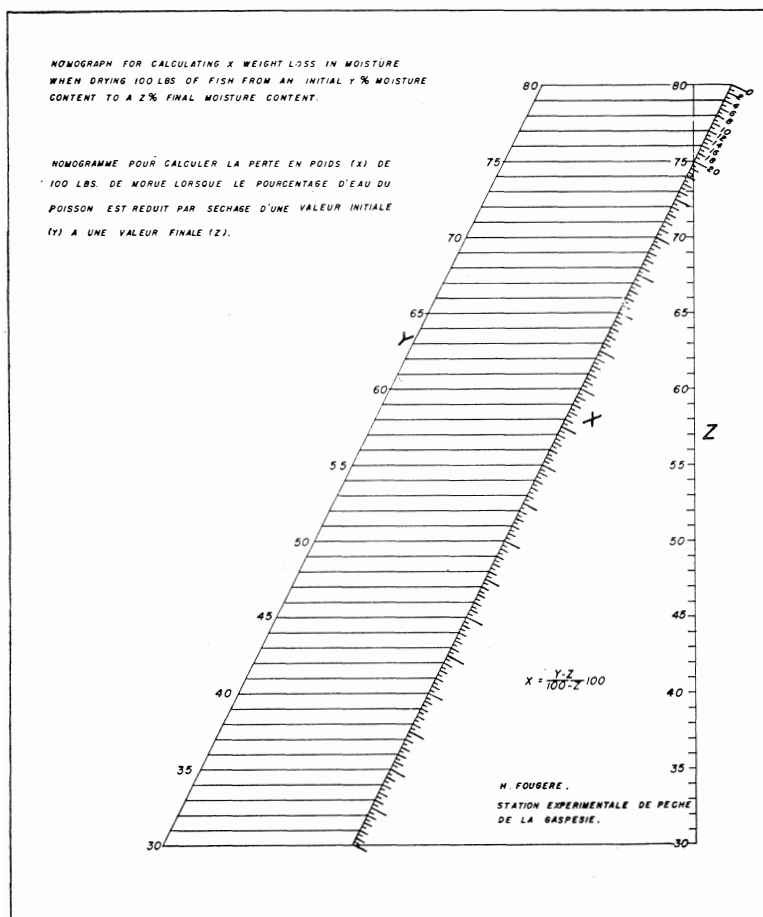= **100** lb. at 35% moisture.

FIGURE 7. Nomograph for calculating X weight loss in moisture when drying 100 lb. of fish from an initial $Y\%$ moisture content to a $Z\%$ final moisture content.

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The same reasoning may be carried out for calculating the yield of heavy salted fish. Since there is a loss of 30% by weight from the split to the green state,

100 lb. round = 60 lb. split = 42 lb. green at 58% moisture.

Since the green fish must be dried from 58% to 40% moisture, there will be an additional 30% loss in weight. Therefore:

100 lb. round = 60 lb. split = 42 lb. green = 29 lb. at 40% moisture.
340 lb. round = 204 lb. split = 143 lb. green = **100** lb. at 40% moisture.

In some regions the merchants buy the fish with the soundbone in, and therefore these calculations for a light cure as above would be as follows ("S" stands for soundbone):

111 lb. with S = **100** lb. split = 84 lb. green = 34 lb. at 35% moisture.
331 lb. with S = 298 lb. split = 250 lb. green = **100** lb. at 35% moisture.

For heavy salted fish the results would be:

111 lb. with S = **100** lb. split = 70 lb. green = 49 lb. at 40% moisture.
159 lb. with S = 143 lb. split = **100** lb. green at 58% moisture.
226 lb. with S = 204 lb. split = 143 lb. green = **100** lb. at 40% moisture.

Similar calculations may be applied to all the other types of fish. Therefore, by taking into account the economic factors which control the margin of profit, a producer may, by the use of such reasoning, predict with fair approximation his potentialities as rated by his available capital.

CHAPTER VIII

BACTERIA AND OTHER MICROORGANISMS
CONCERNED WITH FISH CURING

This Board's Bulletin No. 100, entitled "Spoilage Problems in Fresh Fish Production", published in 1954, tells what bacteria are, where they come from, and how they spoil fish. Although it was principally written to explain the relation between bacteria and the spoilage of fresh fish, a careful reading of that bulletin would also be helpful in trying to understand the relation between bacteria and both the preservation and spoilage of salt fish.

The Effect of Salt Concentration on the Activity of Bacteria

The first and most important thing to understand is that there are many different kinds of bacteria, and *that they are not all affected in the same way by salt*. A certain amount of salt is necessary for the growth of all bacteria. Up to 1% stimulates the growth of those associated with fresh fish spoilage. Many of the fresh-fish-spoiling bacteria are quite active in salt concentrations up to 6%. Above 6 to 8%, they either die or stop growing. As the salt concentration is increased beyond 6%, bacteria of another group, consisting of a much smaller number of species, are still able to grow and spoil the fish. They grow more slowly than those which spoil fresh fish. Among other things, these organisms produce the characteristic slime that forms on the surface of green salted fish. This second group also stops growing when the salt concentration reaches about 12 or 13%.

We have become accustomed to think of salt as a curing agent and a food preservative; that is, that a high concentration of salt prevents the activity of spoilage bacteria. It comes somewhat as a surprise to learn that some species of bacteria simply cannot grow unless they are in the presence of very high concentrations of salt. They are called "halophiles", which means "salt-loving". They grow best in salt concentrations that range from 12 or 13% to saturated brine solutions. These halophiles are the bacteria that cause the chief spoilage of salt fish after it has been struck or cured. The red discoloration that occurs on heavily salted fish is a typical example.

Salt Alone will not Always Preserve Fish

To persons interested in curing fish, this complex relation between salt concentration and the growth of different types of bacteria means two things: (1) that salt cures or preserves fish because in higher concentrations it prevents the activity of almost all bacteria; and the higher the concentration of salt used

on the fish, the fewer the types of bacteria that will survive; (2) that no matter how high a concentration of salt we use on fish, there will always be a few types of bacteria that can survive and grow. Therefore, salting alone will never completely stop the spoilage of fish. That is why salt fish are dried, or held in storage at low temperatures, or treated in some other way; it is to prevent the growth of the few species of bacteria that can withstand high salt concentrations.

Salt Penetration versus the Speed of Bacterial Decomposition

Chapters V and VI of this bulletin have dealt with various salt cures and how they are produced. The bacteriology of each of these cures will be discussed separately. Before doing so, it might be of interest to discuss a critical period that is common to all cures. That is, the race between the penetration of the salt into the fish and the activity of the ordinary spoilage bacteria.

If the fish are left unsalted at room temperature, the common fresh-fish-spoiling bacteria will quickly bring about deterioration. If we could salt fish in such a way that all these common spoilage organisms came suddenly in contact with the strong brine, this type of spoilage would almost immediately stop. But this is not always the case. It may be that the salt is very unevenly distributed or the fish may be pressed so tightly together that it takes considerable time for the salt to reach some of the areas where the spoilage organisms are located. If the salt penetrates before much bacterial decomposition has taken place, a normal cure will occur. On the other hand, if the bacteria are able to decompose a portion of the fish muscle before the salt reached them, a soft, spoiled or dis-coloured area will result. The condition known as "putty fish" mentioned at the beginning of this bulletin is an example. It is obvious that the fresher a fish is, and the freer it is from contamination at the time of salting, the less the chance for this type of spoilage in localized areas.

Climate and Salting Fish

The question is often asked: "Why do we produce most of our salt fish in the more northern countries? Why not produce salt fish in the tropics where much of it is consumed?" In answering that question (apart from the availability of the right type of fish for salting) we immediately run into this problem of the rate of salt penetration versus the rate of bacterial activity.

It so happens that the rate of penetration of salt into the fish is relatively unaffected by increases in temperature. The growth and activity of spoilage bacteria, on the other hand, is greatly affected by increases in temperature. In the very warm tropics, spoilage brought about by bacteria is very greatly accelerated, while the speed of salt penetration remains relatively unchanged. The result is that many fish spoil before the fish has become fully struck. In the northern countries the lower temperatures retard bacterial activity without affecting the rate of salt penetration. It is for this reason that our best salt fish are usually produced in the more northerly countries. It is for the same

reason that in moderate climates, such as that of Nova Scotia, the production of light salt fish is more successful in the cool fall weather than in the warm summer days.

BACTERIAL GROWTH AND EXPOSURE TO AIR

One of the characteristics of most of the bacteria that produce slime on light or medium salted fish is that they grow best on surfaces exposed to the air. They also grow in brines below the surface—but much more slowly. For this reason fish that are cured in pickle must be weighted down to keep those on top from projecting above the surface. If this is not done, the exposed portions will quickly develop a coating of slime which often turns yellow and develops an unpleasant sour odour. Because the bacteria on the exposed surfaces grow so much faster, this portion of the fish not only spoils sooner but also helps contaminate the brine with many additional spoilage organisms.

Frequent enquiries have been made regarding the keeping time of fish held in pickle as compared with those in kench. The answer is not simple, because the characteristics of pickle-cured and kench-cured fish are not always the same. But if it is necessary to hold light or medium salted fish for a period before drying, and if that is the only consideration, those in pickle will remain unspoiled for a longer period. The principal reason for this is that the bacteria in the fish under pickle have less access to air than those in kench.

This does not apply only to the slime-producing bacteria. Many true halophiles, including those that cause reddening of heavily salted fish, grow best on moist surfaces exposed to air and much more slowly beneath the surface of brine.

