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H. W. WILEY, Chief of Bureau.

PREPARATION OF THE COD AND OTHER SALT FISH FOR THE MARKET;

INCLUDING A BACTERIOLOGICAL STUDY OF THE CAUSES OF REDDENING.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Chemistry,
Washington, D. C., August 9, 1910.

Sir: I have the honor to submit for your approval a report made by Inspector Bitting, of this Bureau, on an investigation of the methods of preparing cod and other salt fish for the market. A bacteriological study of causes of reddening accompanies the report, which, it is believed, will increase its interest and practical value. I recommend that this manuscript be published as Bulletin 133 of the Bureau of Chemistry.

Respectfully,

H. W. Wiley, *Chief.*

Hon. James Wilson,
Secretary of Agriculture.

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INTRODUCTION.

Fishing is one of the oldest industries in the United States, and Gloucester, Mass., the point at which this work began, continues to be the center of operations, particularly in the preparation of salt fish. The city was founded in 1623, one of the main objects being to conduct fishing operations, and at no time has this been secondary to any other. The cod is preeminently the fish sought, and it brought succor so often to the colony in early times that it was designated the "Sacred Cod." The other fish which are caught and handled like the cod in dressing and curing commercially are haddock, cusk, hake, and pollock.

The extent of the fishing industry is hard to appreciate from statistics alone. According to figures furnished by the Bureau of Fisheries in 1905, there was a total of 37,339 persons engaged in fishing or fish preparation in New England. The total catch amounted to 480,283,604 pounds, having a value of $14,184,205. Of this total the cod, cusk, haddock, hake, and pollock amounted to 225,182,272 pounds, valued at $4,086,342.

For a long time the general handling of cured fish in the trade was confined to the cooler months of the year and almost no business was done in the summer. During the civil war the price of meats became so high that the fish business was conducted on a limited scale in the near-by cities throughout the year. Long-distance shipments, however, were not undertaken. After the war was over, trade in fish was carried on late in the spring and begun early in the fall, but operations were almost wholly suspended during the midsummer months.

Formerly mackerel fishing occupied the time of the fisherman during the warm months and thus prevented summer from being an idle season, but in recent years the mackerel catch has been very small, and this probably accounts in some degree for the desire to foster a summer business in dried salt fish. With the advent of boracic acid preservatives in 1881, the industry gradually became a continuous business and summer shipments were made to long distances. At the present time

January represents an average month of business, there is quite an increase in February and March, then a sudden drop in April to the lowest sales of the year. Very little business is done in May, but improvement begins and is constant through to October, which is the best month in the year. November and December are good months, though not nearly so good as October. The increase in summer business during June, July, and August is said to have been from 25 to 30 per cent in the past ten years, and a very marked increase occurred with the advent of preservatives.

COD FISHING.

Cod fishing is divided into four classes: Bank or trawl fishing, Georges hand-line fishing, rip fishing, and dory hand-line fishing. The methods can best be described under these four heads.

GRAND BANK FISHING OR TRAWLING.

The vessels for the bank fishing leave Gloucester on their first trip the latter part of January and continue to go out through February, March, and April, the time being controlled somewhat by the weather and the advancement of the season. The first trip is generally made directly for "The Peak," the southeastern part of the Western Banks, as this seems to be the most natural spawning ground of the codfish, or to the southern Treaty coast of Newfoundland. About the middle of May, after the ice has come out of the Gulf of St. Lawrence, the vessels go to the Magdalene Islands or Nova Scotia for bait and finish their trip in the Gulf of St. Lawrence and off Quero and the Western Banks. If the fishing on these banks is not good or the bait has become exhausted, the vessel then goes to St. Pierre, which is the port of entry, proceeds to the island of Miquelon for a baiting of caplin, and finally finishes her trip on the Grand Banks. The caplin baiting is taken about June 15, the aim being to make a return home in July or to wait until the vessel has had a full trip or "wet her salt." Sometimes it is necessary to go to the island of Miquelon a second time for a baiting of caplin.

Sailing vessels only are used in this work and they are of stanch construction. The average crew is eighteen men, though there may be as many as twenty-two. There are two men for each dory carried, and a captain and a cook. The vessel starts out with from 350 to 450 hogsheads of salt and a supply of bait. The first baiting, which is taken from home, consists mostly of frozen squid, but sometimes a few frozen herring are taken. The quantity of bait carried ranges from 15,000 to 25,000 pounds, as a long time ensues before fresh bait can be procured. Codfish will bite herring only while herring are running, and caplin only while caplin are running, but will bite squid

at any time more readily than other bait, though they, too, are preferred running.

The caplin must be purchased at Miquelon, as it can not be taken from home nor obtained from the English colonies. The cod is a particular fish and must be given good bait, otherwise he will not bite. Bait tainted from lack of ice is not satisfactory.

The cod fishing is done in from 20 to 120 fathoms of water off the coast of Newfoundland and on the Banks, and in from 100 to 135 fathoms at the edge of the Banks. Off the Bachalia Banks of Newfoundland the work is conducted in 80 to 140 fathoms of water, but the fish are not so good as they are on the other banks.

The second trip is generally made in July or August and the return made in October or November. This trip is generally confined to Quero and the Grand Banks. The area of the Grand Banks is represented by a distance of 300 miles north and south and 200 miles east and west and lies to the southeast of Newfoundland. The bait used on this trip is principally squid, caught on the fishing ground.

The usual equipment is eight dories; none of the boats carry more than ten. Each dory is 15 feet long and is carried midship. When starting to fish, four tubs of baited lines are put on a dory. Each tub contains nine No. 18 lines. Each line is 50 fathoms or 300 feet long, so that one tub will run a string 450 fathoms or 2,700 feet, and the four tubs clear a distance of 1,800 fathoms or 10,800 feet. Each line carries 85 to 95 hooks or 800 hooks to the tub, 3,200 hooks to the dory. A vessel with ten dories will set 32,000 hooks at a time, which if stretched out in a straight line would extend about 20 miles. The hooks are attached to the line by means of shorter lines or gangings. These gangings are from 27 to 28 inches long.

When the vessel arrives at the fishing ground, soundings are made to determine the depth and character of the bottom, it being always preferable to locate over a pebbly ocean bed. What is called a flying set is made; that is, the trawls are set while the vessel is in motion, and if it shows that fish are abundant the vessel is anchored. In making this flying set the dories are towed astern of the vessel until the right spot has been selected, then one of them is dropped. This dory rows off in a direction at right angles to the course of the vessel, the trawl being thrown out as the dory proceeds, until it is all set. As the vessel proceeds on its course dories are dropped at intervals, all of which row off in the same general direction.

When all the dories have started, the vessel returns diagonally across the fishing grounds, and the first dory, which by this time has set its trawl, is picked up, then the next one, and so on until all are secured. The vessel takes a course diagonally across the fishing grounds to the starting point and, after cruising around for a short time, the dories are again dropped in the same order as in the first

instance. The men proceed to pull the trawls and take the fish off. After all the dories have been dropped, the vessel again proceeds diagonally across the fishing grounds to the first dory, which by this time has taken her fish. Each dory is picked up in succession and the fish taken aboard the vessel. If this flying set is successful and the weather and fishing conditions are favorable, the vessel is anchored and the fishing proceeds. The position of the trawls with reference to the vessel at anchor is usually one directly forward, one astern, and either three or four radiating spoke-like from either side.

The direction of the tide always governs the setting of the trawl. On the side of the vessel toward which the tide comes, the dories are rowed out a distance from the vessel equal to the length of the trawl, and the setting is made with the tide and toward the vessel. On the side of the vessel from which the tide is running, the set of the trawl is started at the vessel and proceeds to the outer extremity. The dories which proceed in other directions from the vessel set their trawls as far as possible with the tide.

In setting the trawl, an anchor is attached at the end of the first line, the anchor rope being 1 fathom in length. At the same time a buoy is also attached, the buoy line being 25 fathoms longer than the water is deep at that point. When all of the trawl has been cast out, an anchor and buoy are attached to the end in the same manner as at the beginning. If the tide is running strong, the set is with the tide to keep it well stretched, otherwise it would become bunched and tangled.

The trawls are set once a day, and formerly it was the practice to leave them out three hours and then draw them. It is now a common practice to set them at 3 or 4 o'clock in the afternoon and leave them out over night, but many vessels make a day and also a night set. The older method seems to be the better, as the fish are more nearly in the same condition when brought in as when caught by hand lines.

In hauling the trawl to take the fish off, it is always preferable to haul with the tide. Sometimes in blowy weather, when the water is rough, the dories all start for the outer buoy and haul in toward the vessel. The man in the bow hauls the trawl and takes off the fish or passes the fish along the side of the boat to be gaffed and drawn in by the man who coils the trawl. The line is usually drawn hand over hand, but when it is very rough or the water is very deep a gurdy may be used. Nippers are used to protect the hands from being cut in the drawing of the trawls.

A dory will carry on an average 1,000 pounds of fish in the bank fishing, but in very smooth water it may be loaded with 2,500 pounds. More than one dory load may be on a trawl at a haul, and if such is the case, a buoy only is attached at the point where the line is cleared

of fish unless the sea is rough and other trips can not be made, then the anchor and buoy are attached as at the beginning of the line.

The fish are passed from the dories to the vessel with pitchforks called pews and are kept in lots on deck by means of division boards so that they will not slide or be bruised by the movements of the vessel. When the fish are all on board, the crew is divided into splitting gangs, each consisting of three men. The first man removes the head and splits open the belly, the second removes the viscera, and the third splits the fish and removes a part of the backbone. These men are known as throaters, gutters, and splitters. The first man seizes the fish by the head in the left hand, places the back on the edge of a tub or pen, and by means of a sharp-pointed knife makes a cut across the throat just behind the gills and another slit is made down the belly. Then, grasping the head and body, backward pressure is made across the edge of the tub or pen, resulting in breaking off the head at the first vertebra. The fish is then passed on to the gutter, who opens the belly with the left hand, removes the liver for oil, and tears out the viscera. It is then passed to the splitter, who places the back of the fish against a cleat on a board and by means of a heavy knife continues the split down the belly to near the end of the tail, care being taken to keep near the backbone. At about three-fifths of the distance from the neck to the tail the backbone is cut across, a slit is made up the right side, and the forward portion of the backbone is removed. In this operation the knife blade is kept close to the backbone to prevent loss of flesh and to keep the middles thick. The loss in weight by removal of head, viscera, etc., is about 40 per cent.

The fish are then well washed and blood spots removed. They are slipped down a canvas chute into the hold, where two men carefully salt and kench or pile them. The fish are laid on their backs with napes and tails alternating, with the exception of the top layer, which is turned back up; a liberal sprinkling of salt is placed over all, an especially heavy portion being put on where the fish come in contact with partitions or the sides of the vessel. In the Banks fisheries, it requires on an average nearly 1½ bushels of salt for 100 pounds of fish. A great deal depends upon the thoroughness with which the work is done, as it is important that every part of the fish shall receive a share. If the salting is well done, it is not often that the fish need to be rekenched; but if the salt is used too sparingly or is unevenly applied, souring may start and necessitate moving whole kenches and resalting. Sometimes the effort is made to salt a little slack in order to make them weigh heavy on reaching port, with the result that the whole lot may be lost. As the fish lose their water from salting, it runs to the bottom of the hold and is pumped out.

The fish are placed in the forward compartment first and kenched from side to side of the vessel, not from fore to aft. When the kench settles, additional fish are placed on top to keep the compartment full. Two men who are especially good at salting are selected for the work and are held responsible for the condition of the fish.

The kenches are usually about 4 by 7 feet and the full height of the hold. The salt is carried in compartments in such quantity that when one is filled with fish the next is empty of salt. All of the fish are salted on the Bank trips. The gurry or refuse is thrown overboard, and the position of the boat is changed a few miles whenever the ground becomes polluted.

When the day's work is done, the fish dressed and in the hold, and the deck scrubbed, the dories are hauled on board.

DORY HAND-LINE FISHING.

The vessels for the dory hand-line fishing usually start on the first trip about April 1 and return in June. The crews consist of eighteen to twenty-four men, with a dory for each man except the captain and the cook. The dories used in hand-line fishing are smaller than in the trawl fishing, the length being 13 feet. In hand-line fishing clams obtained on the coast of Maine and slack salted are used for bait. Only one baiting (75 to 125 barrels) is carried, and if any more is required it is picked up on the ground; squid, clams taken from the stomachs of fish, and hagdens may be used, as may any fresh bait.

The dory hand-line fishing is generally begun at the Western Bank, but during the last few years the principal fishing ground has been Quero Bank. On the late fall trip, about October 1, the vessels frequently go to the Virgin Rocks on the north side of the Grand Banks. The first trip is generally finished and the return made in the latter part of June or July, while the return from the second trip may be as late as November.

When the vessel arrives on the fishing ground, the dories put off in all directions, sometimes as far as 3 or 4 miles, each man for himself. If one place is found in which the fish are particularly plentiful, then a number of boats from the same vessel or from different vessels may come together and form a fleet. The fishing is done at anchor. Each fisherman uses two lines and two hooks on a line. The depth varies from 18 to 40 fathoms. The sinkers on the hand line weigh 4 pounds. The jigger, a lead weight with hooks projecting from the sides, is used until July 1. This can be employed only in water less than 25 fathoms in depth. When the jigger is used, only one line is thrown out as the operation consists in working

the jigger up and down and hooking the fish on any part of the body. Instead of the dory remaining at anchor, it is permitted to drift.

In hand-line fishing, the boats usually go out at sunrise and come in about 10 o'clock, though some may carry a "grub basket" and stay out later, depending on the luck. A boat load before noon and another one after noon make a good day's work. A dory will carry 1,000 pounds in fair weather, but not so much when there is a rough sea. The fish are counted as they are pitched on deck. Those below 22 inches from tip to tip are not counted, neither are the shack, that is, the pollock, haddock, cusk, and hake, as a general rule, although on some trips these shack fish are counted separately.

The dressing of the fish and handling in the boat is the same as in trawl fishing.

RIP FISHING.

The branch of cod fishing known as rip fishing is followed off Nantucket on the fishing ground known as "the rips." The fishing begins about the first of April and continues until the end of October, or until the weather gets too rough to carry on the work. The fish on these trips are sometimes salted and sometimes landed fresh. The salt trips continue for three or four weeks and the fresh trip from a week to twelve days. The crew consists of twelve to twenty men. In rip fishing the work is all done from the deck of the vessel while the boat is drifting.

The bait used in rip fishing consists of cockles from the mud and sand flats, which are put in bags and iced, where they will remain alive for four weeks. This bait is rather expensive, sometimes costing as much as 90 cents to a dollar per bucket; on an iced trip it will require an average of 50 buckets and on a salt trip 200 buckets. Each man uses a hammer and flat rock or iron to break open the shells. In the rip fishing, the positions on the deck are followed in rotation by the crew, with the exception of the cook and the captain. The stern positions are regarded as being the best, and the rotation is for the purpose of giving all an equal chance. Only one line with two hooks is used, the sinker weighing from 3½ to 4 pounds. The count is kept by cutting out the tongues and keeping them in individual buckets.

GEORGES HAND-LINE FISHING.

Hand-line fishing is followed on the Georges Bank southeast of Gloucester. The fishing is usually started during the latter part of February and continues until late in the season, or nearly the year round. The trip usually requires from three to four weeks. This is one of the favorite spots and from a dozen to two hundred and fifty vessels may be found here. In the Georges fishing the work is done

from the deck while the vessel is at anchor, the position and rotation of men are the same as in rip fishing and the count is kept by the number of tongues. The crew consists of fourteen to sixteen men besides the captain and the cook. The bait used is frozen herring or, if that can not be obtained, the boats may go to Edgartown and get pogies, kiaks, bluebacks, squids, and sometimes alewives. These are kept iced, as any spoilage of bait will result in no catch. The fish caught on the Georges Bank are salted, except the halibut, which is iced. The Georges fish are considered the best, the rip fish second, the dory hand-line catch third, and the trawl-caught fish fourth.

The Georges Banks and adjacent fishing grounds off the New England coast furnish about 70 per cent of the catch and that of the Grand and Western banks about 30 per cent. Approximately 61 per cent of the fish are brought in iced and 39 per cent salted. The percentage of different kinds of fish vary with the years; in 1909 the codfish amounted to 62 per cent, haddock 14 per cent, cusk 4.5 per cent, hake 5.5 per cent, and pollock 14 per cent.