TEMPERATURE AND THE GROWTH OF SALT-FISH-SPOILING BACTERIA

There is a very interesting relation between storage temperatures and the growth of the various groups of bacteria concerned with salt fish products. In general terms it is this: the groups of bacteria that withstand the least amount of salt can grow at the lowest temperatures. As the salt requirements increase, there is a rise in the minimum temperatures at which the bacteria grow. Many of the bacteria that grow on fresh, unsalted fish multiply rapidly at temperatures close to freezing. For this reason even well iced fresh fish has a very limited keeping time. Those that grow on lightly salted fish, such as the Gaspé cure, are only a little less sensitive to cold. Undried Gaspé cured fish will spoil in less than a week if stored at 37°F. The slime-producing organisms that grow on the surface of medium salted cure can withstand a higher salt concentration and grow at slightly higher temperatures. For example: fish were kenched for 4 days in a room at 58°F. with 16 lb. of salt per 100 lb. of fish and then portions were removed to various storage temperatures before drying; observations of the development of slime on these fish showed that it required 5 weeks at 33°F., 4 weeks at 37°F., and just under 3 weeks at 45°F. In contrast to this, heavy

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salted fish can be stored for many months at 40°F. before drying, as long as the salt concentration is not allowed to decrease by moisture being absorbed from the atmosphere.

A similar temperature relation holds between temperature and the growth of bacteria that discolour the fish. Red organisms on heavy salted fish grow best at 95 to 105°F. and very slowly below 50°F. Unless fish are grossly infected with these bacteria, they can be stored almost indefinitely at 40°F. or below without discoloration. In contrast to this, the yellow, orange, and buff coloured organisms that grow on lightly salted fish grow well at 40 to 50°F.

THE BACTERIOLOGY OF DIFFERENT CURES

So far we have been discussing some of the general characteristics of bacteria associated with salt fish. Let us now consider what actually happens when we go through the process of producing salt fish.

When fish are split and washed they are ready to be salted. They look clean and the flesh may be fresh and absolutely free from any signs of spoilage. Nevertheless on the surfaces of the split fish there are millions of spoilage organisms. These come from the slime and the intestinal contents of the fish, as well as from contaminated splitting tables, the hands of the cutter and many other sources. They are principally the fresh-fish-spoiling types and if left alone they would soon bring about spoilage. However, the fish is to be salted, and what happens to these bacteria depends upon the amount of salt we use in the cure.

HEAVY SALTED FISH

If the fish are to be heavy salted (35 to 40 lb. per 100 lb. of split fish) almost all the bacteria on the fish will either die or stop growing. Once the fish is struck, only the true halophilic types, such as those that produce red, will survive and bring about spoilage. Actually very few halophilic bacteria come on the fish itself. Their principal sources are the salt used to preserve the fish, and contaminated salt-soaked surfaces in the plant or fish shed. If the fish are left under pickle they may remain in good condition for several months. If they are in kench piles, or removed to storage rooms prior to drying, the halophilic bacteria have a better chance to develop and spoil the fish. Whether they do so, depends upon a number of different factors. Principally they are these: the length of time the fish is held before drying; the temperature and humidity of the storage rooms; and the extent of initial contamination by these halophilic species. If the storage room is kept below 40°F. the fish may be stored for long periods without trouble. There are exceptions to this. If the relative humidity of the air is too high the fish take up moisture. This dissolves out some of the salt, which in turn may reduce the salt concentration in portions of the fish to the point where slime formers commence growing. This can be avoided by adding a little salt from time to time to those portions of the fish showing moist areas, particularly at the napes. Another problem

occurs from using salt that is heavily contaminated with red bacteria and other halophilic types. Sometimes the number of these salt-loving bacteria on fish going into storage is so enormous that a temperature of 40°F. is insufficient to hold them in check. This occurs chiefly in plants that are extremely unsanitary or use heavily contaminated sea salt for curing their fish. Even under these conditions, storage at 32 to 35°F. will retard spoilage for many months.

Once the fish have been properly dried all bacterial action stops. Further spoilage cannot occur unless the dried fish re-absorbs moisture. Occasionally, during shipment and storage in the warm moist weather of the tropics, salt fish will absorb great quantities of moisture; this enables not only the red organisms to develop, but even some of the less salt-tolerant slime producers.

MEDIUM SALT CURE

We frequently classify dried salt fish into "heavy", "medium", and "light" salt cured. In a general way this is true, but, as pointed out on page 13, fish are actually being cured in all ranges of salt content, from the very light Gaspé type to the ordinary heavy salt cure. The so-called "medium" cure has the largest range of salt concentrations, running all the way from 8 to even 16%. For this reason, it is difficult to speak precisely about the bacteriology of medium salt cure. At one extreme it is somewhat similar to the Gaspé cure; at the other extreme it is not far from heavy salt fish. For this discussion we will consider the middle range of the medium cure—that is, fish having 9 or 10% salt after it has come out of pickle.

To cure these fish, 14 or 16 lb. of salt is added for each 100 lb. of split fish. If the weather is reasonably cool (below 68°F.) and the salt is added in such a way that the fish do not stick together, pickle will form fast enough to prevent spoilage by the fresh-fish-spoiling bacteria that are normally on the surface of the fish. Slowly at first, and then with increasing speed, the slime-forming bacteria begin to grow. If the fish are exposed to the air, it is only the matter of a few days at 60 to 68°F. before the first indications of slime are evident. Under pickle it may take 8 to 10 days or more. Up to this point, little or no spoilage has occurred in the flesh. Shortly after this, unpleasant sour odours develop, and if left still longer, the fish softens and various types of pungent and putrid odours develop, rendering the fish useless. It is for this reason that much more care must be taken than in the case of the heavy salted fish to dry it as soon as possible after it has been struck. If it is necessary to hold it for more than a few days before drying, it should be stored in a cool room or refrigerator at not higher than 50°F. and preferably 40°F. or below.

Medium salted fish is a much more perishable product than the heavy salted cures. The salt content itself is not sufficient to prevent the growth of slime-forming bacteria. This is accomplished by drying the fish. It requires the addition of less moisture to start up sliming and spoilage on the medium salted cure during storage.

If the fish contains less than 12% salt, it is not subject to spoilage by red halophiles—for the simple reason that these organisms require more salt than that to live. However, something else takes the place of such spoilage. Quite frequently the surface of medium salted fish becomes peppered with little black, brown or fawn coloured tufts of mould, commonly spoken of as "dun". (See page 36 for further details). This is a type of spoilage characteristic of the medium and light salted cures and rarely or never occurs on heavy salted fish.

LIGHT SALTED, OR GASPÉ CURE

There is one very important difference between the bacteriology of Gaspé cure and that of the heavier salted fish. The changes that take place in the heavy salted fish are physical and chemical and are the result of the action of the salt on the fish muscle, followed by drying. Bacteria take no part in the process, except when they bring about spoilage.

In contrast to this, in the light salted cure, changes brought about by bacteria are part of the normal processing and give the fish some of its typical characteristics.

From 8 to 10 lb. of salt are added to each 100 lb. of split fish, the amount depending upon the temperature. This results in a product that has from 4 to 6% salt before drying. Because of these relatively small amounts of salt, many more bacteria are able to grow. The slime formers grow abundantly at these concentrations, and even some of the more hardy fresh-fish-spoiling bacteria may survive and become adapted to these conditions. If these bacteria are allowed to act for a short time on the fish they first bring about some beneficial results. Something similar to a mild digestion takes place that results in a softer fish with an improved flavour. However, if the bacterial action is not stopped at the right stage the digestion is continued too far and the fish become spoiled. It is for this reason that the production of Gaspé cure requires the most care of any of the salt cures. If the temperature at the time of processing is too high, or if the fish are left a little too long in salt before drying, the very process that gives Gaspé cure its special characteristics will also bring about its spoilage. The curing time of heavy salted fish is usually 3 weeks or longer, while the curing time of the light salted fish is about 2 days at 65°F. As soon as the bacteria, together with the action of the salt, have brought about the right amount of change, the fish must be dried at once to prevent further digestion. If it is absolutely necessary to hold the fish before drying, it must be stored at 30 to 32°F. and not longer than 6 or 8 days.

THE RED HALOPHILIC BACTERIA

The red halophilic bacteria have been mentioned several times in the preceding discussion on the spoilage of heavy salted fish. The defect that they cause is widespread in all the Maritime areas where salt fish is produced and some years the loss due to these organisms is quite serious. It seems worth while, therefore, to devote a special section of this bulletin to them.

The problem of red discoloration in brine is almost as old as written history. In an ancient Chinese treatise, written about 2700 B.C., we can read about the production of salt by evaporation of sea water. It says: "An embankment is made and ditches to bring in the clear sea water. It is then left a long time [to evaporate] and *the colour becomes red*." Exactly the same thing happens today in the production of salt from sea water. It is run into concrete tanks, and at one stage, after considerable evaporation has taken place, the brine takes on a bright red colour just as it did for the Chinese more than 4500 years ago. Today we know why the brine becomes red and we also know the relation between this red brine and the familiar red discoloration that frequently occurs on the surface of our heavy salted fish.

The evaporating sea water is red because it contains an exceedingly large number of living, red-pigmented bacteria. These organisms do not find suitable conditions for growth in ordinary sea water, because there is not enough salt. But once the concentration of salt in the brine reaches about 13 or 14% they begin growing and they will continue to grow in all higher concentrations right up to saturation. They will even grow on the moistened surface of sea salt crystals, giving the salt a pale pink discoloration.

When the salt crystallizes out, the bacteria are left in the brine. They do not get into the interior of the crystals as they are forming. But when the salt crystals are removed, the red organisms cling to their surfaces. The result is that unless they are specially treated, almost all sea salts will contain from ten thousand to many million red bacteria per gram (there are 454 grams in one pound).