The boats which bring in only salt fish are designated as "salters," and those that bring in salted and iced fish or iced fish only, as "shack fishers." The term "shack" is often applied to all fish other than cod, as cusk, hake, haddock, and pollock. It is also applied to fish which have become tainted, and therefore one must understand in what connection the term is used in order to get the correct idea.

CLASSIFYING AND HANDLING THE FISH ON SHORE.

The fish are received from the vessel either salted or iced. If the fish have been salted, they are passed up from the hold by pews to the deck and in like manner to the wharf. The cod are separated into three classes, snappers, medium, and large, according to their size. All codfish less than 16 inches from the curve of the nape to the hollow of the tail are designated as snappers; those more than 16 but under 22 inches are called medium, and those above 22 inches are rated as large. The codfish generally run—snappers 4 per cent, medium 41 per cent, and large 55 per cent. The cusk and hake are generally divided into two sizes, the snappers under 19 inches and the large above that. Each class is weighed and kept separate, being examined for any evidence of spoilage as they are pitched out. If they have not been fully salted or there has been carelessness in applying salt to all points at the ends of kenches or along the partition walls, or if there has been any leakage through the deck, there will be a peculiar sour odor, not very different from that of sauerkraut. Those accustomed to handling the fish become expert in recognizing this trouble and pick out the infected fish instantly. In cases of doubt, two or three of the crew may act as inspectors in detecting the

UNLOADING AND DRESSING ICED FISH ON THE DOCK.

odor. Reddening of fish may occur but it is much less frequent than souring. The spoilage more often occurs in the fish which have been repacked than in those handled only once. The fish are usually washed by pitching them into tanks of water, though sometimes they are scrubbed with brushes. They are then put into butts in the storage houses.

If the fish are brought in iced they are transferred from the boat to the wharf by means of a basket rather than by the pew. Two men, with rope and pulley, hoist the basket from the hold and a third man swings it out onto the dock. The fish are sorted and weighed in the same manner as the salt fish and are then passed on to the different dressing gangs. The first man in the dressing gang seizes the body of the fish in one hand and the head in the other, places the back of the neck in a notch in the dressing tub, and by a backward and twisting movement breaks off the head. The fish is then passed on to a splitter to complete the work of splitting and to remove the forward portion of the backbone, the same as when the work is done on board the boat. The fish are then washed and placed in the butt the same as salt fish, the important difference being in the quantity of salt used. Fresh fish require about 8 bushels of salt to the hogshead, and the fish are piled nearly 2 feet above the top of the butt in order to allow for settling.

CURING.

The curing of salt fish depends upon drying, and this is accomplished in three ways—by the use of salt, by pressure, and by exposure to the air, either in the open air or in a drier. In this country all three agents are employed, as it is not possible to dry the fish in the air alone, as is done in certain parts of Norway.

Salt acts as a drier as well as a preservative, as it abstracts moisture wherever it comes in contact with the tissue, whether this be in the kench in the boat or in the butt at the factory. In the strictly full-pickle fish (that is, fresh fish placed in the butt) the maximum effect of drying by means of salt is accomplished. All the water abstracted in making pickle is so much drying. Kenching and air drying are necessary to complete the operation, though the amount of water abstracted by the latter operations is not so great as is generally supposed. In the " kench cure " there is a combination of salting and pressure. The water abstracted by the action of the salt is less and more dependence is placed on the repeated kenching of the fish, which insures uniform and heavy pressure on all, thus forcing out considerable quantities of water. The kench cure was formerly employed more than at present. There are some who maintain that it gives better quality to the fish, but if such is the case it must be due to some other cause than introducing salt and taking out

water, as the analyses of the final products show no essential difference between the full pickle and the kench cure.

A very large proportion of the fish is cured by a combination of these two processes, being salted and kenched on board the boat and the work completed in pickle at the factory. One of the advantages of the pickle cure is that the fish can be handled at all seasons and at such a rate as the trade may demand. For the slack-salted fish the salt is used as a preservative and the drying is accomplished by pressure and in the air. This can be done only when the weather is favorable.

The more fully the drying is done by salt or by pressure the less time is required on the flakes. Those dried for domestic consumption are not nearly so dry as those packed for export trade. In the former class the moisture content is usually between 43 and 51 per cent, while in the latter it is between 28 and 35 per cent.

PICKLING.

The butts used in pickling are usually heavy molasses hogsheads which are used over and over for years. Some of them have been in use for twenty years or more. The fish are carefully placed in the butts in layers, face (split surface) up, except the last two or three layers. Salt is sprinkled over each layer, care being used to see that every part is covered. The amount of salt used in the butt will depend upon how well the fish have been salted. Those coming from long trips, particularly from the Grand Banks, receive only 2 to 2½ bushels of salt, while those which come from the short trips may require as much as 4 bushels. The well-salted fish are generally piled 6 to 8 inches above the level of the butt to allow for settling. A half bushel or more of salt is placed on top of the pile to insure a strong pickle. To well-salted fish a strong pickle may be added, or a basket of salt may be suspended above the butt and a small stream of water allowed to trickle through until the butt is filled. This is not necessary with fresh fish, as they will make their own pickle. It is a common practice to label the butts to show the vessel from which they were taken, the date, and the grade of fish.

After the fish once settle in the butt and are well covered with strong brine, they will keep until ready for use whether the time be short or long. The only precaution necessary is that the butt be kept full of strong brine. For a full-pickled fish, the kind used in the making of fish cakes for domestic use, the fish must be kept in the butt for from eight to twelve days if salted and for three weeks if fresh. On rush orders the time may be shortened a few days. If the fish are to be slack salted and come in iced, they are put in the butt for from thirty-six to forty-eight hours, using about 3 bushels of salt to the butt. The fish are then taken out, washed in

FIG. 1.—BUTTS AND KENCHES WHERE FISH ARE PICKLED AND THEN WATERHORSED.

FIG. 2.—FLAKE YARD ABOVE A BUTT SHED AND AWAY FROM THE STREET.

clean water, and placed in piles in kenches. The loss of weight from salting for the heavily salted fish is about 40 per cent of the dressed weight or 17 per cent of the live weight, and this loss occurs whether the fish is partly salted on the vessel and completed in the butts or the entire salting is done in the butts on fresh fish.

As before stated, the fish will keep indefinitely in the strong brine of the pickle so long as they are covered. The pickle must be added to occasionally to make up the losses, particularly from leakage. Very rarely a butt will sour because of some oversight in passing fish which had previously been tainted or improperly salted. Reddening will occur if any part of the fish projects above the brine or the brine is allowed to fall below the level of the fish. The losses in the butt, however, are small, and it is customary to keep the fish in that way until they are wanted.

WATERHORSING.

When the fish are taken out of the butts they are piled in a kench to drain off part of the brine. The fish are stacked face down, with the exception of the lowest layer in contact with the rack, in kenches usually about 4 feet high. If there is urgent demand for them, they are left in this condition for twenty-four or forty-eight hours. If more time can be allowed, they are repiled at the end of the first or second day, so that the fish on top may go to the bottom and be subjected to pressure to squeeze out part of the water. If the weather is unfavorable to drying, the kench is repiled every second or third day, and this may be continued for ten days or more. With full-pickle fish it is not necessary to kench or waterhorse so thoroughly as in the case of the slack-salted or hard-dried fish.

When slack-salted fish are taken from the butt they are washed by running water over them and kenching them, as is done for the regular pickled fish, but they are always repiled every other day until they are fairly dry and ready to be exposed to the air. The hard-dried or export fish are taken directly from the kenches in the vessel, and washed, kenched, and rekenched until quite dry, the treatment being the same as for the slack-salted product.

DRYING.

The fish are dried on flakes and the drying yard is known as the flake yard. The flake consists of a lattice bed about 8 feet wide, 30 inches high, and as long as the requirements may demand. The lattice used on this bed is made of triangular strips 1 inch on the base, and these are placed about 3 inches apart. The fish therefore rest upon a sharp edge about every 4 inches. This is for the purpose of giving the maximum circulation of air about the fish. One double-deck flake yard was seen, the space between decks being 18 inches.

The flake yards are located near the fish factory. Formerly the were all placed on the ground, sometimes near a street, but the prac tice has changed, and they are now found above the butt sheds o other buildings, thus avoiding the dirt and dust which might be dis tributed by passing vehicles. Some of the flake yards are built ove the water.

At regular intervals along the flakes, crosspieces are provide over which to stretch a canvas to protect the fish from sunburn dur ing hot weather. Boxes or coops are also provided to cover the fis during rains and at night, the tops of the boxes being pitched t shed the water. These flake boxes are about 38 inches long, 24 inche wide, and 14 inches high, and will cover from 20 to 40 fish; durin the day they are pushed under the flakes.

FIG. 1.—Covers used for protecting fish piles at night and in wet weather.

The fish are spread out carefully on the flakes with the face sid up and the drying is continued as long as may be necessary for th particular grade of fish. The full-pickle fish are dried for th shortest period, as they can not be skinned readily if too dry, an furthermore, the trade seems to desire fish which are moist and n too hard, and these retain practically 50 per cent of their water. the sun is fairly warm and there is a good breeze, the drying can b accomplished in about ten hours as the minimum time, but this ma be greatly increased with unfavorable weather conditions. Only o drying is usual for the full-cured fish.

The slack-salted fish are generally dried for two days, kenched f two or three days to "sweat" them, then placed on the flakes agai for one day. Porto Rican or hard-dried fish are dried for thr

days, "sweated" for two days, then again dried for two days. The object of the "sweating" is to bring the moisture out of the interior of the fish. The drying on the flakes removes the moisture from the surface and crystallizes the salt, but to get the moisture out of the center of the meat the fish must be piled in the kench, where the dry salt takes up some of the remaining moisture, so that the second drying on the flakes has a greater effect. The full-pickle fish lose about 9 per cent of their weight in drying on the flakes. When cured, they retain about 50 per cent of their moisture, the slack-salted retain 35 to 40 per cent, and the hard-dried from 25 to 30 per cent.

In the experimental lots, the loss of weight while on the flakes was as follows:

Loss of weight under different conditions.

Salt.	12 days' pickle.	22 days' pickle.
	Per cent.	*Per cent.*
Table salt	13.7	11.6
Packer's fine	15.5	13.0
Packer's coarse	14.8	11.7
Trapani	12.8	11.3
Iviza	14.0	11.0
Meat	15.0	.....
Butter	13.0	.....

The loss of weight recorded was uniformly greater than occurs in the regular factory operation, as the piles were too small to secure as thorough drainage on the waterhorse.

The Nova Scotia cure differs from the regular pickle cure in that the fish are given a short drying after being skinned. This style of cure is used in the New England trade only, but from the observations made it appears to have some advantages over the regular method. The loss in weight from the second drying is from 5 to 8 per cent.

Fish are also dried in large driers built in the factories. These consist of inclosed rooms in which there are shelves of hot-water pipes, above which trays of fish are placed, and the air is made to circulate over them by means of a large fan. These dry kilns are only partly successful, and they are used chiefly in the drying of export fish and pollock. The heat from the hot-water pipes may damage the cod, and they are never so white as when exposed to the action of light. In the writer's opinion, these driers are faulty in construction, in that the heat is applied close to the fish instead of drying the air and then driving it over them. This would correct some of the objections to the method, though not all. During the foggy season in the fall and in the winter large quantities of fish are dried in these mechanical driers.

The difficulties in drying are sunburn, softening, and, in the case of light salted fish, flyblowing. The sunburning occurs most often in July and August, but can be avoided in a large measure by the use of the canvas cover. Softening is due to insufficient cure and drying during a long period of foggy weather. Flies are due to insanitary conditions, which permit their development, but they are no longer a source of much trouble.

QUALITY AND QUANTITY OF SALT USED.

The salt used in the curing of the fish is nearly all imported and comes from the Mediterranean Sea. That used by the larger number of fishermen comes from Trapani, in the island of Sicily. The other salt is known as Iviza and comes from an island off the east coast of Spain. These salts are strictly solar salts, produced by permitting the sea water to overflow lowland at high tide and then depending upon the sun to evaporate the moisture and leave the salt. Long dikes are constructed along the sea wall and when the water has nearly all evaporated, the dike gates are opened and more water enters at high tide. This is repeated until several inches of salt form on the bed. It is then allowed to dry, is collected in piles, and wheeled to the storage room for use. The crystals formed in this way are fairly coarse—a condition considered to be necessary for the good curing of fish. The salt contains not only the sodium chlorid but also the other salts and impurities incident to the sea water. The salt looks white but is not so good as is generally believed. The following analyses show the composition of four kinds of salt:

Analyses of various salts used for curing fish.

Determinations.	Trapani.	Iviza.	Diamond.[a]	Worcester.[a]
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	6.54	3.71	0.00	0.20
Sodium chlorid	89.50	94.40	99.50	98.94
Calcium chlorid	.30	.47	.00	.19
Magnesium chlorid	1.11	.....	.04	.07
Magnesium sulphate	1.64	.76	.....	.....
Sand	.14	.....	.....	.....
Silica	.....	.06	.....	.....
Calcium sulphate	.....	.....	.45	.59
Insoluble	.....	.....	.01	.01

[a] Connecticut Agr. Exper. Sta. Report, 1907–8, p. 597.

Some conception of the quantity of salt employed in curing fish may be gained from the fact that 25,000 long tons are so used at Gloucester alone each year.

Formerly Cadiz salt was used exclusively in the curing of fish, but when it was believed that the reddening of the cod was due to the salt, the change was made to the Trapani salt, and it is only in

the last few years that any other has been used. The cost of this salt is very low, only about $4.25 per ton at the dock, and there is no duty on that used in the curing of fish.

Just what relation the salt bears to the reddening is not fully determined. It is said that the salt sometimes has a distinctly red appearance on the beds and in the piles while it is curing; that it has been known to have a pink tint in the boat on its arrival; that reddening occurs in the storehouses; and also that the red color is seen on the salt in the butts. We have not had an opportunity to verify all these reports. The germs producing the reddening of codfish have been found on the salt in storerooms and in the hold of salt vessels. A large growth of germs has been observed on the wood in the walls of the salt house for a distance of 2 feet or more above the floor, and the germs have been taken from the salt in the butts. It is certain, however, that much of the so-called pink color seen on salt in bulk—in the hold of the vessel and warehouse—is due to the breaking of the rays of light, thus producing the spectra. It is equally certain that the deep red color seen on the salt in the butts is due, not to the salt itself, but to the growth of the germs in the organic matter which has been extracted from the fish and which floats on top and makes a film over the salt. In every instance in which a heavy growth of red was found in a salt house it occurred on the side next to the butt shed where organic matter from the butts had soaked the woodwork.

The salts do contain calcium chlorid, magnesium chlorid, and magnesium sulphate, which impurities affect their hygroscopic power, that is, the power to absorb moisture from damp air and give it up again in a drier atmosphere. This property of the dried fish is easily seen in a kench, particularly in the case of hake. Water will drop from the whiskers, the tails, and fins on damp cloudy days, and the surface of the fish become damp and slimy. Experiments made by drying the salt in an oven and then exposing it to the air show that it will take up as much as 7 per cent of its weight in moisture, while a refined salt will absorb only from 0.2 to 0.5 per cent. While calcium and magnesium chlorid take up a great deal of water, the amount is not limited to the capacity of these bodies, as the sodium chlorid, which will ordinarily remain dry, will take up water when brought in direct contact with it.

One of the results of the use of a salt which is so hygroscopic is that fish which have been cured and dried to any degree become moist during damp weather. Fish cakes become so wet that water runs from them, and boxes placed on top of each other stick together. Even export fish in drums may "sweat" and need to be redried and repacked. This quality makes the surface of any fish moist and thus gives opportunity for the growth of such organisms as will thrive

in a strong salt solution. The apparently illogical statement often made, and as often doubted, that it is the saltiest fish, full pickle cured, that spoil most readily has, therefore, a sound basis.

The amount of salt taken up by the fish, as shown by the cured product, is as follows:

Amount of salt taken up by fish put up in different forms.

Kind of fish.	Salt.	Moisture.
	Per cent.	*Per cent.*
Fish cakes	18.9	47.6
Slack salted	14.5	37.2
Export	19.6	25.6
Shredded	20.6	46.2

The quantity of salt in the slack-salted product is much higher than is generally supposed by those who prepare them; this is due in part to the lower water content.

The crystals in both the Trapani and Iviza salts are about the same, varying from one-eighth inch cubes to large masses. The advantage of the coarse crystals over the fine ones lies in the slowness with which they dissolve. Crystals which dissolve slowly abstract water from the tisues for a longer time, and the face of the fish does not become "salt burned." This condition occurs from the use of very fine salt, which abstracts the water so rapidly from the tissues with which it comes in contact that it causes coagulation. The salt will crust on such a surface the moment that drying begins. The fish pickled with coarse salt are evenly "struck" in a few days after being placed in the butt, while those treated with fine salt become surface struck within twenty-four hours, but the action seems to stop, and the fish have the appearance of being slack salted. A fish is said to be "well struck" when the tissue will resist moderate pressure from the end of the finger, the term "struck" seeming to have reference to the firmness of the fiber rather than to the quantity of salt present, though the assumption is that firmness and heavy salting are necessarily dependent upon each other.

STORAGE.

After the fish have been dried they are carted to the storeroom and kenched until they are packed for shipment. The kenching does not differ essentially from that before going to the flakes. The kenches are made about 3 feet high. The fish are repiled only when necessary, which during the warm weather may be once in a week or in the cool weather once in two weeks or more. It is while the fish are in the kenches that trouble begins with reddening and freckling, and it is important that the stock of cured fish on hand in the summer

season should be small and kept moving constantly. Here the fish of different classes and sizes are kept separate and made up according to orders.

The Porto Rican export, or hard-salted fish, and the slack-salted fish are packed in drums, boxes, and bundles, of the sizes specified, directly from this floor. All skinned fish—whether whole, in strips, cuts, or in packages—are moved to another room for final preparation.

DRESSING AND PACKING.

The fish are taken to the skinning department according to the orders to be filled. If the fish are to be put up as "absolutely boneless," then the fins are pulled out and the skin pulled off. The skin is started at the napes and pulled in toward the middle of the back and then pulled toward the tail. If the fish has been properly cured the skin can be stripped off clean without tearing the flesh. If it has been sunburned, the skin will not hang together well. After the back has been skinned the fish is turned over and the dark lining membrane of the napes is stripped forward so that the whole fish is clean. The remaining portion of the backbone is cut out and the fish is passed to the bone pickers, who remove with forceps the ribs and any pieces of bone left in the body. If the fish are to be packed as so-called "boneless," then the fins are only cut off and the thick part of the backbone cut out closely, the small pieces of the fins, ribs, and backbone being allowed to remain. The term "boneless" as used in the trade is hardly appropriate and should be changed for one more nearly descriptive of the real conditions.

From bone picking to cutting is a short step. The table at which this is done is made of boards with openings between them at regular intervals. The fish are laid on the cutting table so that the best parts come between the openings. A half dozen pieces or more may be stretched out at a time across these openings, then a long-bladed knife is swept through them and they are ready to be packed into fish cakes, etc. A trough or miter box is also used for securing the same result.

The pieces of fish are passed to girls, who sort them and weigh out exactly a pound or two pounds, whatever the cake or package is to be. Two good slices are selected to make the outside of the packages, and short or narrow strips to make up the middle part. One packer cuts his large fish on the diagonal in strips as wide as his package is deep, so that when the package is made each piece will show a cut across the grain for its full thickness. This is possible only with a large fish.

The fish cakes are all made in essentially the same way. The weighed fish is passed to the cake maker, who selects, first, the piece which will make a whole side and an edge and places it in the galvanized-iron mold; the smaller pieces are then put in, and last, the

remaining large pieces to make a side. The selecting and placing of the pieces in such a way as to make the best appearing cake is quite a knack. The mold is pressed tightly by foot power, held for a few seconds, and a twine string tied securely around near each end. One firm sews the string through the fish instead of passing it around. The package is completed by wrapping first in paraffined paper and then in the labeled wrapper.

LOSSES IN WEIGHT.

The losses in weight during the different operations from catching to the final preparation of the fish for shipment have been calculated

FIG. 2.—Cutting fish for tablets or fish cakes. (The miter box is used by one cutter and the slitted table top by the other.)

from figures based on trip records, and are, therefore, more nearly accurate than estimates based on experimental lots.

Loss of weight in dressing: Head, viscera, and backbone; whole fish weighed 1,200 pounds; dressed 720 pounds; loss 40 per cent.

Loss in salting, full pickle: Fish weighed 720 pounds on going into the butts and 515 pounds on going on the flakes; loss 205 pounds—17 per cent on gross weight or 40 per cent on dressed weight.

Loss in drying on the flakes: Fish weighed 515 pounds when put out and 468 pounds when taken in; loss 47 pounds—4 per cent of gross weight or 9 per cent on salted weight.

FIG. 1.—SKINNING FISH.

FIG. 2.—PICKING BONES.

(In the "absolutely boneless" all ribs and other bones are removed with forceps.)

Loss in preparing "absolutely boneless" fish: Fish weighed 468 pounds before removal of skins, bones, trimmings, etc., and 311 pounds afterwards; loss 157 pounds—13 per cent of gross weight or 33.3 per cent of the dried weight.

Total loss in weight from the catch to the finished product is about 74 per cent, though some of the by-products can be utilized.

SHIPPING PACKAGES.

Fish are packed whole for shipment in boxes or bundles of all sizes to suit the order, but there are regular boxes for 50, 100, 200, 300, and 448 pounds. The 128-pound drum is principally for export to Spain, Portugal, Italy, and southern European countries, while the 448-pound drum is used very largely in the Porto Rican trade. The fish packed in drums are generally snappers, and are all slack salted and well dried, except the hake, which is extra dried. Some large pollock are sent to Porto Rico.

When placed in drums the fish are carefully arranged in circular fashion, with the face up, until several layers have been put in, and then a layer is placed backs up. The fish are then well tamped with a heavy wooden tamper. Fish are again added and the tamping repeated at intervals. When the last fish are finally piled on the drum they will extend several inches above it, and a ratchet or a hydraulic press is necessary to force them down so that the head can be put on.

The fish made up into bundles, wrapped with matting, and corded as a rule weigh 50 and 100 pounds, though the quintal, or 112-pound package, and the 125-pound package are also used.

Skinned fish are put up in strips and middles. The strips consist of one-half the fish split down the middle and are cut to suit the trade—some left whole and some with more or less of the nape and thinner portion at the tail cut off in order to get heavy pieces. These are put up usually in 20 and 40 pound boxes. The middle is the whole fish after being skinned and the nape and tail cut off. How much of the nape and tail is cut off depends upon the number of middles permitted in a box of a certain size. They are quoted by the size, 8 to 10, or 10 to 12, in a 40-pound box. A box containing 10 to 12 middles will usually rate at least one-fourth cent per pound less than when the larger middles are used.

Cusk are often packed as middles, and the price is about 3 cents less per pound than for cod. The hake is more often packed as strips. The English or Nova Scotia style cured strips are made from fish incompletely salted and given an additional drying after skinning. One of the favorite methods is to dry these fish in the kench instead of in pickle in the butts. These strips are put up in 30-pound boxes only and few are sold outside of New England.

A few slack-salted fish are skinned for middles in the New England trade, but all others are full pickle cured. When the middles are boxed they are carefully layered, and in order to get them in tightly they are beaten with large wooden mallets.

Fish are packed in packages usually weighing 1 and 2 pounds, though a few are made up in half-pound tablets. These fish are generally described as "boneless" and "absolutely boneless" and are all full pickle cured. The cakes are usually made of one or two good pieces from the backs, the remainder being the smaller pieces about the nape, tail, etc. The selection of bright-colored fish and choice pieces and special curing decide the grades. The fish put up in these packages is usually well pressed in forms, tied at two points with strings, wrapped with paraffined paper and a wrapper. Twenty-four 1-pound, twelve 2-pound, or twelve 3-pound packages make a crate. The "boneless" fish put up in 5-pound boxes but not pressed run 12 to a crate.

Choice codfish bits are the best ends, napes, tails, etc., from the trimmings and go out in various sized boxes and are mostly sold in New England. The napes from large fish go into the 1 and 2 pound cakes.

Shredded codfish is made up from the trimmings not otherwise used in packing the regular tablets. The material used is as good as any employed, but the pieces are too small to be used well in the regular package. It is run through a machine which tears the muscle into its small fibrous bundles. In order to get this very fine and fluffy it may be necessary to press out part of the water after the first treatment and run it through the machine again and then sift it to free it from all particles of bone. The shredded fish is put up in 5 and 7 ounce cartons and jars, the latter being hermetically sealed in vacuum. Twenty-four boxes or jars make a crate.

Codfish tongues are shipped in brine in barrels and pails; codfish cheeks are dried and shipped in 50-pound boxes; codfish sounds are sold with the tongues, mixed half and half or sold separately. In shipments the cod goes as cod, while hake, cusk, haddock, and pollock are sold as "boneless fish."

The slack-salted fish for the Italian or export trade, if brought in fresh, are salted only overnight or in very warm weather are lightly salted for thirty-six hours. They are then dried harder than for the full pickle. Fish which have been salted on board the vessel may be soaked for about four hours and then dried. About one-fourth of one pound of salt to a pound of fish is used. Porto Rico cured fish are pickle cured and then washed and dried very hard. Pollock cured for the local trade, if brought in salted, are taken out of the vessel, washed well, and dried; or, if brought in fresh, they are

placed in the butts for forty-eight hours, two bushels of salt used, and the butt filled with pickle.

Hake, cusk, and haddock are put up in packages similar to those used for the cod.

BY-PRODUCTS.

The by-products are the gurry or fresh waste, heads, etc., the skins, fins, bones, and the livers and sounds. The heads and other waste portions go to the glue factory and are converted into fertilizer and chicken feed after the little glue is extracted. The cod and cusk skins are the most valuable for glue, and for these a price of $65 a ton is received. They are carefully separated from other refuse. The hake, haddock, and few pollock skins go with the bones and fins at $16 a ton.

The livers are all thrown into hogsheads at the time the fish are dressed and are saved for oil. The oil from the old livers is used for tanning leather, the price being about 20 cents per bucket. The livers from fresh fish are sold for about $3 per barrel for the manufacture of cod-liver oil used in medicine. The oil alone has a large commercial value. One vessel is reported to have received $800 on a single trip for the livers alone.

Cod and hake sounds are saved, the former for food, and the latter for making isinglass for clarifying beer. The price for cod sounds used to be 42 cents and for hake $1.42 a pound, but the price has greatly declined since seaweed has been introduced as a clarifying agent. Cusk skins are also prepared as a clarifying agent, especially for coffee.

FACTORY EXPERIMENTS IN CURING CODFISH.

CHANGES EFFECTED BY SALTING.

Experimental lots of iced fish were put up in 100-pound kegs, the salting being done in the same manner as in the butt. The fish used were of average quality and rather small in size in order to accommodate them to the curve of the keg. At intervals, as shown in the following table, 50 grams were taken from a fish in the third layer from the top for the determination of the moisture and salt content.

Percentage of moisture and salt in fish while curing, using different kinds of salt.

Date.	Day.	Conditions.	Table salt.	Packer's fine.	Packer's coarse.	Trapani.	Iviza.	Meat salt.	Butter salt.
1909.									
Aug. 12	.....	Moisture (fresh)....	74.00	74.20	74.00	74.00	74.20	.....	.....
		Salt.....	.80	1.00	.80	1.07	1.05	.....	.....
13	1st....	Moisture	68.00	64.00	64.00	61.00	64.00	61.00	68.00
		Salt.....	15.92	13.40	14.98	16.62	14.88	15.72	8.82
14	2d	Moisture	60.60	60.60	60.80	61.20	61.20	59.60	65.00
		Salt.....	17.80	13.70	16.40	15.92	17.72	17.00	12.68
15	3d	Moisture	60.00	59.60	59.80	59.20	59.70	58.20	59.40
		Salt.....	18.86	18.76	20.10	18.54	19.64	18.64	19.64
16	4th ...	Moisture	59.90	59.20	58.00	56.80	59.60	58.00	57.80
		Salt.....	19.46	19.62	20.20	19.58	19.90	20.40	19.93
19	7th ...	Moisture	59.80	.....	59.80	57.00	59.80	57.60	57.60
		Salt.....	20.44	.....	20.06	20.00	20.22	20.86	20.23
20	8th ...	Moisture	58.00	57.40	57.20	56.60	53.60	.....	.....
		Salt.....	20.48	20.86	20.50	20.20	20.44	.....	.....
23	11th ..	Moisture	.....	57.20	55.00	55.20	.....	56.00	56.00
		Salt.....	.....	20.42	20.88	20.00	.....	20.76	20.41
24	12th ..	Moisture	55.00	56.00	55.00	54.80	56.40	54.00	55.60
		Salt.....	20.22	20.70	20.68	20.14	20.48	21.06	21.84
Sept. 3	22d ...	Moisture	54.80	55.60	53.40	53.00	56.00	.....	.....
		Salt.....	21.84	20.66	21.64	20.76	20.76	.....	.....

One of the interesting facts shown by this table is that there is little difference in the action of fine and coarse salt in abstracting water from the tissues of the fish. A physical examination of the fish, particularly during the first four days, indicates that the fine salt has accomplished much more than the coarse salt. Competent judges considered that those treated with fine salt were as well advanced in the pickle at the end of two days as fish ordinarily are after a week or eight days in the regular pickle. At the close of the salting period all of those treated with the fine salt had the appearance of being slack salted. The fish had a peculiar white semi-translucent appearance rather than the solid, white, opaque appearance resulting from the coarse salt. These fish were all pronounced to be "struck" at the end of the second day, the fine-salted fish being better than the coarse salted. At the end of the first period (twelve days) the fine-salted fish had made little change, but the coarse-salted fish were the firmer. To the sense of taste the finely salted fish were apparently much the saltier for the first four days, and there was also a sweeter taste.

A few of the fine salted fish were said by the packers to be "salt burned," that is, the surface presented the effect of being slightly coagulated, the salt crusted into the tissue, and the interior of the tissue remaining soft. From the appearance of fish described as "salt burned," and others seen at the factory, it is evident that these fish come in contact with such quantities of salt in a fine state of division that it unites with the tissues so rapidly as to cause coagulation of the surface albumen and this apparently resists the penetration of the salt to the deeper structure. This is said to be one of the objections to the use of fine salt. The coarse salt dissolves more slowly and is supposed to maintain a more even strength in the pickle.

It would seem, however, that the latter assumption is not well founded, as an excess of salt above that which can be taken up by the fish is used in all cases and as long as the brine is saturated it is as strong for pickling purposes as it is possible to make it, and it does not make any difference whether the excess above saturation in a given volume is an ounce or 10 pounds. The fish handlers invariably speak of the pickle getting stronger in going from the top to the bottom of the butt, and yet the salinometer will show 100° at all points. It is obvious that the brine can not be stronger, for only a given quantity of salt can be held in solution in a given quantity of water. It is the belief of the writer that the difference in the appearance of the fish supposed to be due to a difference in the strength of the pickle is wholly due to the effect of pressure in the butt. Unfortunately no samples were taken from the bottom of the kegs to determine the effect of pressure, as its importance in connection with the salting was not known at that time.

It is the general belief among superintendents at the fish factories that salt once used in pickle, though not dissolved because of the excess employed, becomes exhausted. Such salt is generally thrown upon the docks to preserve the boards. This assumption is not based upon good evidence. It may not be desirable to use such salt a second time, but when tested by placing it in solution a salinometer will show that it has lost none of its strength.

The rate at which the abstraction of water and salting takes place shows that this operation is practically completed in twenty days and that three-fourths of the work goes on in the first two days. There is a displacement of about 20 per cent of water in the tissues by the action of the salt, and between 14 and 15 per cent is displaced in the first two days. The changes proceed slowly after the third day, and the custom of allowing the fish to remain from 17 to 20 days in the butts to become full pickle cured is based on long experience and finds full vindication by experiment. One result produced by keeping the fish in the pickle is to harden the tissues, for although little salt is taken up after the sixth day, there is a progressive hardening of the tissues, and this is quite noticeable up to the twelfth day; after that time the change is too slow to be measured by appearance alone.

About half a pound of salt is used to the pound of iced fish in the regular course of curing the full salted fish; for export fish about three-eighths of a pound is used, and for slack salted one-fourth of a pound. As the cured fish contain only from 14 to 20 per cent of salt, it is evident that about 33 per cent of the amount used serves as a preservative while the remainder acts as a drying agent, and it would seem that improved methods might effect a marked saving in this part of the process.