ORIGIN OF RED HALOPHILES

No one knows for sure where the red organisms first came from. Numerous tests have shown that on rare occasions these red bacteria have been isolated from sea water, fish slime, sand, soil, and even in animal faeces. But the tests also show that these same organisms cannot *grow* in sea water, slime or soil without the addition of a considerable amount of salt. In fact, when large numbers are purposely added to fresh or sea water they all die off in a few hours. But this we know: anywhere in nature that strong brines are left standing at relatively high temperatures these organisms are found. We have also learned that if the salt is free from impurities they will develop much more slowly or not at all.

As far as the fishing industry is concerned, their initial source is the untreated sea salts that are imported from tropical countries for curing salt fish. From the salt they spread throughout the plant. They can be isolated easily from walls, floors, bins, tools and implements used for handling the salt fish; they are found also in the salt-soaked surfaces of kegs, barrels, and pickling tanks. These organisms are not easily destroyed by drying, and tests have shown that they are blown about in the air of sheds where dried, red-contaminated fish are stored.

Analysis of many samples has shown that salts taken from underground mines are almost completely free from red bacteria. However, if a plant is already contaminated with red bacteria, merely switching from contaminated sea salts to mined salts will not cure the trouble, as these organisms grow on fish salted with mined salt as well as with sea salt. If a change is to be made from contaminated to red-free salt, it should be preceded by a thorough clean-up and disinfection of the plant.

EFFECT OF TEMPERATURE ON GROWTH OF RED HALOPHILES

We can learn something of the temperature requirements of the red halophiles by examining the conditions under which they first developed. The hot tropical sun beating down on the evaporating tanks raises the temperature of the brine to well over 100°F. and frequently up to 120°F. (This is quite different from the temperature where our fresh-fish-spoiling bacteria have their origin. They come from the depths of our northern seas where the mean temperature is within a few degrees of freezing.). Tests have shown that most strains of red halophiles grow in temperature range of 60 to 180°F. Growth is stopped or greatly retarded below 60°F., it is slow between 60 and 80°F., rapid between 80 and 90°F., and very rapid between 90 and 115°F.; the remarkable thing is that some strains will continue growing even at temperatures that would cause a severe scald on the skin of human beings (180°F.). For this reason the red organisms are called "thermophilic" (heat-loving), as well as "halophilic" (salt-loving).

These facts suggest that one of the most useful ways of controlling the development of red on contaminated fish is by lowering the temperature below the point where these organisms can grow. What should this storage temperature be? Usually temperatures of 45 to 50°F. check the development of red, but if the fish are heavily contaminated and if considerable growth has already taken place before the fish are placed in the cool room, then these temperatures are not sufficient to hold it in check. In this case the storage room should be below 40°F. Some commercial firms are making a practice of holding their storage rooms at 35 to 37°F.

The temperature requirements of the red bacteria also help to explain why red becomes so prevalent in the hot summer days and tends to disappear in the winter and cooler periods of spring and fall. It also explains why salt fish, leaving our plants apparently free from red, sometimes becomes badly discoloured during shipment and storage in the tropics.

THE TYPE OF SPOILAGE CAUSED BY RED HALOPHILES

We sometimes hear that the spoilage caused by red halophiles is insignificant, that it is merely a matter of surface colour that can easily be washed off. Very rarely would the persons making such statements use a heavily contaminated red salt fish for their own dinners.

Actually there are several different types of bacteria able to grow on the surface of salt fish and produce red or pink discoloration. Bacteriologists divide them into two groups, represented by *Pseudomonas salinaria* and *Sarcina littoralis*. Quite frequently both these types are found in contaminated salt or on spoiling fish. *Ps. salinaria* is the most common and also the most objectionable. As well as producing the red colour it attacks the fish muscle and gives rise to a characteristic unpleasant odour that is familiar to almost all who have had experience with red salt fish. Part of the odour is due to indole and hydrogen sulphide produced from the fish by most of these organisms, some of which can decompose proteins.

There may be individuals who have become accustomed to the flavour of partially decomposed food products. There may be others who, for economic reasons, are forced to use very low quality foods. But that is no reason for suggesting that the discoloration and the spoilage odour of red salt fish is insignificant and to be considered lightly from the standpoint of grading for quality.

Washing and Disinfecting the Plant and Equipment

After all stocks of red-contaminated fish and contaminated salt are removed from the building (and the farther away the better) the floors, walls, and equipment should be washed and scrubbed, using plenty of good clean water. Fresh water is preferable, but if this is not available, sea water can be used. The chief object in washing the plant is to remove "gunk", slime, and the salt that has soaked into the wood. Nothing does this better than scrubbing with plenty of water. The second reason for using water freely is that it *kills* many of the red halophilic bacteria. These organisms are not only salt-loving, but they must have salt in order to survive. If casks and barrels are made reasonably clean, and if the salt is then soaked out of the wood and the barrels refilled with fresh water, the red halophiles will die off rapidly (in a few days). If shovels and other tools are thoroughly cleaned and then left soaking in salt-free water, they also will be freed from red bacteria.

After the plant and its equipment have been washed and scrubbed, it can be of some benefit to disinfect it. It should be remembered, however, that red halophiles are extremely resistant to almost all disinfectants. Lye and compounds containing active chlorine are among the most effective, but even with these materials the concentrations used and time allowed for their action are much greater than are required for most other food-spoiling bacteria. Hypochlorite or any commercial disinfectant containing active chlorine should be made up to have a strength of 500 to 1000 p.p.m. of free chlorine. If this is slightly acidified by the addition of a weak solution of acid, its germicidal activity will be increased. It is sprayed or mopped onto the surfaces to be disinfected and the treatment should be repeated after a period of 20 to 30 minutes.

On floors, powdered chloride of lime can be sprinkled generously and left overnight before washing.

In place of chlorine solutions, a 2% solution of lye may also be used and left for the same contact periods.

Lye and strong chlorine solutions are corrosive and should be handled with care.

CONTROL OF RED ON SALT FISH

Control of red in salt fish plants is not an easy matter. But it is possible and some plants have almost entirely eliminated the problem. It is very definitely one of those problems that cannot be solved by half measures. There is no use disinfecting the plant if you are immediately going to bring in a lot of contaminated salt. There is no use in using red-free salt if you are going to pile the fish in the same room that contains another lot of badly contaminated red salt fish. Consideration must be given to each of the following things:

1. *Choice of salt*—It is obvious that salt free from red bacteria should be procured. This does not mean that we should avoid all sea salts, but it does mean that if we are going to buy sea salt we should accept only those that are free from red bacteria. In the past years *all* sea salts were contaminated. But some of the modern producers claim to be able to treat their salt in such a way that all red bacteria are destroyed. In case of doubt, send a representative 1-lb. sample to a reputable laboratory and have it tested. As an alternative, the mined salts can be used without fear of red.

2. *Contaminated stocks of fish*—Get rid of all contaminated red fish. There is no sense trying to control red in a plant if you persist in retaining a pile of contaminated fish. Bits of this dry contaminated red fish are ground almost to dust by trampling underfoot and under the wheels of conveyor carts. The slightest breeze or even a mild draft spreads this bacteria-bearing dust all through the plant. Piles of red-contaminated green salt fish are almost as bad. The brine, carrying the bacteria, gets on the floor; the hands of the men carry them throughout the plant; and altogether it is a poor business to try to clean up red without removing these major sources of contamination.

The same applies to the salt. All stocks of red-contaminated salt should be removed from the building and the storage bins cleaned and disinfected before new red-free salt is brought into the plant.

Experience has shown that where plants use red-free salt, make a thorough clean-up at least once a year (preferably in early spring), and take reasonable precautions the rest of the time, they can eliminate loss through red bacteria.

Some plants salt very little of the fish they handle. They buy the green fish direct from the fishermen and then dry and store them for export or local markets. It is obvious that the control measures described above cannot all be applied here where they have no control over the salt or the curing of the fish. They can, however, do three things: (1) refuse to buy the poor quality fish, which experience has shown most frequently contain red; (2) use

proper storage facilities with temperatures that will control the development of red; (3) encourage the fishermen to use salt that is free from red and to take proper care of their fish and curing sheds.

THE "DUN" MOULDS

As stated previously, the red halophilic bacteria grow only in the presence of high salt concentrations. For this reason they are found on the heavy salted fish or on the upper range of the medium salted cures. They will not grow on light salted or Gaspé cure fish. In contrast to this, there is another type of micro-organism that grows well on the light and medium salted fish and is found less frequently on the heavy salted fish. It also causes a considerable annual loss. Every producer of light and medium salted fish is familiar with a type of spoilage in which the surface of the fish and particularly the skin side becomes peppered with numerous small tufts of black, brown, or fawn coloured material. It is most commonly observed in the fall on those fish that have been held in storage during the summer months. Unlike the red halophiles and most other types of spoilage, dun does little other than disfigure the fish; it produces no significant breakdown of the flesh and has no characteristic spoilage odour.

Dun is one of the few types of fish spoilage caused by moulds and not by bacteria. Moulds are much more complex than bacteria. Each mould plant consists of two parts. Beneath the surface of the food on which they are growing (in this case the salt fish) moulds develop a network of root-like threads. This is the main portion of the mould plant, but because it is beneath the surface it cannot be seen. The second portion of the mould plant grows above the surface of the food. It consists of little chains or clusters of spores, and is the part of the mould that we see growing on the food. These tiny spores are somewhat like seeds and are the mould's method of reproduction. Each mould spore that lands on a suitable place will germinate and produce a whole new mould plant. Because the spores are so very small and so very light the slightest draft or air current will carry them throughout the plant.