In order to determine whether the kind of salt used had an influence on spoilage, 14 kegs of 100 pounds each were packed in the usual manner, using seven different brands of salt. One keg of each kind of pickle was taken out on the twelfth day and the second keg on the twenty-second day. The work was done in the factory by the factory employees, and the conditions were the same as for the regular packed fish except for the salt used. The fish were kenched one day, each lot in its own pile, and weights placed on top in order to secure approximately the same conditions found in larger piles of fish. Each fish was labeled and kept in its proper place on the flake. The skinning of the different lots, making into cakes, and packing were done separately. Each lot received exactly the same treatment. They were shipped from Gloucester, Mass., to Lafayette, Ind., by freight, early in September, while the season was quite warm, and then kept under ordinary grocery conditions. The fish (sixteen tablets from each lot) were examined at intervals of thirty, forty-five, sixty, and seventy-five days. At the end of thirty days there was no spoilage, only faint traces of red being discernible on a few tablets. After forty-five days the spoilage amounted to from 12 to 16 per cent in the different lots. In most cases, however, the reddening amounted to only a trace. At the end of sixty days the spoilage amounted to from 50 to 60 per cent, and after seventy-five days to 75 per cent. After the forty-five day period the brown mold made its appearance and was a conspicuous factor in the spoilage. Tablets which did not show reddening exhibited a considerable amount of mold or freckling.

There was no clear-cut difference in the spoilage of the various lots of a sufficiently constant nature to enable one to say that one salt was considerably better than another. The refined salt lots showed reddening as well as the solar sea salts, thus indicating a general infection from some other source. These cakes were all very wet, containing from 48 to 51 per cent of water, and it was evident that they would not be affected much by humidity in the atmosphere. The packages which were opened and rewrapped spoiled more quickly than those which had not been opened. Packages from another lot which were not opened until the sixtieth day showed as little spoilage as those opened on the thirtieth day, then rewrapped and again examined on the forty-fifth day.

Whole fish were also saved from each lot. The five fish from the bottom of each kench were kept together, and six were taken from the remainder of the kench. The fish in contact with the rack all reddened, about 75 per cent within thirty days and the remainder inside of forty-five days. The fish not in contact with the rack did not redden, with the exception of some of those pickled with the sea salt, but did freckle in about sixty days. These fish dried more

thoroughly than did the cakes, the moisture content being from 40 to 41 per cent. The effect of the humidity on these fish was very noticeable. Those pickled with high-grade salt remained dry, while those pickled in the sea salt became very wet and the surface was covered with a film of moisture.

One set of four cakes from each lot was given a second drying, which resulted in a reduction in weight amounting to about 10 per cent. The attempt was made to duplicate the Nova Scotia style cure, but the pieces were so small that the appearance of the product was injured and the real drying was carried a little too far. The tablets which were once dried remained so when cured with the refined salt, but those prepared with the Trapani and Iviza salt took up considerable moisture on damp days and were slow in losing it. The spoilage at the end of seventy-five days showed 80 per cent more reddening for the Trapani and Iviza salt and 60 per cent more mold or freckling than in the case of the refined salts. This experiment, as well as that with the whole fish, would indicate that sufficient drying and retention of that dryness under varying weather conditions will assist in preventing spoilage. In these experiments the occurrence of the brown mold was frequently observed. This was rarely mentioned at the factory, but when spoilage was not due to redness the mold took its place.

As a check against these experiments, six cakes of regular pickled fish and six cakes of fish treated with sodium benzoate were obtained from seven of the prominent fish packers and kept under the same conditions as the experimental lots. On opening the untreated lots, 65 per cent were found to have started spoilage in thirty days and 85 per cent in forty-five days. Of the fish treated with sodium benzoate, 12 or 13 per cent showed reddening or mold at the end of forty-five days, but no subsequent change was observed. The moisture contents of the benzoated and non-benzoated fish were the same.

Variations in commercial fish due to season, style of pack, etc.

	Description.	Moisture.	Salt.
		Per cent.	*Per ct.*
Season pack	September packed cod (five firms)	45.4	19.19
	December packed cod (five firms)	48.7	19.80
	February packed cod (five firms)	51.0	.....
Style of pack	Cod, Nova Scotia style cure	46.8	19.30
	Cod, export, very dry	31.6	21.76
	Do	31.0	22.22
	Cod, Italian cure, very dry	28.6	22.16
	Cod, Italian cure, for domestic trade	35.0	19.56
	Hake, boneless	46.2	19.56
	Hake, strips	44.8	20.86
	Hake, Nova Scotia style cure	43.6	20.90
	Hake, not skinned, very dry	40.6	21.40
Part of package	Cod in box just opened	51.9	.....
	Cod in box looking very dry	42.0	.....
	Cod, dry side of a cake	50.4	.....
	Cod, inside of the cake	53.7	.....
	Cod, moist side of a cake	53.1	.....
Moisture limit for reddening.	Cod reddened, then no further change	39.2	25.00
	Do	33.2	29.04
	Do	38.6	28.20
	Do	35.0	26.84

A number of fish having more or less reddening were dried until all growth ceased. A test of the moisture content showed a range from 33.2 to 39.2 per cent.

There is a limit to which the drying can proceed commercially. The hard-dried Italian cod has a moisture content of 28.6 per cent, and the Porto Rican or export cod from 31 to 35 per cent. Both of these are drier than would be used in domestic trade, and both will redden, because the salt used will take up moisture when the atmosphere is very humid. Fish dried to such an extent could not be used in cakes, and all fish to be skinned should not contain less than 46 or 48 per cent of moisture. The Nova Scotia cure is the only exception to this rule, and in this case the fish are dried again after skinning. The only fish in which there was no spoilage was of this cure and the water content was from 41 to 43 per cent. They did not have the appearance of being excessively dry, and it is believed that they could have been made into very good cakes. The lowest point to which the drying can be carried and make good cakes, and the upper limit at which the fish will keep under commercial conditions, remain to be determined.

EFFECT OF THE DIFFERENT KINDS OF SALT ON SKINNING AND APPEARANCE.

The fish cured with the different kinds of salt were given numbers so that the employees in handling them would have no knowledge of the kind used and would not be prejudiced in favor of one or against another.

The fish cured for twelve days skinned better than those cured for twenty days, but all except one lot were said to skin very well. One lot was pronounced to be "sunburned," though only slightly so, causing some softening about the napes. This lot had been cured with the finest salt used. The fish cured with the regular salt used in the factory were identified as "working up as the fish usually do." The fish cured with the coarse refined salt were said to skin most easily, showing the least tearing, and presenting the best appearance. When the cured fish were submitted to a number of fish packers for judgment as to quality and appearance, there was a difference of opinion, and some were unable to distinguish between the fish cured with fine salt and those cured with coarse salt.

EFFECT OF EXCLUSION OF AIR.

It was observed that reddening occurred only on fish which were exposed above the brine in the butts, and in the few cases in which reddening was present below the surface of the brine it was a fair assumption that the brine had leaked at some time and exposed the

fish for a time before refilling had taken place. This fact indicated that the germs required the presence of air for growth.

Experiments were made using fish cakes and parts of cakes, wrapping well in paraffin paper and cheese cloth, and dipping in hot paraffin in order to exclude the air. Twenty-five packages were treated and a like number not treated. The treated packages retained their weight and fresh appearance and suffered no loss, while the untreated lost in weight, became very dry, salty on the surface, and reddened. While this method is too crude to be commercially successful, it is proof conclusive that exclusion of air will prevent reddening. It is the practice of the factories to put up shredded cod in glass jars sealed in a vacuum. This will not spoil so long the seal is intact.

An experiment was also made of putting forty-eight 1-pound cakes in tin meat boxes and sealing in vacuum. Twelve of the cakes were red at the time of sealing. The reddening did not proceed after sealing, nor did reddening develop in the good cakes. These fish were kept near a furnace from October 25 to March 15, when the temperature averaged about 85° F. The ordinary cakes, unsealed, spoiled under like conditions in from ten to fifteen days. This test was much more severe than the fish should ever be subjected to in trade practice. The fish were the full pickle cure and contained about 50 per cent of moisture. On opening they appeared to be very moist, and in fact a few drops of free brine were found in the can. The appearance and odor resembled those of fish taken out of old brine rather than those of a fresh fish cake. They were good, but not so attractive as might be desired. Some of the cans were opened at the end of one year and the fish pronounced to be good, while others seemed to be more or less sour. In all cases the color became somewhat darker or more yellowish. The tin was only slightly attacked. A comparison of the moisture and salt content of this fish with that of beef and ham put up in a similar manner shows that both were too high in the fish, and that possibly a better result would have been secured by using the slack-salted product.

The experiments indicate that spoilage can be avoided by packing in sealed boxes or otherwise excluding air.

Some of the large meat-packing establishments put up chipped beef, sliced bacon, and sliced ham in tins from 1 to 5 pounds, and these keep perfectly. The larger cans are for the use of retail butchers and grocers whose sales of dried beef or bacon would not be more than a few pounds per day or week. It would seem that the same principle could be applied to the packing of salt codfish. Most fish are sold for Friday consumption, and for the grocer or dealer who can not use a case per week this small package would serve as an excellent substitute. There would be neither loss of weight nor spoil-

age, and the product obtained would be in a more cleanly and sanitary form for handling. The added cost in packing would be offset by the saving in losses by present methods. At present shredded fish are put up in vacuum glass and in tin cans, and they keep well. Fish can be shipped in brine, or in cakes and be submerged in a saturated brine at the retail store and keep without reddening. This method, however, is not in commercial favor.

EFFECTS OF TEMPERATURE.

Reddening of the cod does not occur during the cooler months of the year. The spoilage at the factory is almost wholly limited to July, August, and September, but shipments which go to the interior or to the Southern States may spoil in transit or after being received, owing to the higher temperature. Fish shipped by freight during the hot months are often set on a siding for varying lengths of time, the interior temperature of the car may vary from 90° to more than 100°, and under such conditions spoilage will occur quickly. Reddening seldom occurs in the holds of vessels in transit from the fishing grounds to the factory, except during very warm days, as the temperature of the sea water is sufficient to prevent the growth of the organisms. Farlow states that these organisms will not grow in a temperature below 65° F. In these experiments, however, some growth was found to occur at as low as 45° F., but it was slow even below 75° F. It is evident that it does not require so low a temperature to keep salt fish as it does to keep salt meats and that if they were handled in a similar manner there would be little loss. It would not be good management for a packer in Chicago to start a carload of good salt meat for Boston in a plain box car in the middle of August, when the thermometer is registering from 90° to 100°. It would not be good judgment to keep such meat in a wholesale grocery or provision house for a period varying from ten to forty days after arriving at its destination and then to reship to the jobber in lots which would supply his demand for from thirty to sixty days. The practice is to ship in refrigerator cars to a cold-storage depot, to distribute quickly and only in such quantities as the retailers can readily move in a short time. Quality depends upon careful handling from producer to consumer, the time intervening being made as short as possible.

Salted fish is not different from other salted meat products except that it is less likely to spoil. The cooling in shipment or in storage need not be carried far, but the principle of having proper storage houses for distribution ought to be developed. Small but repeated shipments to retailers, two cases every two weeks instead of ten cases every sixty days, is being tried and with success.

In order to get a fair idea of the quantity of salt fish sold and the method of handling in a small inland city, the groceries in Lafayette,

Ind., were visited. Of the 62 groceries found, 50 handled codfish. A few of the better groceries each sold one case in two weeks, while some of the smaller ones sold only one case in seven weeks, the average being one case in five weeks. There were also two meat markets selling fish. The total sales amounted to about twelve cases per week, the season beginning November 1 and ending April 1. A few stores carried stock until about June 1, but only four kept a supply through the summer. In only six stores were the codfish to be seen except upon inquiry. They were kept usually in a back room or in the cellar, but no attempt was made to display the goods on hand. The fish were purchased through wholesalers and fish houses, only two stores making purchases directly from the factory. Formerly it was the practice to buy a half dozen or ten cases at a time in the fall, but now more dealers take only one or two cases and keep their stock fresher. An examination of the stock showed some to be fresh and much of it to be of excellent quality, but dried to such an extent that the salt was crystallized and the cake was not attractive, indicating that it had been in the hands of either the wholesaler or the dealer for too long a time.

It was evident that if these fish had been delivered directly by the packer, thus eliminating the time consumed by the handling of the jobber, there would have been an improvement, and it would be still better if delivery could be made to one firm which could deliver five, ten, or twenty cakes to the individual grocers each week, according to their needs. The cost of delivery would probably not be greater than at present, when a dozen or more wholesale agents compete for the business. The sales organization at present is not such as to secure this desirable condition, but it is believed that decided improvement could be made in this direction.

It is evident from records and observation that codfish can be handled at a low temperature without spoilage. The range of temperature at which reddening occurs permits an easier and less expensive method of handling than in the case of other cured-meat products.

USE OF ACETIC ACID TO PREVENT REDDENING.

At a meeting of the board of trade in Gloucester, a packer stated that he had used acetic acid successfully in preventing fish from reddening, and showed specimens which had been red and from which after treatment the color had disappeared. His method was to apply a small quantity of a 10 per cent solution of glacial acetic acid to the exterior of the fish cakes. In his experiments an ordinary nasal atomizer was used for the purpose of applying the acid. He reported the results to be highly successful. Other fish packers raised the point that an odor and a taste might be imparted which would be

objectionable. It was evident from the statement of the method of application and the quantity used that the acid would not be an antiseptic for most germs, and if efficient in this case, it was due to the particular organisms having no resistance to a faintly acid condition. The effect of distilled vinegar was tried on twelve cakes and a like number was used as a control, all of the cakes selected being slightly red. The treated cakes showed that the vinegar had a decided inhibiting action, but an objectionable odor was observed in the cases where the most good was accomplished.

In tests made to determine the quantity of the acid required to prohibit growth a gelatin was made which would to some degree approximate the conditions existing on the fish. Ten grams of peptone, 100 grams of gelatin, and 1,000 cc of sea water were mixed, cleared in the usual way, and titrated. To portions of this gelatin acetic acid was added before sterilization in the following amounts: One-twentieth, one-fifteenth, one-tenth, one-fifth, and one-half per cent, respectively. Inoculations were made of the coccus, the bacillus, and the *Oidium*. The check for this coccus developed a slight surface growth and was thin and tapering along the stab. No development occurred in the tubes containing the acetic acid, indicating that even as small an amount as one-twentieth per cent was sufficient to inhibit development. The bacillus in the check gave a development in twenty-four hours, a slight growth and liquefaction appearing. The development later was rapid, but none occurred when the acetic acid was used, one-twentieth per cent being sufficient to inhibit. In the tests with *Oidium* a growth appeared in the check and in the tubes containing one-twentieth per cent of acetic acid inside of twenty-four hours, being slightly less in the acid than in the check. As growth proceeded, the slight check produced by the acid was more apparent in the smaller amount of liquefaction than in the actual decrease of growth. In the one-fifteenth per cent of acetic acid, growth was delayed three days, but after that it was only slightly less than in the one-twentieth per cent. No growth occurred in any of the other tubes. Evidently for this organism the amount necessary for inhibition is about one-tenth per cent. Ordinary gelatin was used in like tests with practically the same results. These tests indicate that acetic acid in very dilute solution is sufficient to arrest the growth of the organisms.

SANITARY CONDITIONS.

HANDLING AND STORAGE.

On board the fishing vessels the handling of the catch is conducted under fairly sanitary conditions. The boats are thoroughly scrubbed before leaving on a trip and the fish are dressed and washed soon after being caught. They are salted or iced as they are put into

the hold, the vessel is filled one compartment at a time, and the liquor abstracted by the salt or the water from the melted ice is pumped off promptly, so that this part of the operation is generally satisfactory. The difficulties which may arise on the fishing vessel are due to insufficient protection of the fish on hot days, not bleeding them promptly, and haste in dressing, thereby not getting rid of all traces of viscera and blood spots. Sometimes the fish are slightly slack salted in order to have them weigh heavy, and if the trip should take more time than anticipated or the weather should be warm, some spoilage may occur.