In the case of dun on the salt fish, each little dark or fawn coloured tuft is a cluster of tens of thousands of these spores. Some processors imagine they can remove dun from the fish by brushing or scraping off the visible tufts. For a short while the appearance of the fish will be improved, but the mould has not been removed. This is like trying to kill grass by mowing the lawn. Both the mould and the grass have root systems that will shortly shoot up new growth above the surface.

Conditions that Favour the Development of Dun

Experience has shown that dun flourishes in old plants built on low ground, and especially where little or no care is taken to keep the place clean and sanitary. It will grow on damp, salt-soaked boards; also on bits of discarded

salt fish, salt-soaked soil, and in fact, almost any damp organic matter that contains sufficient salt. Dun flourishes in fish plants that are not kept clean and dry.

It has frequently been noticed that where fish have been piled close to a hole in the floor, or in the lower portions of the wall, dun develops on the adjacent fish surfaces, as though the draft from under the building had carried in the infecting mould spores. Such holes should be plugged or covered.

It grows most readily on light and medium salted fish and occasionally on heavy salted fish. Temperatures of 70 to 80°F. are the most suitable. The lower limits are between 40 and 50°F. and the upper limits are between 85 and 95°F. They are not thermophilic like the red bacteria.

CONTROL AND PREVENTION OF DUN

There are two approaches to the control of dun on salt fish. The first is to prevent the fish plant and the fish from becoming infected with dun spores. This is done by keeping the plant as free as possible from dirt and debris on the floors, etc., where the moulds could seed themselves down. Remove all scraps of salt fish and particularly any fish showing dun infection. Most common disinfectants will destroy the spores. There are special paints which will prevent the germination of spores on wood surfaces as well as keep out the salt and moisture. Because the moulds grow best in damp places, ventilation and sunshine are helpful remedies.

The control of dun by adding preservatives to the fish should only be attempted after the plant sanitation has been carried out. Even the best of preservatives are not completely satisfactory and will not stop a heavy infection. Of those that are available, a dip in a 0.1% solution of sorbic acid appears to be the most useful for controlling dun.

TABLE IV.—Amount of water to be removed to reduce salt fish from water-horse to 38% moisture.

Type of cure	Moisture content in water-horse	Water per 100 lb. of fish to be removed to make 38% moisture fish
	%	lb.
Light cure..........................	74	58
	72	55
Medium cure.......................	70	52
	64	42
	63	40
Heavy cure (pickled)...............	60	35
(kenched)...............	58	32
	56	29

CHAPTER IX

MACHINE WASHING

Salted fish are washed before drying to remove surface salt, dirt, blood and slime, all of which, if left on the fish, will make the dried product most unattractive. The need for washing varies with the care taken in dressing and in washing from the knife, the type of cure and the duration and condition of storage. A number of conditions which make for difficult washing come to mind readily. The slime left on fish before kench salting may be difficult to remove from the crease in the back and from under the fins. Dirt or impurities in the salt may become deeply embedded in the flesh of kench-cured fish stored in the bottom of the schooner's hold under the weight of superimposed fish. Re-salting light salted cures or leached heavy cures may result in the presence of considerable quantities of hard-to-remove surface salt. Transportation or handling of the pre-dried product in boats, vehicles, or plants where foreign matter may come in contact with the fish adds to the difficulty of producing a satisfactorily washed fish. The difficulties encountered in washing fish are increased when the raw material is stored for extended periods in refrigerated rooms since the fish at the top of the piles become dehydrated and hard. As a result of non-uniformity in the condition of the surface of pre-washed fish, it seems fair to say that during washing the relative importance of the action of brushes, flexing of the fish, and the use of water either as a soaking medium or as a flushing agent often varies, particularly with respect to the kench-cured heavy salted product. Until recently, hand and hand-assisted mechanical methods of washing have been used with the result that the appearance of the washed fish could be controlled fairly closely without too much being known about the actual mechanics concerned with the production of a well-washed fish. Production slowed down when difficult-to-wash fish were encountered, and increased when cleaner raw material became available. Recently the trend towards automation in the salt fish industry has resulted in the design of automatic mechanical washers which have replaced hand labour and hand-assisted mechanical washers, and ensure high productivity at all times. Decreased cost of handling brought about, among other factors, by lower washing costs, has enabled producers to sell fish that could not be produced economically by slower hand methods.

With the development of automatic washers the overall appearance of a proportion of the volume of washed heavy salted fish has deteriorated somewhat. It is believed that the performance of automatic mechanical washers now on the market does not equal that of hand labour for removing slime in the crease in the back of the fish for example. Nor will the washers retain fish long enough

in one pass through the machines to remove all salt, salt impurities, and dirt embedded in the flesh of some of the most difficult-to-wash fish. But the great majority of all fish handled can be washed in mechanical washers sufficiently well to produce a good saleable product. To achieve best results on difficult-to-wash fish, it is recommended that water under considerable pressure – the pressure being determined by the cure, etc. – be sprayed on the backs of the fish before brushing and the fish should be passed through the machine a second time if this is required.

The Musgrave Washer

The Musgrave washer, a dependable hand-assisted mechanical washer (Fig. 8), employing a pair of counter-rotating brushes between which the fish are drawn back and forth by hand, has been used successfully for several years in a number of Nova Scotia and Newfoundland plants handling heavy salted fish. For a complete operation, which includes the labour of moving fish to the washer, of washing, and of piling the washed fish, average production per machine per man hour is slightly more than 300 lb. Where the fish require a separate soaking operation, the production is about 10% less. The cost is about $2,000 for a structural-steel fabricated machine employing vegetable fibre brushes.
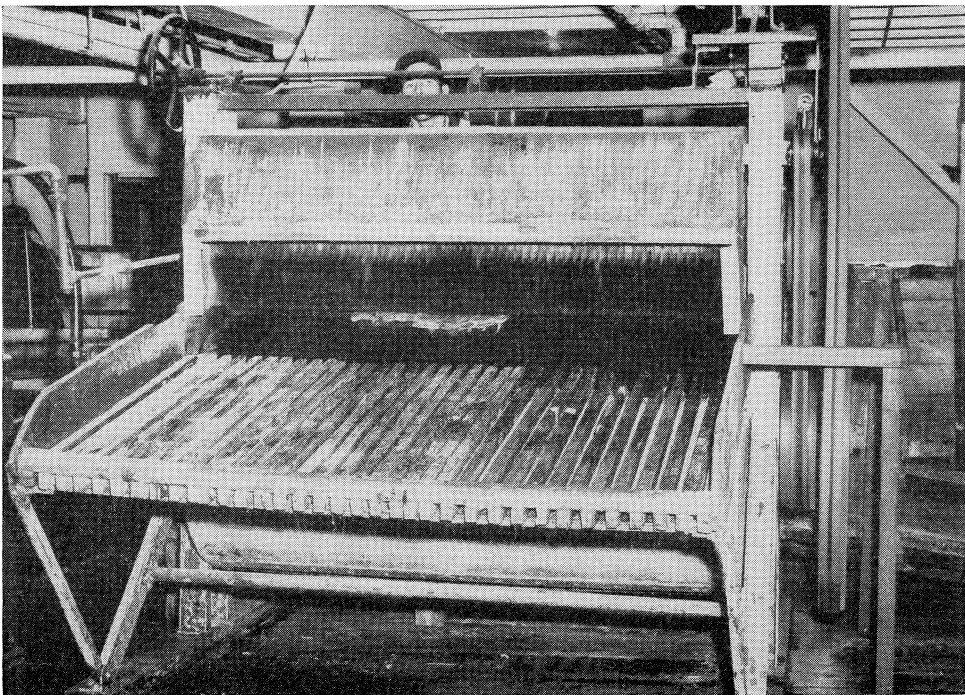

FIGURE 8. Two fish, held by their tails by the operator, are being worked back and forth between the two brushes in a Musgrave type washer.

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THE MacCALLUM WASHER (Type I)

First model. The first model of an automatic washer for washing kench-cured heavy salted fish and light salted fish out of pickle was developed by the Fisheries Research Board of Canada's Halifax Technological Station in 1953 and 1954. (Patent pending in Canada and Norway). Machines of this model have largely replaced the two-brush Musgrave type washer in five Nova Scotia plants. One machine is in operation in Newfoundland. Construction of machines is permitted, subject to the payment of a small royalty to the Crown company holding the patent rights, viz. Canadian Patents and Development Ltd., National Research Building, Sussex Drive, Ottawa. Enquiries from the trade concerning the design features and application of the washer will be welcomed and should be sent to the Fisheries Research Board of Canada, Technological Station, Halifax, N.S.

The machine employs a novel type of brushing action. Certain brushes brush the fish against resistance offered by other brushes and in this sense the washing duplicates hand performance. The fish are effectively scrubbed *on both sides at the same time* under a spray of water and are *flexed* to loosen the dirt from the fish surfaces. The dirt is simultaneously brushed and flushed away. Counter-rotating brushes are employed, and these provide for automatic travel of the fish through the machine along a definite reversed curve path.
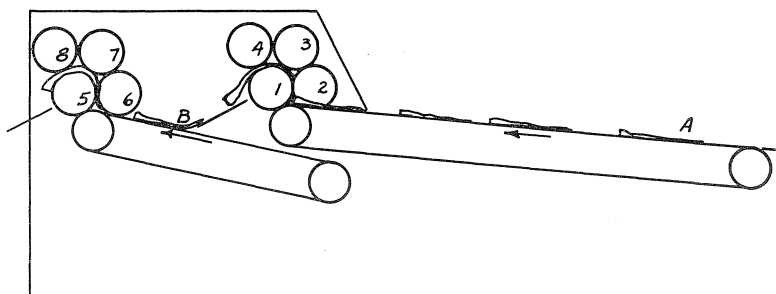

FIGURE 9. Schematic drawing showing belt and brush arrangement of the MacCallum washer, Type I, first model.

Referring to the schematic drawing (Fig. 9), the fish are placed on the top side of the conveyor belt at *A*. One, two or three men can feed the belt from the sides and from behind the conveyor roller. The dirt is softened on the fish as they are carried on the conveyor belt under a spray in the pre-washing soaking stage (Fig. 10). The salt from re-salted fish can be effectively dislodged at this stage also. The fish move automatically from the belt between brushes *1* and *2*, and then between brushes *1* and *3*, and *1* and *4*, respectively (Fig. 9), and finally slide to a second conveyor belt at *B* which carries them to the second group of brushes which duplicates the first group. The fish slide from between brushes *5* and *8* down a guide into a waiting cart, receptacle, or onto a conveyor belt.

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The mechanical equipment used is simple, and all components such as gear motors, sprockets, chains, spur gears and bearings are stocked by a number of equipment manufacturers.

The gear motors can develop 3 and 1 hp. respectively. Water requirements for the washer and pre-washing soaking conveyor are 17 gallons per minute at about 15 lb. per square inch (gauge). The water used on the soaking conveyor could be recirculated and filtered in localities where water is scarce or costly.
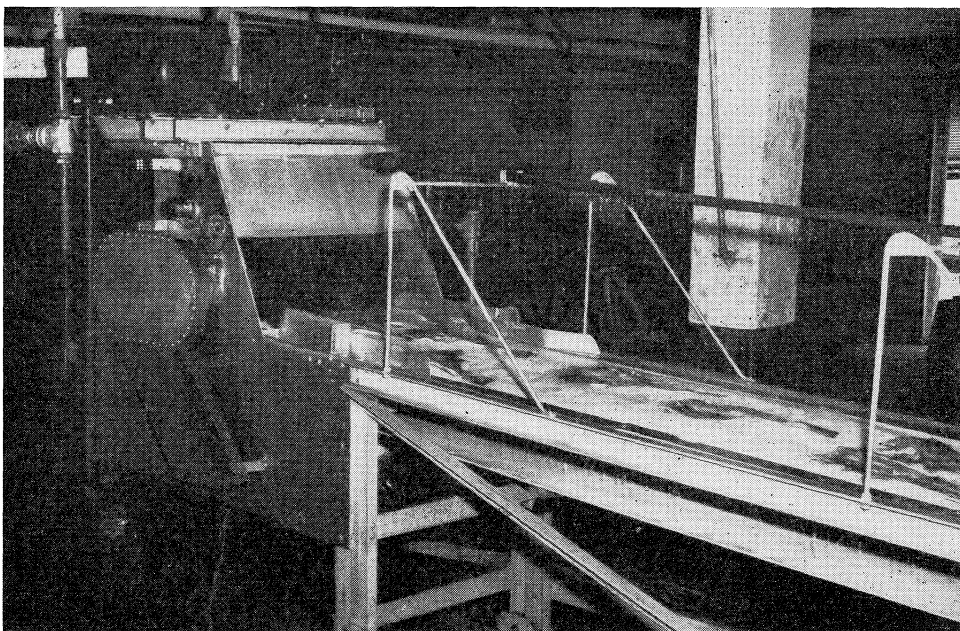

FIGURE 10. A conveyor belt carries the fish through the pre-washing soaking stage to the brushes of the MacCallum washer, Type I, first model.

The new machine can be built and installed ready for operation in Nova Scotia at a cost of about $3,800. This provides an aluminum alloy structure, a short conveyor, nylon brushes, corrosion-resistant Monel shafting and separate magnetic switches for the two gear motors, as well as wiring and piping.

The floor space occupied by the machine with its short conveyor is 3 feet 6 inches by 15 feet. Ceiling height required is less than 8 feet. An extension of the conveyor belt by an additional 6 feet provides sufficient length for removal of most of the surface salt from re-salted fish prior to actual brushing. The extra cost for this conveyor is about $200.

The design provides for loading the conveyor belt at about table height while fish are discharged from the machine at sufficient height to provide for automatic collection in conventional carts if this is desired.

The washer will handle about 50,000 lb. of small and medium-sized green fish per 8-hour day, but few plants have sufficient drying capacity to handle

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such a high continuous production. Small, medium and large fish are handled in the machine. Records in one plant in which the machine is installed show a production for the machine of about 900 lb. of green fish per man hour of attendance at the machine and at the piling operation which follows the washing. In this case the production per man hour is approximately 2.4 and 2.7 times greater than when the Musgrave type washer is used. The former ratio applies to fish not requiring soaking and the latter to fish requiring soaking.

Productive capacity per man hour of attendance over that of the two-brush hand-manipulated machine indicates that the new machine under actual commercial conditions will pay for itself for every $2\frac{1}{2}$ to 3 million pounds of fish washed.

A feature of the new machine is the economy of intermittent operation in the smaller plant, as compared to conventional washing methods. One or two men on the washer can successfully wash batches the size of one or of a number of carts. One man can feed the machine at the high rate of 4,000 lb. per hour. Between periods of washer operation, he has time therefore to assist in piling fish.

Second model. A second model of the Type I washer which employs the same principles of brushing has been in operation periodically in first one
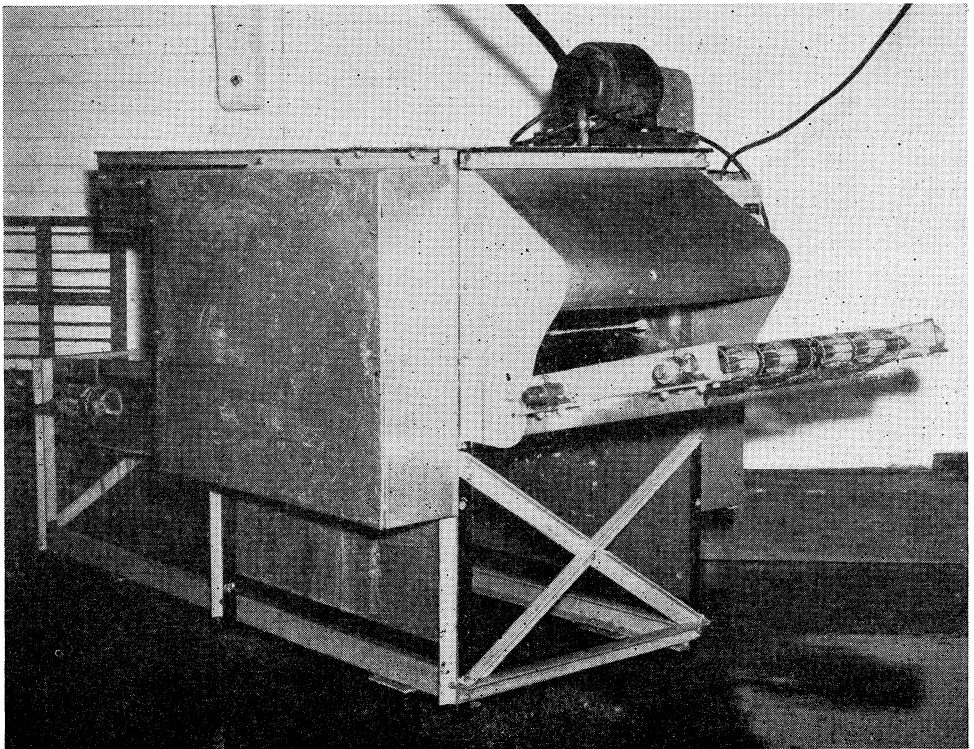

FIGURE 11. A three-quarter view of the MacCallum washer, Type I, second model, the discharge conveyor being nearest the reader.

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and then a second processing plant since early in 1956. This prototype, built at the Halifax Technological Station, is shown in Fig. 11. Five machines of this model have been ordered from local machine shops by Newfoundland and Nova Scotia salt fish producers. Construction of the machines is permitted on the same basis as outlined previously for the first model.

The second model employs only one brush group, and automatic transfer of the fish to an intermediate conveyor belt as with the first model is unnecessary as shown in the schematic drawing Fig. 12. Fish are placed on the loading belt at *A*, from which they are removed by brush *4* and thereafter travel along the curved path determined by the location of brushes *4* and *3*, *4* and *1*, *4* and *2*, *4* and *5*, *5* and *7*, *5* and *8*, *5* and *9*, and *9* and *6*. In this travel, the fish are flexed and brushed in the presence of a water spray. The fish leave brushes *9* and *6* and are carried from the machine by a discharge conveyor belt.
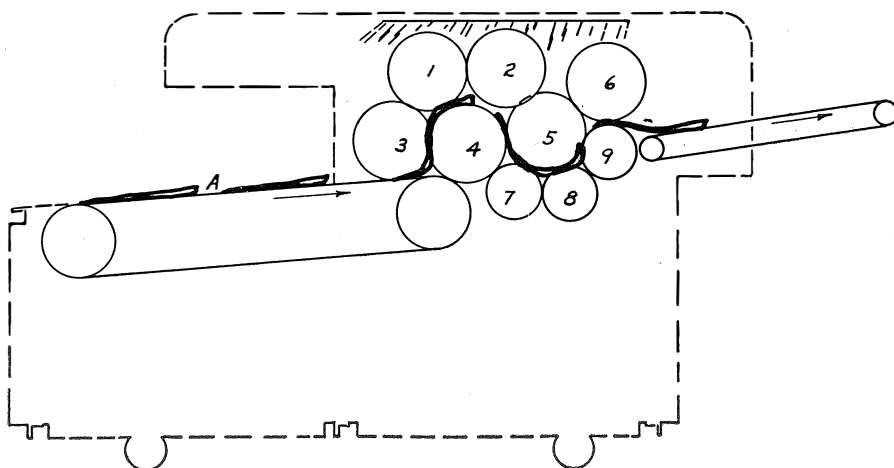

FIGURE 12. Schematic drawing showing belt and brush arrangement of the MacCallum washer, Type I, second model.