Insufficient icing is also attended with disastrous effects. In order to overcome troubles from this source, the owners of the factories promulgated rules for the captains and skippers of vessels relative to "shack fish" the past season and enforced them by dockage and refusal to accept injured cargoes. The notice was as follows:

At a recent meeting of the buyers and shippers of fish it was decided that if Gloucester is to hold her position as the largest fishing port the quality of our goods must not only be maintained, but improved, and with this end in view it was suggested that we ask the cooperation of captains and crews of the fishing fleet.

You are well aware that during the summer months fish require extra attention and unless they get proper care on the vessels they will not comply with the regulations. We beg, therefore, to call your attention to the following suggestions for the proper care of fish, viz:

All fish that are salted on the vessels should be dressed while new or before they become suncooked, which in summer is sometimes the case, and plenty of clean water used to remove all blood stains, and then plenty of salt to insure that whiteness that is so necessary, and to prevent all taint which so often occurs from light-salted fish. On fresh fish, only the second baiting on long trips should be iced, and even then the utmost care must be used to have the fish gilled and properly cleaned before icing, as no others will find a market in Gloucester in future.

The shippers who know what the trade requires are agreed that large shack trips landed during the summer months are getting to be a great injury to the business, and unless these fish are landed in first-class condition they will be rejected by the buyer, and in no case will fresh fish be bought where a vessel has made two baitings, unless all fish caught on the first baiting are salted.

The requirements of the Pure Food Law are such that poor or inferior fish can not be marketed at any price, and the coming year will see this law more strictly enforced than ever before.

It becomes necessary, then, for our own protection, as well as for the best interests of the business, to strictly enforce the above rules, and we trust you will take due care and govern yourself accordingly.

The good effects of the order were said to be clearly noticeable in improved quality throughout the season. A further improvement may be expected when payment is scaled on quality rather than on the basis of a uniform rate.

The salt fish are handled from the hold to the deck of the vessel and from the deck to the wharf, then to the scales, and finally to the wash water by means of pews. This results in puncturing the fish

from four to seven times, and while it may not be demonstrable that this is injurious or objectionable, it does not give an impression of the careful handling which the product deserves. The handling with the pew means, first, throwing the fish upon the deck of the vessel, then upon a staging, if the tide be low, and lastly upon the dock. The men walk among the fish, frequently stepping on them, and whether their boots are clean or not this does not seem to be taking proper care. The use of slat platforms on which to pitch the fish was introduced this season and is an improvement but not a sufficient one. A flexible conveyor working from the hold of the vessel to the scales would not be difficult to construct and is certainly needed; as a labor-saving device it should quickly repay the cost of installation.

While the fish are being pewed from the vessel to the scales, they are examined for spoilage, and this work is very thoroughly done. The writer had an opportunity to see a number of cargoes inspected, and the work was done as carefully as if the presence of an official inspector had been known.

The fish are thrown from the scales into a tank of water and dipped out again onto trucks to be wheeled into the butt shed. If the fish show any crusting of salt or a poor surface, they may be hand scrubbed with brushes. Sometimes they are passed through two tanks, the water in which is changed frequently, but it soon looks dirty, as would be the case with any like body of water into which are thrown fish or any other product on which there is discolored salt and soluble matter. The washing of the fish at this time or after they have been in the butts is the most disagreeable part of the work about the fish factory and could be greatly improved. It is probable that it could be done with some mechanical appliances much more effectively and economically than by hand.

The newer butt sheds certainly leave little to be desired from a sanitary point of view. They are built in a most substantial manner on an incline with cement floors and water is supplied to all parts so that everything may be flushed clean. The older sheds have nearly all been repaired until they are in good condition. Some of the butts are old and have been used over and over for years, but apparently are good for many more. The fish are not subject to spoilage of any kind while in the butt and covered with brine.

The drying is accomplished in the driers and on the flakes, where the greater part of this work is done. Formerly the flake yards were placed on the ground, but these have been moved to the tops of the buildings and out upon the docks in order to avoid the dust from the street. There are only two large flake yards remaining along the roadside and the statement is made that no drying is ever done when the wind is from the direction which would carry dust from the street onto the fish, because the wind blows from this direction

only in wet weather. There can be no doubt that much improvement has been made in this phase of fish preparation in the past few years.

The dried fish are stored on the ground floor of the building in which the skinning and packing are done. It is here that the first evidence of redness occurs; it may be evident in a very few days or it may be some weeks, depending upon the temperature, etc. The dried fish are kenched upon racks or upon the floor. The rack is generally used, and is made about 4 feet square of slats about 3 inches wide and 3 inches apart, on crosspieces which raise them 2 inches from the floor. These racks are placed side by side until they cover the floor. It has been the custom to place the kenches too near the walls and too near one another to permit the proper circulation of air. This assists in the growth of the germs causing reddening and has the effect of inoculating the fish. The examination of the walls, woodwork, and fish where crowding was practiced showed that this custom of close kenching can be improved. The kench racks are too low and permit of dead-air spaces but not of circulation, all of which conditions favor the development of the red organism, with its attendant inoculation of the fish. The kench racks are used over and over without disinfection and without frequent washing. They are all inoculated with the organisms causing red discoloration. Sometimes this woodwork will be very red, and the fish touching the kenches invariably become inoculated. When repiling is necessary, as is always the case with fish not used in a short time, those in the kench are mixed with those above and thus the infection is spread. Experiments were made in which fish were taken from racks which showed no redness and from the tops of the piles. In every case all the fish in contact with the rack developed the red color, while only comparatively few of those taken from the top became red.

The changes which can be advantageously made in the handling of the fish at this stage are: Kenching in such manner as to leave an air space between the kench and the wall and between racks, and raising the kench rack higher from the floor. The platforms should be disinfected after every period of service. (See page 38.)

The work of skinning, cutting, and packing is done in a cleanly manner. The most important recommendation to be made is that all tables be plain, without shelves or cross partitions beneath, so that no pieces of fish can accumulate. Tables obstructed with shelves, boxes, partitions, etc., are never well cleaned. There should be at least one thorough cleaning each day to insure that no bits are being left which will act as centers of infection.

The general provisions for the cleanliness of the workers are good at the majority of the factories. Toilets are provided and water for washing the hands. Smoking is prohibited because of insurance

regulations, and spitting should be interdicted for sanitary reasons. These observations on the sanitary features of the work are in line with reasonable and possible improvements comparable with those demanded of the manufacturers of meat food products.

THE WATER SUPPLY.

It is generally agreed among the fish packers that sea water is much to be preferred for washing the fish and making the pickle. Well water or fresh water is said to cause some changes which are objectionable. At the beginning of this study it was understood that the sea water used was obtained at some distance from the plants and that it was pure. In the course of the examination of the fish organisms were found which were recognized as being ordinarily associated with polluted water, and this led to an investigation as to the cause of their presence. The water used by the packers is from the Gloucester Harbor, and is taken only a few feet from the end of the docks. This harbor is long and narrow, surrounded on three sides by the city, and the surface water from the streets drains into it. Many private sewers and a few fairly large ones discharge into this basin, besides numerous closets upon the docks and those connected with cottages that overhang the water. All the brine from the butts, the water from washing fish, and more or less gurry are added to this volume of impurities. The result is a very high bacterial content and the presence of forms that would condemn the water for any domestic use. Tests were made of the water at all the packing plants and at various places in the harbor beyond the breakwater and in the open sea. There was a marked variation in the number of organisms present in the different places and at different stages of the tide. In no case could the water be said to be pure within the inner harbor. The long narrow shape of the harbor and the position of the breakwater preclude the movements of the tide from changing the water each day. A short distance beyond the breakwater, however, and at all points along the eastern coast pure water was obtained, and this should be used.

DISINFECTANTS.

A disinfectant is as much needed in fish packing as in any other line of food production. During the part of the year when steam can be used it is very satisfactory for this purpose. A jet of steam directed upon the butts, kench racks, carrying boxes, or any other object with which the fish come in contact will be effective if used often. This may be done with a hose by turning the steam upon the walls, etc., or by keeping the apparatus to be disinfected in a tight chamber until a proper temperature has been reached. It is not practicable to

use steam at some places nor at all times, and some other agent is needed for supplementary use. Whitewash is good, and has a place as a disinfectant for the woodwork, walls, and ceilings. Sulphurous acid can probably be employed wherever the whitewash can not be used and as a substitute for steam when the latter is not available.

Tests were made of the disinfecting power of concentrated sulphurous acid as it is purchased in the open market. These consisted in adding one-sixth, one-fourth, one-half, 1, 2, 3, 4, 5, and 6 per cent, respectively, to sea water and beef broth gelatin, which was inoculated with the bacillus, the coccus, and the brown mold. The bacillus and coccus were checked, though not killed, in the solutions containing one-half per cent of the acid or less. They were killed in the 1 per cent solution. The mold was more resistant as growth took place, but it was delayed in the 3 per cent solution, and was killed by the 4 per cent solution.

Tests were also made by spraying the woodwork and kench racks, which had reddened to a greater or less degree, with solutions of the acid. Where growth was very abundant a solution of 1 part of the acid to 50 parts of water was effective, and where it was less pronounced a solution of 1 part to 200 worked well. On the butts, kench racks, floors, etc., a solution of 1 part in 100 is recommended, and for the carrying boxes, table tops, etc., 1 part to 200; the dilution might be carried further after repeated use has been made of it. After a vessel has been unloaded, burning sulphur in the hold will have the same effect as spraying. Precautions should be taken, however, to remove any excess of sulphurous acid from the room before the fish are handled or stored in it.

PRESERVATIVES.

Boracic acid was introduced as a preservative in the fish industry in 1881 and was used continuously until 1907, when it was superseded by sodium benzoate. The boracic acid is still used on some of the export fish, and is regarded as the best preservative for the purpose. It is applied to the fish when they are being shifted in the waterhorse or to the outside of the completed cake. It was also used in the kenches in the storeroom to prevent spoilage. The quantity of the acid used was not generally known, though it was agreed that its use had been abused.

Since 1907 sodium benzoate has taken the place of boracic acid. The sodium benzoate is mixed with finely ground salt and applied by means of a powdering can like a large pepper box. It is used upon the fish in the storeroom if the weather conditions demand it, but its principal use is upon the fish as they are being weighed out into tablets. This preservative is used chiefly from March 1 to November 1. The amount used is not weighed, but is dusted on to cover the whole

surface, the effort being to apply from 0.3 to 0.4 per cent. The packages of fish bear the following label:

INSTRUCTIONS FOR REMOVING PRESERVATIVE FROM SALT FISH.

To keep these goods in perfect condition, they are cured with pure sea salt and contain four-tenths of 1 per cent of benzoate of soda. Make use of the following instructions to remove the preservative: Rinse the fish at least five minutes. Then soak fish in a proportion of 1 pound of fish to 1 gallon of water for an hour. Repeat this process in the same quantity of new fresh water. In cooking add salt, if the fish is too fresh.

Samples of the fish were submitted for the determination of the quantity of sodium benzoate present, and the results are shown in the following table:

Amount of sodium benzoate on washed and unwashed fish cakes.

Sample No.	Unwashed fish cake.			Washed fish cake.		
	Dry material.	Anhydrous sodium benzoate.		Dry material.	Anhydrous sodium benzoate.	
		Wet basis.	Dry basis.		Wet basis.	Dry basis.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
20839	52.13	0.21	0.40	31.06	0.02	0.06
20840	51.58	.35	.68	30.90	.40	.13
20841	52.66	.29	.55	34.72	.13	.37
20842	49.04	.12	.24	30.34	.01	.03
20843	50.08	.74	1.48	30.44	.11	.36
20844	52.88	.45	.85	31.91	.05	.16

These figures indicate that all of the sodium benzoate was not removed by the washing and that the original experiments upon which the instructions were based had been made upon fresh material and not upon packages which had been in commerce for a couple of weeks or more. Sodium benzoate in small quantities is not a good preservative of neutral or alkaline foods and, therefore, it is not very efficient for the preservation of codfish.

BACTERIOLOGY OF REDDENED CODFISH.

EARLIER INVESTIGATIONS.

Codfish and some other salt-cured fish are subject to spoilage when exposed to a temperature above 65° F. The spoilage is manifested by the surface of the fish turning red and emitting a foul odor. The discoloration was first studied by Dr. W. G. Farlow,[a] who ascribed it to a fungus known as *Clathrocystis roseo-persicina*. At that time the technique of bacteriology was undeveloped, so that the findings on the organisms are subject to revision; however, the general obser-

[a] U. S. Fish Commission Report, 1878, p. 969, 1880.

vations and recommendations are as fitting as if made recently. Doctor Farlow also found a micrococcus which he named *Sarcina morrhuae*, and subsequently a fungus of a higher order which produced brown spots and which he named *Oidium morrhuae.*

Later Doctor Farlow reported[a] that the redness had been studied in Algiers as a result of sickness among the troops produced by eating codfish which was infected to the stage of decay. The color in the Algerian fish was ascribed to a fungus, *Coniothecium bertherandi.* On sending a description and plate of his *Clathrocystis* for comparison, and receiving samples of red fish from Bordeaux and Dieppe, it was determined that the *Coniothecium* and the *Clathrocystis* were identical. It also developed that the *S. morrhuae* was identical with *S. litoralis*, a form found by Poulsen on mud near Copenhagen, and, as the description by Poulsen was published before that of Doctor Farlow, the name *litoralis* had priority. Doctor Farlow reports further that Saccardo and Berlese consider *Coniothecium* and the *Sarcina* to be identical, and that Zopf considers the organism to be a condition of *Beggiatoa roseo-persicina*, under which name he also includes *Clathrocystis roseo-persicina* as a zoogloœa form. Doctor Farlow did not consider the *Sarcina* and *Clathrocystis* to be identical, as there was a variance between the two forms as to size and color; neither does he consider the *Clathrocystis* as a form of *Beggiatoa.* A description of the *Coniothecium* by Megnen, reported by Layet,[b] is as follows: "Round spores of very pale rose color, with granular contents, and a small kernel measuring from six to ten thousandths of a millimeter in diameter; the largest of these spores are divided into two or four equal parts, which become new spores; a short mycelium, hardly discernible, in most of those diminutive spores."

The Scotch fish commission caused an investigation of the reddening of fish to be made and the work was done by Doctor Edington,[c] of Edinburgh University, who describes several organisms associated with this phenomenon. He attributes the coloration to a bacillus, to which he has given the name *Bacillus rubescens.* This was the only one of the forms isolated by him which caused reddening. He reports no inoculations from his cultures on fish, basing his conclusions as to the causative organism on ability to produce a red color on artificial media. This same name has been given by Jordan[d] to a bacillus which he reports as nonliquefying, motile, and in which no spore formation was observed. This was isolated from sewage.

[a] U. S. Fish Commission Bul., 1886.

[b] Layet, A., Observations on the red flesh of the codfish. U. S. Fish Commission Bul., 1889, vol. 7.

[c] Report of the Fisheries Board of Scotland, 1887.

[d] Jordan, Mass. State Board of Health Report, 1890, vol. 2.

As a result of his work on the reddening of cod, Dantec[a] distinguishes two stages of reddening. The first he designates as healthy red cod. In this stage the characteristics are the presence of a non-viscous mucus which can be readily removed, the flesh beneath being sound, and the presence of three forms of organisms—an alga, a bacillus, and a coccus. In the second stage, or spoiled red cod, the red matter is viscous, has a strongly alkaline reaction and a sickening odor. The coccus is the only organism present. He states that the transformation from the first to the second stage requires from two to three months.

The alga he describes as being composed of spherical cells, from 12 to 18 μ in diameter, containing spherical granulations, and a greenish pigment. He used various media, but was unable to obtain a pure culture. He states that the organism has no coloring power, as it is found on white cod, and that it is always present in the aponeurotic interstices of the cod. He also states that it is very probable that this is the organism which has been described under the names *Clathrocystis* and *Protomycetes*.

On account of the viscosity of the red layer difficulty was experienced in the separation of the organisms. A method which he adopted as being successful and easy of manipulation was to take advantage of the resistance of the spores in the bacilli. A fragment of the red was separated in distilled water, then heated to 95° C. for one minute. The material was then used in a plate culture. The bacillus varied from 4 to 12 μ and more according to the medium and was slightly thicker than the tetanus bacillus. It was motile, slowly liquefying, formed a spore at one end, and in colonies sometimes produced a uniform red color, or might be darker around the edges. It grew best on gelatin, producing a funnel-shaped liquefaction. Dantec ascribes the reddening in the first stage to this organism, in proof of which he states that he took some flesh which was white, firm, and almost free from organisms and inoculated it with the pure culture of the bacillus, producing a reddening. He reports that the redness was more intense on the side of the inoculated piece of fish which was exposed to the salt, and also fewer spores developed than on the artificial media. He also tested its pathogenicity by feeding reddened cod and also pure cultures to a dog, guinea pig, and rabbit. He made subcutaneous and intra-peritoneal injections in the guinea pig, with negative results in all cases.