It is possible for two men to feed the loading belt, and to keep it fairly well filled. The washing capacity is about the same as that given for the first model.

The machine is short, compact, light, portable, and manoeuvrable. It may be moved by one or two men from place to place in the plant if this is desired.

The maximum horsepower requirements are about $1\frac{1}{2}$, a considerable reduction over that of the first model. Water consumption is about 12 gallons per minute at about 12 lb. per square inch (gauge). A simple water inlet of $\frac{3}{4}$-inch tubing is used. A hose as shown in Fig. 11 may be connected to the water inlet within a few minutes from the time the machine is moved to a new location. Electric wiring connections are made with equal ease. Overall machine dimensions are: length, exclusive of delivery conveyor, about 7 feet 9 inches; length including delivery conveyor, about 10 to 12 feet (limits of this

range are determined by the length of the loading belt specified); width, about 4 feet 4 inches; height exclusive of motor, 4 feet 6 inches. The estimated cost of the machine, using suitable corrosion-resistant materials is about the same as that for the first model. Included in the price of the second model is the cost of several improvements which could be incorporated in the first model as well, but at extra cost. A short stainless steel mesh belt of which the discharge end may be adjusted for height, is provided to carry all fish to a cart or receiving table. Some of the water on the washed fish drains off in the course of this travel. Latest specifications are for one motor to drive the clockwise rotating brushes and another to drive the anti-clockwise rotating brushes. This is intended to reduce wear and noise associated with a reverse gear drive.

THE ANDREWS WASHER

Type I. This washer (Can. Pat. 725,127) is reported to be giving good service in washing light salted fish in Newfoundland. One side of the fish only is washed at one time in this machine. Fish are placed on the conveyor belt at the right side of the machine, as shown in Fig. 13. While moving under a spray of water, the fish pass between rotary brush *1* mounted above the belt, and the
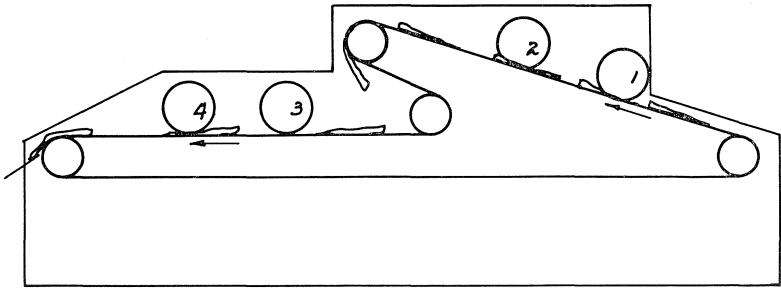

FIGURE 13. Schematic drawing showing belt and brush arrangement of the Andrews washer, Type I.

belt itself; then between brush *2* and the belt. The change in direction of the belt beyond the first two brushes permits the fish to turn over and also to turn end for end. The fish then pass between rotary brush *3* and the belt and between rotary brush *4* and the belt. They may be collected in a box, cart, or by other means as they come off the conveyor belt. Production rates (as given in the 1954 Annual Report of this Board) for machine washing of heavy salted fish, are as follows:

Small cod (12 to 18 inches) . . . . 2,694 lb. per hour
Medium cod (18 to 23 inches) . . . . 4,494 lb. per hour
Large cod (above 23 inches) . . . . 7,120 lb. per hour

The rate for light salted fish is much the same. In washing light salted fish however, the face of the fish is merely sprayed, as brushing tends to roughen it.
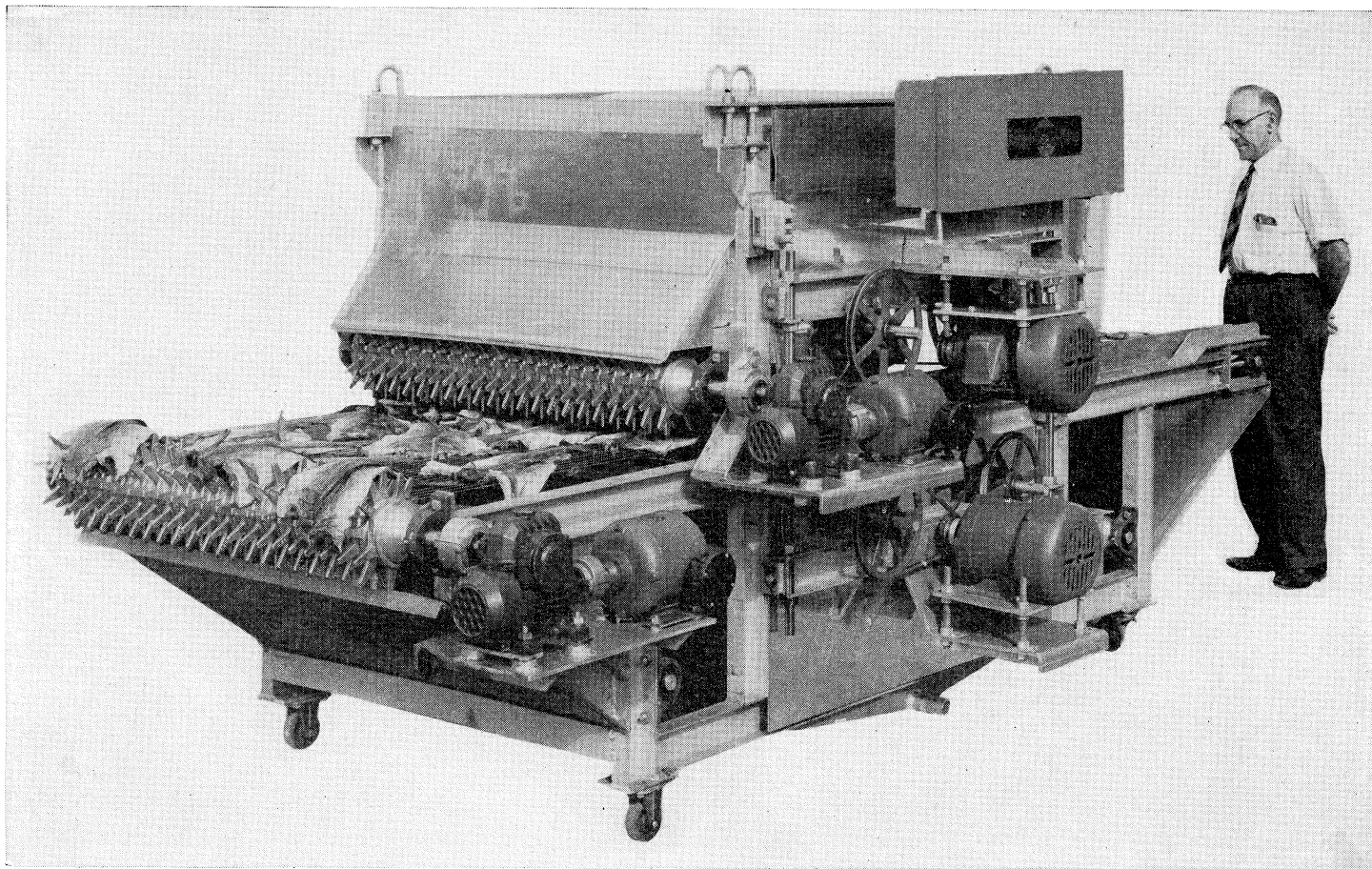
FIGURE 14. The Andrews washer. (Photo courtesy of Messrs. Richards-Wilcox Canadian Co., Ltd.)

Type II. The second Andrews machine (Fig. 14), which was announced in the November 1955 issue of the Canadian Fisherman, washes *both the front and the back of the fish at the same time.* As shown in the schematic drawing Fig. 15, the fish proceed through the machine under a spray of water under the control of upper and lower continuous cords so arranged that the bristles of brushes *1* and *2*, and *3* and *4*, are free to brush the surfaces of the fish.
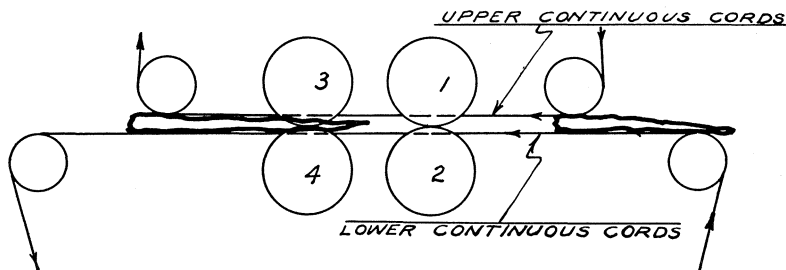

FIGURE 15. Schematic drawing showing belt and brush arrangement of the Andrews washer, Type II.

The machine is much shorter than the Type I Andrews washer. It is also portable. It is reported to handle about 60 fish per minute. Information on maintenance, serviceability and cost of the machine may be obtained from the inventor

CHAPTER X

DRYING SALT FISH

The term "drying" is usually considered to mean taking water out of a substance by some method such as evaporation, absorption, or mechanical separation. The sail of a vessel is dried by allowing the water to evaporate from it to the air. Wet hands may be dried by wiping them on a towel, which absorbs the moisture. A sponge may be squeezed or pressed to remove water from it. Drying salt fish simply means removing water from it by one or more of these processes.

If salt fish were made to be eaten immediately, drying would not be necessary. However, most of our salt fish is shipped to foreign countries where the weather is warmer and damper than in our Atlantic coast provinces. It sometimes takes months before it reaches the people who will eat it. The light salted fish, such as Gaspé cure, will keep only for a few days out of pickle under such weather conditions. Even heavy salted fish spoils after a few weeks. Experience has shown that if we dry some of the water out of this salt fish, a product can be made which will keep quite well at temperatures up to 85°F.

Drying, then, is a process designed to keep the fish in good condition longer than can be accomplished by salting alone.

Two important questions will introduce the subject of drying:

1. How much water must be removed from salt fish just out of pickle or kench?

2. How can the removal of this water be accomplished?

The answer to the first question depends upon how long and under what conditions the finished fish is to be held, and how the fish was salted.

It is generally accepted that heavy salted fish, to be suitable for shipment to tropical countries, should be dried to a moisture content of 38%. This means that water must be removed until 100 lb. of the salt fish contains 38 lb. of water.

There are a great many answers to the second question, "How can the removal of this water be accomplished?" First, let us list some of the methods which have been tried:

(a) *Evaporation.* This is probably the oldest and most successful system of drying salt fish. It operates by spreading the fish out where it can be exposed to a warm, dry breeze until the necessary amount of water has evaporated or

been carried off into the air. Variations of this system range from the historical outdoor or "sun" drying, so common along our coast in past years, to the modern "air-conditioned" dryers with which the trade is now familiar.

(b) *Absorption.* Every so often someone brings up the idea of drying salt fish by "absorption". As Mr. Cathcart Thompson of Halifax, N.S., was one of the first to demonstrate this process in 1890, a brief description of his suggestions may be given to describe the system. In its improved form, this method consists of piling layers of fish, each separated by a pad of moss and sawdust, and placing the whole pile under pressure. It is reported that 200 lb. of fish, put under Thompson's process, after 312 hours gave a weight loss of 36%. Because this method takes quite a long time and the absorbent pads still must be dried, it is not popular.

(c) *Mechanical separation.* Practically everyone in the trade is familiar with the most common mechanical means of reducing the water content of salt fish: the press-pile, or water-horse. If the fish are piled high enough or placed under high pressure, it is possible to remove considerable water by simply squeezing it out.

The press-pile is a very necessary thing for another reason. When salt fish dries, the outside layer dries much quicker than the inside of the fish. Once a crust is formed, drying becomes slow because it takes longer for the water to make its way from inside to outside than it does to evaporate it from the surface. Fish placed in press-pile after a partial drying will "even out". That is, water will be pressed out to the surface of the fish, where it can be readily removed during the next drying period.

The common method of drying salt fish at the present time is by evaporation. Two systems are used:

1. Outdoor or "sun" drying.
2. Indoor or "conditioned air" drying.

Outdoor drying is the older method and is simple if the weather is suitable. After the fish have been cured, washed, and trimmed (if necessary), they are spread on flakes in the open where there is a good circulation of air. Wooden flakes of triangular 1-inch strips spaced at about 3 inches and held together by a frame, have been practically superseded by those made of wire netting stretched across frames. The flakes are on supports which hold them about 30 inches above the ground, so as to permit a very free circulation of air underneath. Drying on rocks or brush flakes is inferior and is apt to spoil the fish from sunburn. Better drying is obtained in the cool dry weather of spring and autumn than in hot, moist summer weather. The rate of drying depends upon the dryness of the air and the extent to which it circulates.

In hot weather there is danger of "burning" or cooking which reduces the value of the product. If the temperature of the fish reaches about 75°F.,

there is very serious danger of its becoming partially cooked, whereupon it becomes mushy and soft. This is often known as sunburn. Therefore on very hot days when there is little or no breeze the fish may need to be protected from the sun. During damp weather, the fish must be piled and covered. During the latter stages of drying the fish are placed periodically in large press-piles. This intermittent piling causes the fish to "sweat", permitting the water from the interior to work out to the surface, where it evaporates in the later drying period.

The rising labour costs of spreading and piling salt fish, together with the considerable losses due to poor weather, have tended to diminish outdoor drying.

Conditioned air drying has replaced outdoor drying almost completely in Nova Scotia and New Brunswick and to a large extent in Quebec. Newfoundland is changing to this method. The foremost reasons for this are that air-conditioned drying allows continuous drying day and night for at least 9 months of the year, and is independent of weather conditions. Spoilage is practically eliminated and the overall drying cost compares favourably with outdoor drying.

This procedure may be described as follows: the wet salt fish are placed on wire screens spaced about 4 inches apart, over which air, heated to 80°F. and at a suitable relative humidity, is blown at a speed of 400 feet per minute. Suitable fans and heaters are used together with modern controls to maintain constant conditions, and the entire apparatus is enclosed to form a unit, which is called a "dryer".

Salt fish dryers have been made in different sizes and from different designs. The first dryer known to have been successful in drying heavy salted fish commercially from salt bulk is known as the Turbo dryer.

Figure 16 indicates the general features of the Turbo dryer. Air velocity over the fish is provided by a central fan rotating on a vertical axis. Supply air, added by a separate fan, is dehumidified by a chemical process (Kathabar), heated, and added to the dryer through the inlet ducts. The fish are placed on trays which in turn are carried on twelve cars into the dryer, where they are mounted on a turntable. If it be assumed that a 12-hour drying period is required, then each hour one car is removed, re-loaded with fish, and returned to its place. The turntable is then moved one-twelfth of a revolution to bring the next car into position for removal.

Although the initial cost of the equipment is relatively high, this continuous batch type of operation requires less labour than most of the other systems. Good heat efficiencies are possible and with the dehumidification equipment, 12-month operation each year is obtainable.

The next two installations were of different design. These dryers reproduced the same fundamental conditions of temperature and air flow but lacked dehumidification equipment. The initial cost is less but more labour is required.
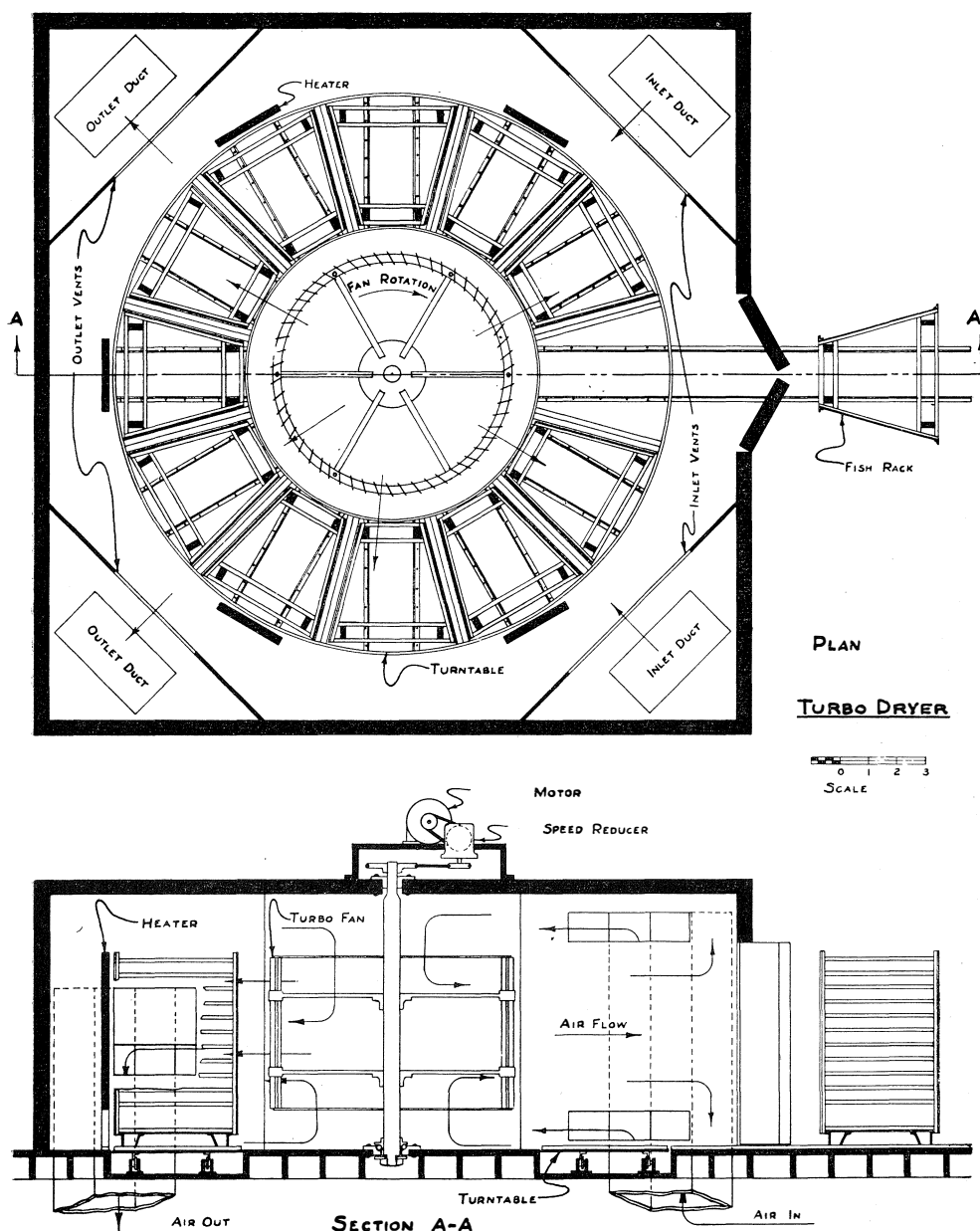
FIGURE 16. Turbo dryer.