The coccus was present in both stages, but in greater numbers in the second stage; it is grown with difficulty on artificial media, as it is always associated with the other organisms. It is from 3 to 5 μ in diameter, with a line present in the middle at times. On gelatin

[a] Dantec, M. le, Annales de l'Institut Pasteur, 1891, vol. 5.

plates the colonies look like those of the bacillus, but are smaller, rarely a millimeter in diameter, and require more time to develop—about two weeks. The colony forms a tiny mound in the center before spreading out, and from a pale red at first becomes darker according to its age. It grows better on agar than on gelatin. Alone it is incapable of producing redness, but if associated with a small liquefying coccus, which is found with it on the cod, develops a distinct redness. Dantec ascribes the redness of the second stage to this organism, which requires that the cod be previously spoiled by other organisms. The muscular tissue crumbles easily. The red has a strongly alkaline reaction. This was also tested for pathogenic properties in the same manner as the bacillus, and was found to be innocuous.

Dantec also found a yeast (*Rosa hefe*) which produced redness on cod, but only at incubator temperature, and a red "mildew" which formed small, irregular granulations. Other organisms and other chromogenic changes were also present. To prevent the occurrence of the redness, Dantec recommends that from 10 to 15 per cent of bisulphite, nitrate, or hyposulphite of soda, etc., be mixed with the salt used.

GENERAL OBSERVATIONS ON REDDENING.

The reddening of codfish is an old difficulty in the industry, but formerly was not of the commercial importance that it is at the present time. The business was limited to the cooler months of the year and such spoilage as did occur in summer was discarded as a necessary loss. The fish were cured harder, and there was less attention paid to the niceties of the product. The development of the skinned and boned fish in strips, middles, cakes, and tablets has made the product more attractive to the general consumer than the hard-dried fish, and has created a demand for the product throughout the year. The increase in the labor of preparation, in packing, shipping, etc., has added to the initial value of the product, while at the same time it has become somewhat more perishable. The losses which occur are, therefore, more keenly felt and that which was once thought to be a necessity is now considered preventable and a subject for investigation.

The trouble is not of a local character but occurs wherever fish are cured, along the New England coast, Nova Scotia, Newfoundland, on the Pacific coast, and in Europe. The character of the spoilage in these places is the same, the only difference being the amount.

The source of infection causing the red discoloration of dry salt fish has not been fully determined. The organisms probably have a normal habitat in the salt water and the lowlands along the coast and, being saprophytic, they will grow upon the salt fish when brought

in contact with them. This seems to be borne out by the fact that the organisms can grow freely upon fish or wood that is salty to any degree and even upon the surface of salt crystals. Salt acts as a preservative by preventing the growth of most organisms which would cause spoilage in foods, but it has no such effect in this case.

Farlow states that the organism, *Clathrocystis*, which caused the reddening was present in the bogs, marshes, and the lowlands in the vicinity of Gloucester, and that the growth was so abundant that it gave a reddish or purplish tinge in the fall of the year to the vegetation or material infested. He found the organism in the salt used, especially the Cadiz salt. Edington also found a chromogenic organism in the salt, to which he ascribes the reddening, in the cases which he investigated. In Norway,[a] red bacteria appear in summer in such masses that the borders of the sea are sometimes colored an intense red.

The discoloration was observed and an organism obtained capable of producing the reddening when grown artificially, and also when inoculated on the cod. The specimens were taken from the following places which had reddened—the woodwork in the salt house, damp places in the butt sheds, the butts in which fish had been pickled, in the cracks and on the undersides of planks on the fish docks, the kench racks, and various parts of the woodwork of the storage rooms. The organism is abundant and infests everything with which the fish come in contact. In the salt house the woodwork may show an abundant growth for a distance of 2 feet or more above the floor. Planks taken from the floors of the docks will have their undersides as red as if they had been painted. A dock contractor on being questioned said that no such condition of the timber existed on docks where salt and fish were not handled. The kench racks and butts were so coated that there seemed to be an appreciable thickness to the covering. The same was true of the wood in corners and inaccessible places in the storeroom. The reddish discoloration was observed in the marsh, but later it was established that the organism causing it was not the same as that found upon the fish. The latter was obtained from the water in different parts of the harbor.

The finding of the organisms on the salt in the hold of a salt steamer and on the salt in the storehouse is evidence that it must have been infected where it was produced. The salt used is solar sea salt; the salt beds are all on low ground, and marshes are near by, making it easily possible for infection to occur during its preparation.

If the infection were wholly a local trouble, then fish caught, cured and dried during cold weather should show very little reddening

[a] Antoine Magnin (translated by G. M. Sternberg), Bacteria, 1880, p. 32.

for the snow and ice prevent outside infection and the low temperature arrests growth within the butt sheds and storerooms. The fact that winter-cured fish spoil when exposed to a warm temperature shows that some other source of infection must be acting continuously. If the infection were due wholly to the salt, then the use of mined salt or sterile salt would suffice to prevent spoilage. Experiments made by using the refined salts showed some improvement over the use of the solar salt. The fish packers on the Pacific coast have much less trouble than those upon the east coast, and ascribe the improvement to the use of a higher grade of salt. In the English prov-

FIG. 3.—Marked reddening on the wall near the floor in the storeroom.

nces some mined salt is used, but spoilage occurs, whether in less degree than when solar salt is used could not be learned. The infection takes place during the preparation of the fish, for the spoilage s the same no matter in what form or where the fish may be shipped. t can not, therefore, come from external infection of the finished product.

With local conditions such that the infecting organisms abound naturally, they may be carried into the boats, the butt sheds, the flake ard, the storerooms, and preparation rooms, by the wind, on the oots, clothing, or hands of sailors and factory employees, and by the se of water in making pickle and cleansing the buildings.

Cod and haddock redden easily, the cusk not very readily, and the hake is the most resistant. Just what causes this difference in susceptibility is not known. The cod and cusk are the fish richest in gelatin and glue; the former reddens easily, while the latter possesses considerable resistance. The haddock and hake are poor in gelatin and glue, yet the former is the most sensitive of all, and the latter the most resistant. The division, therefore, can not be made upon the basis of gelatin content.

The acid reactions of the cured meats of these fish were compared, and while there was some difference, the hake being more strongly acid than the cod, the difference was but slightly more than that

FIG. 4.—General reddening of fish cakes.

between different lots of the same kind of fish and was too small to account for the resistance. Halibut, mackerel, and some other salt fish may also redden if exposed above brine for too long a time, though fish like the mackerel, which are rich in fat, tend to "rust" instead of reddening.

Reddening is essentially a surface infection. It does not appear below the surface except as it follows fissures in the muscles, cuts, or breaks where the air has free access. On the whole fish, the favorite point of attack is near the backbone, and this is due to the greater thickness of flesh, which insures more moisture at all times. It is oftenest found upon the outside of the cakes or tablets, but the mold is most prevalent upon the inside of the cake.

Cold checks the growth of the organisms causing the reddening, and in addition it also has the effect of bleaching the color which may be present. In some of the experimental lots, fish which had become quite red in the fall appeared white in the spring after having been exposed to the low temperature of the winter. A short exposure to heat was sufficient to establish new growth and to restore the color.

The coloration of the cod varies in appearance, sometimes being of a pale pink color, at other times a bright red. The pink is caused by the germs being in a thin layer on very moist fish; the more intense color appears when the fish is drier and the germs form thicker spots or a series of colonies. The germs have a moister and more oily appearance in the latter stage. Both conditions may appear on the same fish. The redness occurs on any part of the fish, the skin as well as the flesh, though it is not so readily seen nor developed on the skin. The infection, so far as known, occurs on the salted fish only, but this may be due to the slowness of development and the fact that the fresh fish are not kept sufficiently long for the color to appear; it may be present in the incipient stage, since the germs were found in the water which is used to wash the fresh fish.

DESCRIPTION OF ORGANISMS.

There were many different lots of red fish examined, the material being taken from various infected spots on each. Some of them were examined in Lafayette, Ind., during June and July, the fish being shipped from Gloucester; some during August and September in the factories in Gloucester; and still others were examined in Lafayette, Ind., during the winter months, the fish with one exception being from Gloucester. The exception was a piece of red fish from California, received in January. The salt used by the packers and obtained from different places in and around the factories was examined, as were also scrapings from the woodwork and scum from the top of the brine in the butts.

In nearly all the cases cited there were three organisms found—a coccus, a bacillus, and the cells of a mold-like fungus; in the exceptions the bacilli were sometimes absent, sometimes the mold cells, and in a few cases both of these organisms. Of 34 examinations, in which record was made of the predominating organism, the coccus predominated in 10, the bacillus in 4, and the mold cells in 2; in the remaining 18 the three organisms were present and seemingly in equal numbers. The pieces examined were of varying degrees of redness, and those in which the mold cells predominated had the typical red color. Where the mold grows apparently alone there are brown spots formed that are wholly distinct in appearance from the reddening.

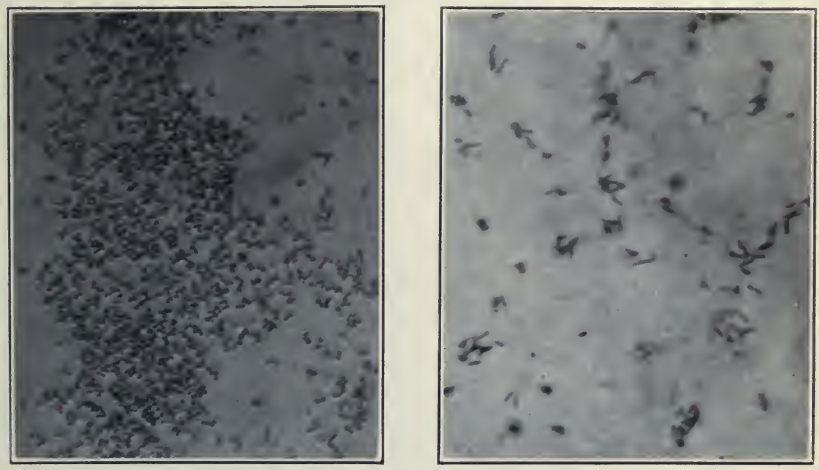
In obtaining samples for examination the red growth is found to be very viscous, the material drawing out in fine threads from the

needle point. The viscosity does not seem to be so great in the pink spots when first appearing as on the older and redder spots, but it can be demonstrated by placing the infected point in a small drop of water on a slide and working the needle round in the drop, then drawing it gently away, when elastic threads are formed that are as long as those from the older infection. The viscosity makes it difficult to separate the organisms, and often, in spite of the most vigorous preliminary shaking, the resulting colonies will sometimes show mixtures, and as the development of all three organisms is very slow the detection of the mixtures is correspondingly slow. Then again very few colonies develop on a plate, so that after some preliminary trials no dilution was used in making plate cultures directly from the fish.

COCCUS.

The coccus is the organism which produced the reddening both on artificial media and on fish. This form occurs in pairs and tetrads and less frequently, singly. The coccus varies in size, the average being about 2 to 2.5 μ in diameter; sometimes larger cocci occur, varying from 3 to 5 μ in diameter. When these were first seen, since they correspond in size with the coccus described by Dantec, it was supposed that there was a mixture, but as many times a pair will be found composed of a large and a small coccus, or a tetrad with one two, or three large ones joined respectively to three, two, or one small ones, the occurrence seemed to be merely an idiosyncrasy of development. At first, when the large cocci were noted in the red growth on fish or in an artificial culture, isolation cultures were made, but the resulting development in no case gave a colony composed of the large cocci. In a vigorous growth the four cells of a tetrad, the members having different sizes, can be seen in process of formation, sometimes a divisional line showing in the large cell. No spores have been observed. In artificial media the coccus is nonmotile, but occasionally from a culture on fish some may show a tumbling movement, but this is slow and deliberate. So far flagella have not been noted, though cultures of various ages and on various media have been tested Löwit's method being used. The organism is capsulated, the capsule being seen readily in both unstained and stained preparations. When grown on solid media a viscous mass is formed which draws out into elastic threads and which adheres to the needle; in liquid media, some days after the liquid becomes turbid, zoogloea masses of various sizes form on the surface.

The color varies from a pink to a bright red, the red having a stronger and more oily appearance than the pink. Usually the pink appears in the young cultures, but occasionally both the gelatin and fish will have the bright-red color from the start. When examined



A *B*

FIG. 1.—*A*. COLONY OF COCCUS ON GELATIN PLATE (×700). *B*. BACILLUS (×550).

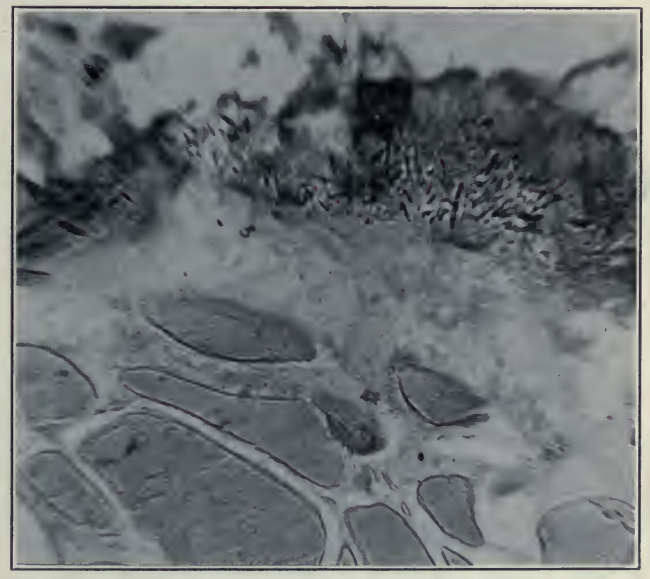


FIG. 2.—CROSS SECTION OF FISH THROUGH RED LAYER (×550).

with a lens, the pink of the thin layer looks red also. Growths taken from gelatin and from agar and placed in both cold and hot alcohol did not fade even when the alcohol was boiled; neither were they affected by chloroform when treated in the same manner as in the alcohol, nor when these were left for some days in the light. Weak potassic hydrate and ammonia had no apparent effect, but weak acetic acid caused the color to disappear in a short time. The viscous mass from the fish was much more sensitive, as the color disappeared in twenty-four hours in the light in alcohol and in chloroform, while weak acetic acid caused the color to disappear in a short time.

The organism is aerobic; in stab cultures the growth tapers gradually from the surface to the bottom of the tube. Parallel lines of growth were formed on both agar and gelatin plates, parts of which were covered with sterilized cover glasses. Clean cut lines of growth developed, stopping abruptly at the edge of the covers, no development occurring under the cover. After some time the growth ran around the edges of the covers, connecting the broken ends on either side. This property is also seen in the lack of development of redness on the fish cakes which were sealed in vacuum in tin boxes, no red developing on the cakes which were free from red when sealed, and on the cakes which had reddened no increase took place.

A peculiarity which was noted on the fish and in the cultures was that when tested with neutral litmus paper a slightly alkaline reaction was obtained, but when phenolphthalein was used as an indicator an acid reaction occurred. When these results were noted, fresh, sensitive litmus paper was obtained, but the reaction was the same, indicating that the litmus was not the proper indicator to use. Dantec obtained a strongly alkaline reaction with litmus, but does not state whether any other indicators were used.

The organism stains readily, having been tested with Löffler's alkaline methylene blue, carbol fuchsin, gentian violet, and other stock stains.

Growth in Various Media.

Beef bouillon.—The coccus grows well in feebly acid, neutral, or feebly alkaline beef broth. It causes a slight cloudiness at first, the liquid clearing, however, as a sediment forms, the pink color not being perceptible for three weeks or more. Patches of growth form on the surface, and later a thin ring of growth may develop. In cultures three or four months old a thick, viscous, red sediment is formed, which draws out into elastic threads.

Milk.—No perceptible change occurs in milk until the culture is about a month old, when a pink ring forms, after which the ring thickens and deepens in color somewhat, and a thin pink film forms on the surface.