Each of these designs was for large units, capable of producing more than 56,000 lb. per week, and required a steam boiler installation to provide heat. Much of the dried salt fish has always been produced by small operators along the coast, and large, steam-heated dryers were economically unattractive to this

section of the industry. To introduce indoor drying to such producers this Board's Technological Station at Halifax, N.S., undertook the design of a salt fish dryer to cost less than $2,000 and to be capable of finishing 11,200 lb. of fish per week, without the necessity of steam. In 1943, the first model was installed in West Dublin, N.S., and achieved exceptional success. Some 125 units of this A.F.E.S. dryer have been installed since then. A sketch of the design is shown in Fig. 17.
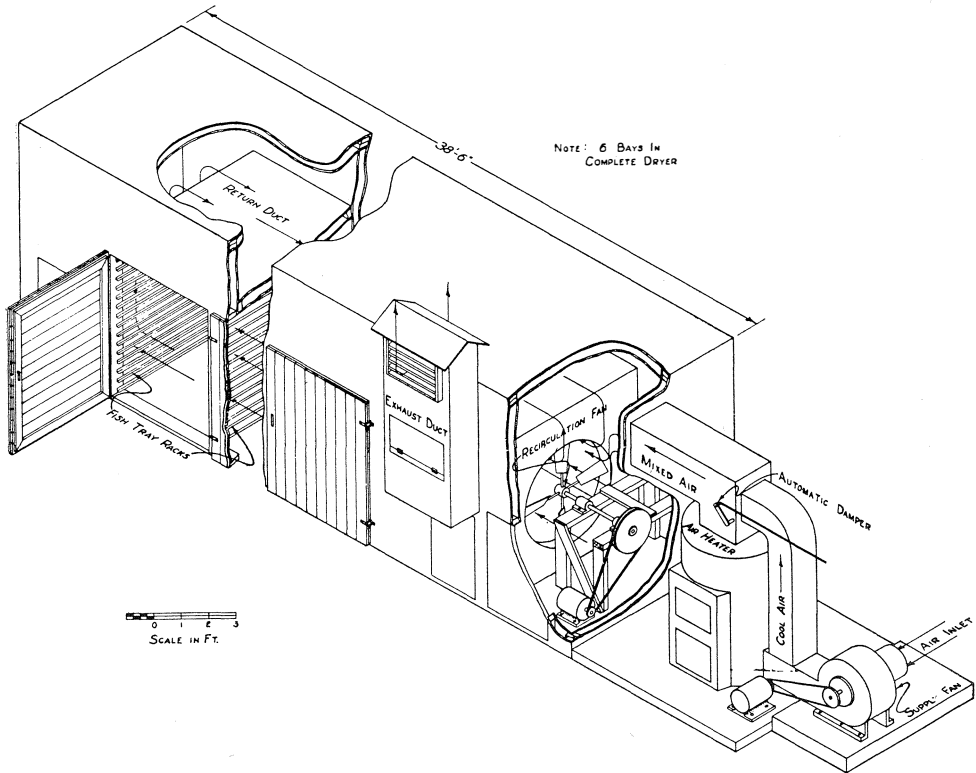

FIGURE 17. A.F.E.S. (Halifax Technological Station) salt fish dryer.

During the last few years, several other designs have appeared. The most impressive of these is a dryer of approximately the same shape as the A.F.E.S. unit, but about twice as large. The significant feature of this design is that supply and recirculated air are handled by a single fan. Considerably more supply air may be passed through this dryer than through the previous types, which extends its operation through more days without the use of dehumidification, and increases its drying potential during normal drying weather. The capital cost and operating expense should be approximately the same as A.F.E.S. dryers of equivalent capacity.

The term "dehumidification" has been used in the preceding text, and should have a few words of explanation. The amount of water vapour which

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the air in a given space can hold depends upon the temperature of that space. If the temperature is high, more moisture can be held than when the temperature is low. This principle may be likened to a sponge, which can hold more water if it is allowed to expand than if it is squeezed.

During periods when the outdoor temperature is below 60°F., the amount of moisture mixed with the air is small enough so that when heated to 80°F., this air can be used for drying salt fish. However, at higher outdoor temperatures this air becomes less useful until, of course, at 80°F., if it should be a damp day, the air is of no use for drying at all. Under these conditions, the air may be made useful for drying by first cooling it to below 60°F. before admitting it to the dryer. This lowering of temperature causes the air to give up some of its moisture by condensation on the cooling surfaces, in much the same way that the air you breathe out against a cold window pane will leave some of its moisture on the glass.

This procedure is known as "dehumidification" and may be accomplished, as described above, by passing the air through a box of ice or through a coil of tubes which are cooled by mechanical refrigeration. There are also various chemical processes for absorbing moisture from air, some of which are practical for use with dryers.

The term "relative humidity", followed by a value expressed as a percentage, has also been used in the text. Such values represent the proportion of moisture vapour actually in a body of air, as a percentage of the maximum amount of moisture vapour that same body of air could hold at the same temperature.

The procedure for drying salt fish indoors varies somewhat depending on the type of cure.

Heavy salted fish may be dried commercially in two or more drying periods, depending upon the size of the fish and the costs of labour, power, and steam. Since the appearance of white, salt crust on the face of the finished product is not considered objectionable, the exact times for drying and press-piling are not as critical as in the lighter cures.

Under average conditions, heavy salted fish are usually admitted to the dryer with air conditions of between 78 and 80°F. temperature, 45 to 50% relative humidity, and 350 to 450 feet per minute air velocity. These conditions must be maintained and sufficient air brought into the dryer to carry away the water that evaporates from the fish. The rate at which water may be removed from heavy salted fish is about 0.5% of the weight of the fish per hour. Small fish may be dried to 43% moisture in a single drying period of about 30 hours. Medium-sized fish will require at least two drying periods of 20 hours each, with press-piling between. Larger fish may require three 20-hour periods, with two press-pilings between.

It is important to note that no drying will take place at relative humidities in excess of 73%. When the humidity exceeds this figure, dried or semi-dried fish will take up moisture from the air.

The most lightly salted dried fish is the Gaspé cure, and is more difficult to process than the heavy salted, because the finishing procedure is actually a race between drying and spoilage.

Mechanical drying of Gaspé cure fish must be carried out by successive drying periods and press-piling. Best results are obtained at an air temperature of 80°F., and at an air velocity over the fish of 300 to 400 feet per minute. The relative humidity of the drying air should be maintained at 50 to 55% during the first drying period and 60 to 65% during all subsequent ones.

The first drying period should be long enough to reduce the water content of the fish to about 55% (wet basis). The loss of weight during this period is approximately 45% of the original weight of the fish, and under optimum drying conditions will take 30 to 35 hours. The length of subsequent drying periods may depend upon the size of the fish; but as a general rule, they should not last much longer than 12 hours each.

Because Gaspé cure in the finished state must be roughly 35% moisture, of an amber colour, translucent, and show no white salt on the surface, press-piling in relation to the frequency of drying periods becomes extremely important. It is recommended that the room in which the fish is to be press-piled be maintained at a temperature of 55 to 60°F., and have a relative humidity of about 65%.

The duration of press-piling depends on several factors, such as water content of the fish, water distribution in the fish, size of the fish, size of the pile, and atmospheric conditions. As a general rule, it may be said that the press-piling has been of sufficient duration when the surface of the fish has become wet. Since the diffusion rate is increased by pressure, the surface of the fish becomes moist much more rapidly at the bottom than at the top of the pile. Therefore to equalize the diffusion process it is necessary to re-pile the fish from time to time. Moreover, this re-piling process promotes the formation of a thin layer of salt at the surface and greatly enhances the final appearance of the fish. Experiments have shown that a press-piling period of 24 hours with several re-pilings between the first and second drying period is sufficient. Then the duration of the second press-piling will be about 4 to 6 days and that of the third will be 8 to 10 days. Re-piling every second day is of great benefit.

Newfoundland salt fish varies in cure from the light salted Gaspé variety to the heavy salted type common to Nova Scotia. Generally, the great bulk of fish produced in Newfoundland has a salt content somewhere between the two, with the largest quantity being of the light salted variety (i.e. closer to the Gaspé type). From the standpoint of subsequent drying procedures, three classes of Newfoundland salt fish may be distinguished:

Heavy salted. "Mechanical" or "artificial" drying in the same manner and under the same conditions as previously outlined is employed. It is frequently dried to 35% moisture (hard dried) in Newfoundland, consequently necessitating long drying periods.

Light salted. This ranges in salt content from that of the Gaspé cure to about mid-way between the Gaspé and heavy salted cures. The higher salt content fish in this class may be dried in the same manner as for heavy salted fish; the light salt cures by processing under the same general conditions as for Gaspé type fish.

Very light salted (Italian grade). The best results are usually obtained when this is dried and press-piled frequently for short periods; however, economic considerations tend to make such a procedure impractical in Newfoundland. Except for very large fish, drying is carried out in two periods of about 35 to 40 hours each, with one intermediate press-piling usually for 24 to 48 hours. The fish is dried to 43 to 48% moisture in the first period and to slightly below 35% in the second. Drying is usually carried out at about 80°F. and 55% relative humidity, the temperature being dropped 10 degrees in cold weather with a corresponding adjustment of relative humidity.

The drying of light salted fish has been carried out in Newfoundland only on a commercial experimental scale, with about 5,000 to 6,000 quintals having been produced over three seasons.

The greater proportion of "mechanically" dried fish in Newfoundland is fish that has been merely finished in a dryer—heavy salting procedures and conditions are generally followed for this type of processing. The initial drying takes place outdoors on flakes; it is then press-piled for various lengths of time, depending on atmospheric conditions and moisture content, then finished in the dryer in one period.