Gelatin.—Like the development in bouillon, the gelatin may be neutral, faintly acid, or faintly alkaline without perceptibly affecting the development. In a gelatin stab the growth is mostly on the surface, a flat, rather thin layer forming, which is about 10 mm in diameter, in from three to four weeks. The color is a bright red with a pale border, shining and viscous. The puncture is tapering, and, except near the surface, without color. No liquefaction takes place and no odor develops. The gelatin is darkened slightly near the surface.

Agar.—On agar there is a more abundant growth than on gelatin, the surface layer is thicker, not so deep in color, and may cover the surface of the medium. In agar plus 1.5 per cent potassium hydroxid the growth was thinner and paler, with a tendency to spread. The puncture is the same as in gelatin.

Since the red growth is found on fish having salt crystallized on the surface and is also found in the scum on the saturated brine in the butts, it was thought that addition of salt to the agar might aid in development. This was tested, using 5, 10, 15, 20, and 25 per cent, respectively. Development was delayed slightly in the 5 per cent and considerably in the 10 per cent, none taking place in the agar containing the larger amounts. The growth was thinner, but deeper in color, with the addition of the salt. The Trapani salt was first used, then compared with refined salt, the latter checking the growth even more than the former.

Sea-salt gelatin.—Gelatin was made, using sea salt dissolved in 1,000 cc distilled water instead of beef broth. This makes a clear gelatin that keeps well. In this the growth was slightly ahead of the control at first, then slightly less, and in a couple of months no difference could be noted.

Bread paste.—This was made by adding sufficient sterilized water to finely ground bread crumbs to moisten thoroughly. It was sterilized for fifteen minutes on three consecutive days. The organisms grew well on this medium, forming a bright-red waxy growth on the surface. No color was imparted to the paste adjoining.

Rice.—Rice grains were placed in about three times their volume of water and sterilized in the same way as the bread paste. On this the growth was fair, forming a thin spreading layer. On rice paste made with about six times the volume of water, so that the mass was watery, the organism grew around the swollen grains, and in about a month the whole mass had a pink tint. In paste to which a trace of sodium carbonate was added the growth was better than on the rice alone, being about as thick as on agar.

Pea broth.—To make the broth the liquor was poured off of a can of peas and a can of water added, after which the peas were boiled for about half an hour, filtered, an egg added to clear the solution,

boiled again, and filtered. This solution is a good medium for many organisms, but no development of the coccus took place.

Pea gelatin.—This was made by adding 10 per cent of gelatin to pea broth. On this medium a thin line of growth was perceptible on the fourth day, after which no further development occurred.

Tomato broth.—This was made by adding to a can of tomatoes a can of water, and proceeding as with the peas. Tomato broth and tomato gelatin were used, but no growth took place in either one. The tomato broth has an acidity of +3.

Codfish broth.—This was made by washing a pound cake of codfish, then soaking it twelve hours, after which it was broken up in a liter of water, boiled, filtered, egg added, boiled again, and filtered. This was used also with 10 per cent of gelatin. No development occurred in either medium when the culture from which the inoculations were made was not vigorous. When development did occur it was slower and less abundant than that on the beef gelatin.

Temperature Tests.

Inoculations were made into agar and into gelatin and one set was placed in the refrigerator at 44° to 50° F. In six days there was a tiny spot, faint pink in color, at the puncture, and a faint line along the stab. At 72° to 75° F. one-half of the surface of the agar was covered, the growth being fairly heavy and pink, with a tapering growth along the needle track. In the gelatin the growth was more abundant and a deeper color. At 90° to 95° F. one-third of the surface of the agar was covered, thinner than at 72°, and a pale pink. In the gelatin which was liquid at that temperature there was a slight pale pink sediment.

Reaction of Media.

The organisms were grown upon gelatin and in bouillon of known acidity and after thirty days tests were made for any change which might have taken place. No change was found as a result of the growing of the coccus.

The reaction of the normal fish was obtained by cutting 10 grams into very fine bits, placing in a flask, and making up to 200 cc. After being shaken repeatedly and standing for four hours, 100 cc were filtered off and neutralized with a tenth-normal alkaline solution. A like procedure was followed for the reddened fish and for the red growth scraped from the surface of the fish. The results were not constant. In some cases the red fish had an acidity greater than the normal and in others there was no appreciable difference. The red growth which could be scraped off usually had an acidity about one-half that of the flesh below it. The red fish tested all showed a mixed infection.

BACILLUS.

The bacillus is a rod, thicker at one end than the other, due to the formation of a spore. The bacilli vary in diameter from 0.9 to 1.3 μ and in length from 3 to 10 μ on bread, while in sea-salt gelatin the length is 5.7 μ and over. In beef gelatin and agar the length varies between that on bread and that on sea-salt gelatin. They are motile in young cultures on nearly all media used, and produce liquefaction in gelatin. They are colorless on all media except bread, which assumes a pink tint. They are aerobic, the growth tapering gradually from the surface in stab cultures, and in plates in which parallel lines of growth were made, parts being covered with sterilized cover glasses, no growth occurred under the covers; in gelatin plates there was no liquefaction under the covers. No viscosity is found in the cultures. The organism stains readily, the same stains being used as on the coccus.

Growth in Various Media.

Beef bouillon.—The organism causes turbidity in this medium, a thin film forms in a few days, and in a week a fairly heavy sediment is developed.

Milk.—An oily ring is developed at the surface, but no perceptible change occurs in the milk.

Gelatin.—The bacillus liquefies the gelatin slowly, in five days a funnel-shaped depression being formed. When the gelatin is entirely liquefied, it is clear, with a medium amount of grayish sediment. Many spores are formed in this medium. The reaction of the liquefied gelatin is +1.

Agar.—In this medium a thin oily, grayish growth is formed on the surface, with a white rim at the edge that appears thicker than the older central part, and a thin uniform development along the puncture. No development took place in agar plus 5 and 10 per cent of salt, respectively.

Sea-salt gelatin.—The organism grows very slowly in this medium, liquefying it much more slowly than the beef gelatin, small zoogloea masses being formed. When entirely liquefied, a very small amount of sediment is present, and the gelatin is perfectly clear. The organism attains a greater length in this medium than in any other tested.

Bread paste.—On the paste a thick, creamy layer is formed over the entire surface. The organism penetrates the paste; in eight days that near the surface has a pink tint, and in two months the paste to a distance of three-quarters of an inch is a decided pink with a somewhat watery appearance. As the culture ages, the creamy color darkens, becoming brownish.

Tomato broth.—No development took place in the broth, nor in broth to which gelatin was added.

Pea broth.—No development in this nor in pea gelatin.

Codfish broth.—No development in this nor in codfish gelatin unless the inoculating culture were vigorous.

Enzyms.

Bouillon to which 1 per cent of corn starch was added was inoculated. After twelve days it was tested with Fehling solution for the presence of sugar, but gave negative results. Beef gelatin which had been liquefied by the bacillus had chloroform added to kill the organisms. The liquid frothed at first, and was afterwards filtered. One part was added to a 1 per cent starch paste and another to a tube of gelatin. Thymol was added to prevent any growth. The paste was tested for sugar and gave negative results. In twelve days there was 1 cc of the gelatin liquefied, and in thirty days 3 cc were liquefied. It is evident that there is a proteolytic enzym formed by the bacillus, but no diastase nor rennet, as shown by the behavior in the starch medium and in milk. No tests were made for other enzyms.

Brown mold.

Brown mold, as already stated, forms brown, freckle-like spots on partially dried fish. It occurs usually on old fish, but may be found on comparatively fresh fish also. Hake, haddock, and pollock are the fish most affected by the fungus; it occurs to a lesser extent on cod, cusk, etc. One is told sometimes that hake or pollock is the only fish on which it occurs, which means that in that particular locality the fish named is the one most subject to attack. Occasionally the reason for the greater prevalence of the fungus on some one kind of fish is that as the fish is cheap, it is not powdered.

Appearance of Mold.

The fungus affects both sides of the fish, even covering the fins and tail. On old fish it will sometimes form in lines, making odd patterns, following irregularities on the surface, or it may develop in such abundance as to form a layer of brown dust over the surface.

The spots of the fungus when young are indistinguishable without the aid of a lens, as they are the color of the fish, but as they become older they turn brown, giving the fish the freckled appearance. The brown spots, when magnified, often show a colorless center and brown rim, in others the entire spot is brown. The brown rim is formed by a comparatively large number of spores germinating in one spot, sending out the hyphæ from the outer side, and then forming conidiophores which turn brown as they mature.

Effect of Fungus.

The fish on which the fungus occurs are usually yellow from age, and when thus affected are discarded. The muscle fibers on which the fungus grows, when mounted on a glass slide for microscopic examination, separate into fine particles, and are found to be corroded, having jagged edges. Whether the corrosion is produced by this fungus alone is difficult to determine, as no examination made of the fish either at the factory or in the laboratory showed the fungus growing alone; there were always present the cocci and bacilli, though in most cases there was no indication of redness.

Loss.

So far as known the loss from this source is slight. When it is found on comparatively fresh fish, they are scrubbed with a brush in running water, after which they are powdered. Little attention, however, is given to this fungus, so that the loss may be greater than is supposed.

Morphology.

The fungus grows close to the tissue of the fish, but, not developing the cotton-like mycelium of the ordinary molds on this substratum, is not perceptible until the mature conidia are formed, when the darkening occurs. The description as given by Farlow[a] is for this stage of the fungus: "Spores spherical, 3.5 to 5 μ in diameter, fuscous, attached in chains (average 12–15), arising from secundly fasciculate hyphæ, which are pulvinately compacted in scattered spots."

The fungus is pleomorphous, developing chains of oidia, when germination takes place on the fish as a substratum, each oidium developing a short stunted hypha. This hypha becomes a conidiophore, developing conidia acropetally. The oidia remain colorless and form septa at various angles, dividing the cell into two, three, or four parts, and these again may subdivide, by the formation of further septa. The conidia and the conidiophores darken, and at this stage the fungus becomes perceptible on the fish.

Germination.

When inoculations are made into nutrient media directly from the fungus on the fish, development is very slow and scanty, only a few spores developing, and the time may extend from eight to twenty-three days. In one case a germination occurred in three days. The form of the fungus when developed on artificial media is so different

[a] Loc. cit.

FIG. 1.—WELL-DEVELOPED CASE OF "FRECKLING" OR BROWN MOLD ON A FISH CAKE.

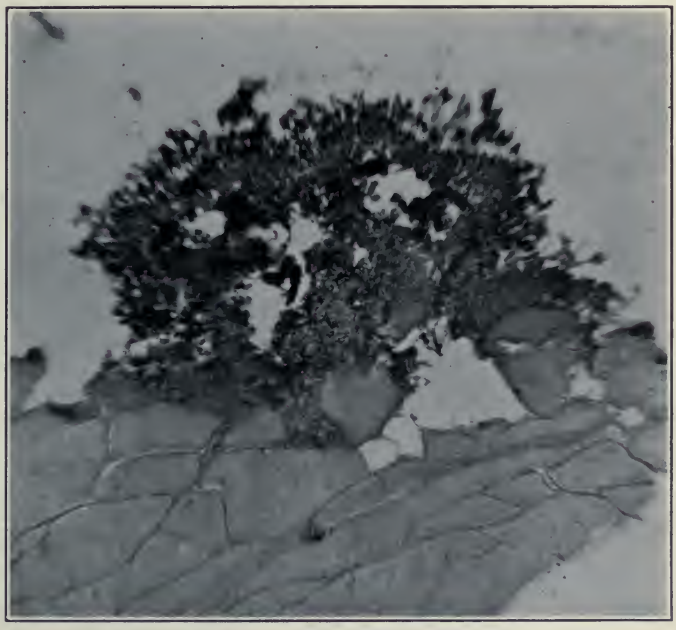


FIG. 2.—SECTION THROUGH A BROWN SPOT ON THE FISH, SHOWING THE HYPHÆ EXTENDING INTO THE CONNECTIVE TISSUE BETWEEN THE MUSCULAR FIBERS (×140).

from that on the fish that at first it was not recognized as a different form of the same organism. The connection was made in an accidental manner. Some of the fungus was placed on a slide in a drop of distilled water for microscopic examination. Before the examination was completed it was put aside, a ring of vaseline being placed at the edge of the cover to prevent evaporation. The slide was overlooked for about a week, and when again observed it was found that in one place where air had entered, the hyphæ growing out of the water and into the air had developed into the ordinary form, while the part of the hyphæ in the water formed a chain of oidia. This same phenomenon was observed later in a scraping of red from a fish, which was shaken in distilled water, and then exposed for one minute to a temperature of 95° C. In twelve days a chain of the fungus colonies had developed across one end of the plate. In each colony the hyphæ on first developing formed oidia, then the growth became normal, conidiophores developing from the sides of the normal parts of the hyphæ.

Growth in Various Media.

Beef bouillon.—In this medium, in three days at room temperature, a few colonies developed along the sides of the tube; in nine days a ring had formed at the surface. The growth is toward the center from the ring until the surface is covered by a thin, flat, tough mycelium. The surface darkens, becoming finally a rusty black. The solution remains clear but darkens gradually from the surface down, the submerged colonies remaining colorless. The bouillon was neutral to phenolphthalein, but when tested after a month's time it was +11. The increase in acidity is in accord with the fact that the fungus grows best on hake, which have the highest acidity of any of the fish considered.

Agar.—The fungus grows close to the surface, forming a line of interrupted colonies which darken in about five days; at the same time hyphæ grow down into the agar. The hyphæ have a fascicled appearance in the agar, due to the development of many short side branches from practically one plane, but growing in various directions, then a length of the main hypha free from side branches, and again a group or fascicle of side branches, this arrangement holding for the length of the main hypha. In a stab culture the same method of development occurs, the growth tapering from the surface to the bottom of the tube. The agar darkens gradually from the surface down.

Gelatin.—In three days there is a slight development on the surface, and a thin line along the stab. In six days the surface growth has covered about two-thirds of the surface, darkened, and dropped into the funnel-shaped depression formed by the liquefaction of the

gelatin, the solid gelatin forming a thin rim on the outside. The gelatin darkens.

Bread paste.—This is a good medium; the organism covers the surface and pushes down along the sides. In eight days it is very dark, later becoming a solid black mass.

Tomato bouillon.—In three days many colorless colonies are formed along the sides of the tube and in the bottom. Later a layer forms on the surface, which darkens as it ages and hardens, so that it is difficult to separate. The liquid remains clear but darkens. The submerged colonies remain colorless.

Sea-salt gelatin.—In this medium the development is slow, the mycelium forming slowly on the surface, and darkening gradually. The gelatin is liquefied and darkened, though it remains clear.

Agar plus salt.—In agar plus 5 per cent salt the growth is uncertain; sometimes a thin line of separate colonies forms along the streak, and then development ceases. Sometimes no growth takes place. With larger amounts of salt no development occurs.

Temperature Tests.

When agar and gelatin were inoculated and placed in the refrigerator, the temperature varying from 44° to 50° F., a tiny spot developed at the puncture point in six days, no further development taking place. At 72° the agar had one-third of the surface covered, and was black; the gelatin had a still larger layer of mycelium, and about three-fourths of the gelatin liquefied. At 90° F. no development took place in either medium.

INFECTION EXPERIMENTS.

INOCULATIONS.

When red fish were received from the factory, pieces of fresh fish were inoculated directly from the reddened spots to determine the time required for the reddening. The pieces were placed in covered glass dishes and kept at a temperature of approximately 20° C. In ten days a perceptible pink layer had formed, which spread gradually. As the fish dried, salt crystals formed on the surface, but the reddening increased. A foul odor developed even when a small amount of reddening was present.

At first, inoculations were made from the coccus, as that was the only organism which produced red color. Afterwards the bacillus and mold were used, and also the coccus and bacillus together, and these two with the mold. In the earlier inoculations, fish which had been sterilized by heating in the steam sterilizer was inoculated, but the fish spoiled by softening and became foul before the germs causing the reddening had time to develop. The raw fish was then used exclusively; large pieces from the tablets were selected, the sur-

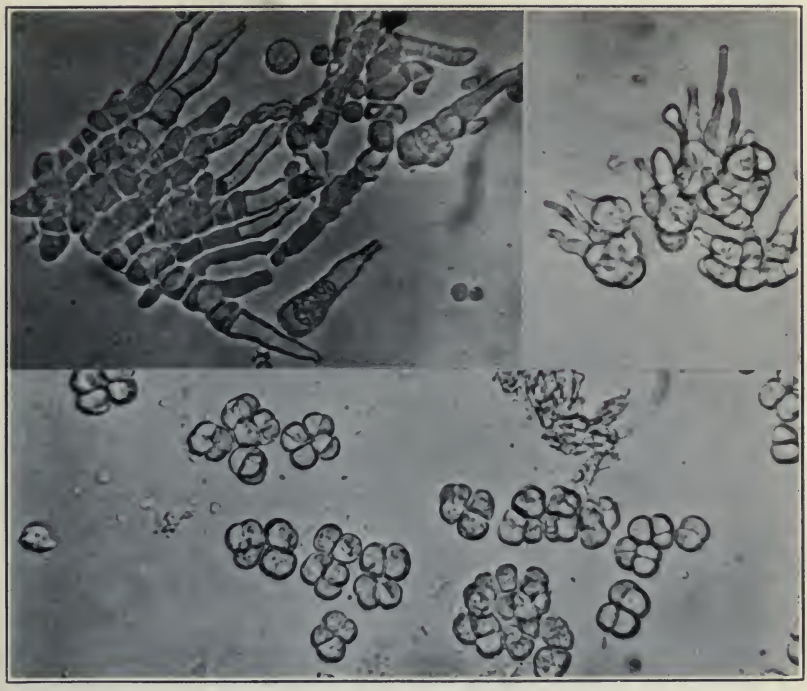
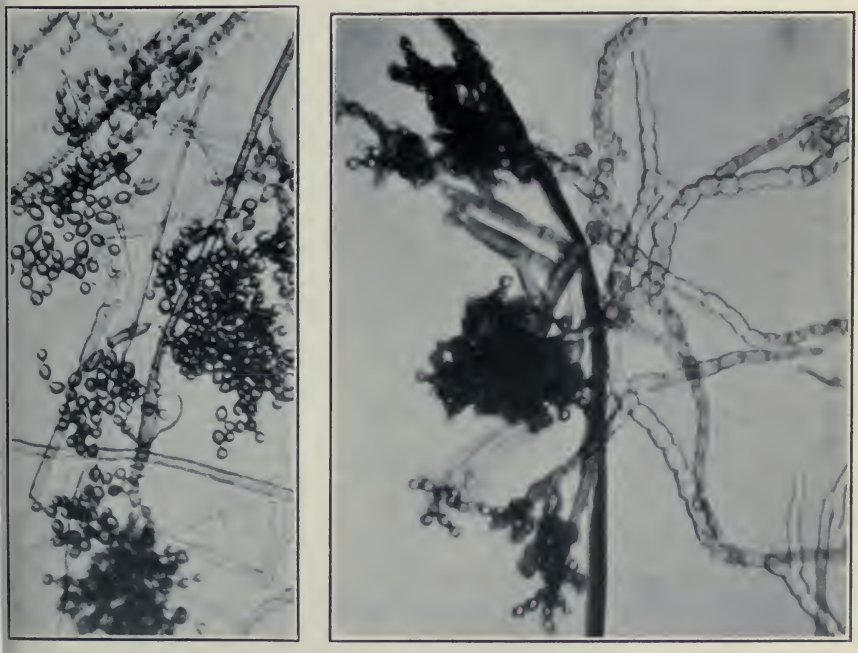


FIG. 1.—MOLD TAKEN FROM FISH, SHOWING THE DIVISION OF HYPHÆ INTO OIDIA (×550).



A *B*

FIG. 2.—*A*. MATURE CONIDIOPHORES; CONIDIA SEPARATING (×550). *B*. GROWTH OF MOLD ON SLIDE, PART IN AIR AND PART IN WATER, SHOWING TWO METHODS OF DEVELOPMENT (×550).

face removed with a sterilized knife, and the pieces placed in large, covered glass dishes. Inoculations of the coccus alone at room temperature developed spots about a millimeter in diameter in from two to three weeks, then increased very slowly. In about five to six weeks reddening developed, usually at places on the fish other than the points of inoculation, and after this the fish reddened fairly rapidly.

Fish inoculated with the bacillus developed clear, jelly-like colonies from one-half to one and a half millimeters in diameter in from two to three weeks. Sometimes growth would cease, or there might be a slight development. Then, as with the fish inoculated with the coccus, reddening developed, usually on other parts, and proceeded in a similar manner.

When the coccus and bacillus were used together, at first there developed a colony having a red center and a clear, jelly-like envelope, after which a general reddening developed, sometimes at the point of inoculation, sometimes at other points.

Development from inoculation with the mold was very uncertain. On some of the fish many small white dry-looking colonies formed; on other pieces no development took place. The time of development was practically the same as for the coccus and bacillus.

MICROSCOPIC EXAMINATION.

Examination of the early stage of the reddening when a small colony only had developed at the point of inoculation gave the coccus alone, or the coccus with but a few bacilli, and possibly a few of the oidia of the mold; as the reddening increased, however, the number of the bacilli and oidia increased. A similar condition was found when the bacilli were used for inoculation. The transparent colony consisted of the bacilli with many free spores. After reddening developed the coccus was always present, though the bacillus might predominate. The mold was usually present also.

The colonies of the mold, even in the early stages, nearly always had cocci and bacilli present.

The pieces of fish used for control in the foregoing tests remained free from reddening in most cases. In those in which reddening did occur the first appearance was from three to four weeks later than the general reddening on the inoculated pieces.

From the results of these tests it was decided that the pieces of fish were not sterile when inoculated and that the organisms must penetrate farther into the flesh than was supposed, in order to account for the presence of the organism or organisms not used in the inoculation and also the slower general reddening. A different method was then employed. The thickest pieces of fish obtainable were cut into pieces 2 to 3 inches square with a sterilized knife, used while hot, and were then sliced into halves, so as to get a new surface at the greatest

depth from the exposed surfaces of the fish. These pieces were then dipped into hot paraffin and placed in sterilized covered dishes. A portion of the paraffin about an inch square was removed from the surface with a sterilized knife, in order to afford a surface for inoculating.

There were five pieces inoculated with the coccus, five with the bacillus, five with the coccus and bacillus, and five uninoculated for check purposes. They were kept at about 20° C., and were slow in developing. In thirty-four days the surfaces of those inoculated with the coccus were covered with thin pink streaks. Two of those inoculated with the bacillus had a small transparent colony at the point of inoculation, one had pink streaks, and two had no development. Those inoculated with the coccus and bacillus had reddened. The checks remained sterile. In fifty-six days there was an increase in the amount of reddening in the pieces inoculated with the coccus. The red growth was viscous, and composed of a mass of cocci embedded in mucus, with a few rods of varying short lengths and a few free spores. The transparent colonies on two of those inoculated with the bacillus were not distinguishable from the rest of the fish, but the pink on the streaked piece had increased, it was viscous, and the organisms were in the same proportion as in the coccus-inoculated pieces which it resembled. Those inoculated with the coccus and bacillus had a slightly more pronounced development than those inoculated with the coccus alone, and the organisms were in the same proportion. One of the check pieces had commenced to redden. In this piece the cocci were the predominating organism, but there were more free spores of the bacilli than in the other pieces. The mold was absent from all.

This set of tests was more satisfactory, as a more nearly sterile condition of the fish was obtained, though the results indicate that some of the pieces were not sterile when inoculated. It seems to be evident, however, from this and the preceding tests that the coccus is the organism which produces the reddening. The coccus predominated in all, in some only a very few bacilli being present. Also the coccus when isolated and grown on artificial media produces not only the red color, but also the characteristic viscosity. These tests proved conclusively that the mold is not necessary for the production of either the reddening or the foul odor, as these pieces had both characteristics, but no mold.

INVOLVEMENT OF TISSUES BY INFECTION.

Examination of sections of the fish show that the bacterial infection is upon the surface, that the muscular bundles are not penetrated, but that there may be penetration of the intramuscular connective tissue to some depth. In all cases, however, in which th

bacteria were found very deep in the tissue, it seemed probable that the entrance was gained by breaks in the tissue due to handling. Where the tissue remained firm and penetration depended wholly upon invasion of the connective tissue, few organisms were found and these were only short distances from the surface. Fish which become very red show only surface involvement except in open fissures. These fissures are produced very easily in the salted fish, and infection takes place so readily that there is difficulty in securing sterile pieces, even though the surface is removed with a sterile knife. The effect of the microorganisms upon the muscular bundles is to produce a softening and crumbling of the side involved.

The mold is also a surface-growing organism. It produces slight depressions or pits at the points of attack. The filaments do not penetrate the muscular bundles, but do follow the interconnective tissue for short distances.

PATHOGENESIS.

In the studies thus far made upon the red cod no pathogenic property has been ascribed to the organisms except when they become mixed with other organisms which cause decomposition. It is reliably stated that employees at the factory prefer the fish which have just started to redden, much as some people prefer beef which has been held in cold storage until it has "furred," or a Virginia ham until it has "aged." Before the advent of the fish cake it was the custom to hang the whole dried fish in a shed until used, and the presence of a little reddening was not looked upon as in any way deleterious. Reddening may be considered as a warning that other organisms may find entrance and thereafter cause decomposition.

OTHER ORGANISMS.

In the plate cultures made from the red spots and the mold there were usually other organisms developed, but these were not constant. The pink yeast, *S. glutinis*, occurred a few times, red colonies of bacteria occasionally, and a bacterium which produced yellow colonies quite often. Other forms which are common in the air were often present. The fish itself sometimes has a decidedly green tint, but the juice expressed from the flesh thus colored was nearly free from organisms, other than the occasional ones always found, which were on the surface; this would indicate that the coloring must be due to other than bacterial causes.

Specimens of reddening were obtained from the marshes in the vicinity of Gloucester and along the coast as far as Lynn. The lower part of the marsh grass in places had a decidedly reddish or purplish red color, due to an adherent slimy material. This was

composed of irregular masses of a clear matrix containing refractive red granules. The granules occur singly, in pairs, and in tetrads, but oftener without definite number, and in them is the red pigment. Masses were present containing much larger nonrefractive bodies, which were not so red as the refractive granules. From cultures it was found that this organism was not identical with that on reddened fish, and therefore this source of infection has not the importance previously ascribed to it.

DISCUSSION OF BACTERIOLOGICAL RESULTS.

Some of the results of the work seem to be at variance with those obtained by Dantec. He states that the first stage of reddening is nonviscous. This appears to be the case when the growth is examined on the fish and without testing the material in a liquid. He states that the red mucus can be readily removed in the first stage, leaving the fish healthy. This can be done also to cod which have reached what he calls the second stage. Tablets of cod which had been sealed in cans were taken out and kept in a moist warm place until they were very red, coated with a thick viscous layer, and possessed of a foul odor. The red was scraped off and the flesh beneath had a firm, white, healthy appearance. This, however, is not always the case, as the flesh beneath the red will often crumble more or less when the scraping is done; fish of this character are actually putrid throughout, due no doubt to organisms other than those which are found in the reddening.

The bacillus produced no reddening on any medium, except the pink color produced in bread paste. Dantec states that on gelatin plates the colonies look like those of the coccus. This is at variance with the results obtained, as the bacillus produced no color, and the gelatin was liquefied, so that at no stage were they at all alike. In attempting to separate the organisms in the manner he describes, by heating for one minute at 95° C., the bacillus failed to develop. There were a few red colonies which were much retarded in development, but the mold developed many more colonies than on the regular plate culture.

The organism which Dantec calls an alga is without doubt the brown mold, and the brown color in the conidia and conidiophores might be easily mistaken for the green pigment which he mentions, as only the younger conidia were examined. Dantec regretted his inability to obtain pure cultures, but it is probable that they were pure, though he did not connect the two stages of growth. He states also that the fish used in his experiments were "almost free from organisms," which expresses the condition used in these experiments, except for some of the pieces dipped in hot paraffin which were sterile.

No attempt has been made to name the organisms found on the red cod, as the early descriptions are so meager that it is impossible to decide as to their identity with those described later. Doctor Farlow, in a recent communication to the writer, states that when the *Clathrocystis* is young or when it breaks up it might be considered a coccoid form, but that the perfect stage is reticulate or clathrate. He does not agree with the views of Zopf as to its polymorphism, or that *Clathrocystis roseo-persicina* is a stage of *Beggiatoa roseo-persicina* or even a *Beggiatoa* at all. There is no question as to the identity of the brown mold with the *Oidium morrhuæ*, as the illustration which Farlow has given in his paper and his description coincide with the condition of the mold when grown on fish. He states that he has no doubt that the *Oidium* is identical with the older *Torula epizoa* Corda, sometimes called var. *murina* or *morina*, which occurs on salted meats, as he has compared his form with the *T. epizoa* and they appear to be identical. To the writer the name *Oidium* seems to be the proper one, leaving out of account the question of priority, as the morphology does not agree with that of *Torulæ* as now understood.

The further the bacteriological work on the cause of reddening of salt fish is carried the stronger the evidence becomes that it is due to factory infection, to the use of contaminated water, and to the methods of handling. The outside influences, particularly the germs found in the lowlands and in the vicinity of the factory, have probably been greatly overestimated. The amount of infection due to the use of solar salt has not been definitely determined, as in the experiments intended for that purpose the amount due to factory infection was not wholly eliminated. What at the beginning appeared to be primarily a problem of how to avoid spoilage in an infected product by preventing the growth of the organisms present now appears to consist rather in the usual difficulty of preventing infection.

RECOMMENDATIONS FOR THE PREVENTION OF FACTORY INFECTION.

1. The fish should be handled from the vessel to the scales without being thrown upon the deck or dock where they may become infected from the boards or be stepped upon by the workmen. All of the docks are infected with the red organisms, and fish coming in contact with them become inoculated.

2. The floors, scales, dressing tables, wash tanks, wheelbarrows, and everything with which the fish come in contact in making them ready for the butts should be frequently washed with water under considerable pressure. A relatively small stream of water under strong pressure is far more effectual in cleaning than a larger stream of water at low pressure.

3. The fish should be washed by sprays of water or by a machine. The sprays should have sufficient force to do the work well. The present method of pitching the fish into a tank or dory and then out again is not sufficient for cleaning, and, furthermore, it tends to disseminate any organisms which may be present.

4. The water used upon the fish or upon anything with which the fish come in contact should be of undoubted purity. The use of harbor water for any purpose can not be justified, as it is filled with the germs which come from emptying the butts and washing fish and docks. It is also apt to be polluted with sewage from the city, as was found to be the case in the investigation here reported.

5. The butts should be thoroughly cleaned inside and out and steamed for twenty minutes or sprayed with a solution of sulphurous acid.

6. Before fish are taken out of the butts water should be turned in to cause the brine to overflow and wash away any reddening which may have occurred on the top.

7. The fish should be passed through a spray of water to remove the adherent salt, as this adds weight and does not increase the time of keeping.

8. Racks used in waterhorsing should be steamed or sprayed, and the work be done in the light and in one place in the factory rather than at any point in the shed where the butt may happen to be.

9. The drying should be carried as far as possible and still permit proper skinning. A second drying, or Nova Scotia style of cure, should be encouraged.

10. The kenching in the storeroom should permit a circulation of air and not cause dead air spaces. The kench racks should be steamed or sprayed after each period of use.

11. The walls, posts, and floors should be sprayed often, once a week during the cool season and twice a week during the summer.

12. Treading the fish in drums should be prohibited. Workingmen coming in from the street in their dirty shoes obviously should not be allowed to tread the fish in the packing operation. A mechanical appliance would accomplish the same purpose in a cleanly manner.

13. The boxes used in carrying the fish from the storeroom to the skinning loft and from the tables to the cutters and packers should be washed each day.

14. The skinning or cutting tables should not have shelves or boxes beneath to catch bits of skin or fish. They should be well washed each evening. The simple brushing with a hand broom is not sufficient. The floor should be cleaned often.

15. All refuse should be removed from the room promptly. Bits of fish in barrels and boxes act only as incubators to perpetuate the infection.

16. The finished product should be held in a reasonably cool place in summer, and when shipped it should be handled under proper temperature conditions as are other meat products.

17. All new construction or remodeling should make ample provision for light. Many of the present structures are too dark.

18. All rubbish, as barrels, hoops, staves, waste, etc., should be removed from the flake yards and docks.

19. Concentrated sulphurous acid should be used as a disinfectant when steam is not available. One part of the acid to 50 parts of water is effectual where much reddening has occurred, and 1 part to 200 parts of water will be effective in preventing growth if used often.

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