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THE DRIED CODFISH INDUSTRY

BY

Dr. N. L. MACPHERSON

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THE DRIED CODFISH INDUSTRY

I. DESCRIPTION

THROUGHOUT the whole history of Newfoundland right down to the present day, the method of preservation of the large supplies of cod for storage, shipment, and distribution to the consuming markets of the world has consisted of salting and drying. Now all dried codfish are not the result of the same amount of salting and the same intensity of drying. In the beginning the local conditions of the locality of fishing dictated different procedures in the methods. For example, the Labrador fishery cannot be prolonged beyond a certain time of year, owing to unsettled weather conditions, and it is not very suitable to remain on the land in Labrador to dry the fish. Sea conditions become adverse in the fall, and shipment of the finished product becomes impossible owing to the icy conditions. A very few elected to live on the coast; they were called the "liviers," who later became comparatively poverty-striken and dependent on a charitable organization.

The great majority, however, merely remained temporarily on the shore, "stationers" or planters, or anchored in the schooners, "floaters," to pull out for the south as the weather got worse, in order to finish the curing of the fish in the northern bays of Newfoundland itself. This delay in getting the drying of the fish commenced necessitated the use of a greater quantity of salt to prevent deterioration of the fish. Thus conditions dictated methods. In the same way the bank fishery, commencing in the early spring, demanded the use of a fairly large amount of salt, because, in this case, there might be delays in getting back to land, and, further, the spring weather might not be entirely suitable for drying. On the other hand, in the case of the inshore fishery of the Island itself, where the catch could be dried after a short time in salt, light salting became the recognised method. It is interesting to remark that the introduction of the trap methods of fishing, bringing with it large catches which could not readily be handled speedily, probably affected the quality of the "shore cure," as the light salted method is called, inasmuch as it would have been necessary to employ large numbers of men to handle the large quantities as speedily as possible. This was probably not done, and the result was either to salt heavier or to get spoilage—a deterioration of quality in both cases. Thus the type of cure produced grew out of the exigencies of the local conditions.

The various types of product, each with its varying degree of perfection, were offered in the markets of the world, and gradually a demand was created for one particular type. Southern Spain showed a preference for light salted thick fish from the shore cure variety, and to-day is still prepared to pay in order to get it. Italy began to prefer a medium sized, fairly thin, light salted shore cure fish. Both countries, of course, made a certain demand for the heavy salted Labrador cure. The important point to be made is this, the fishermen of the early times, when leaving for Newfoundland, did not have an order for fish of a certain type from certain places. What happened was that they offered several varieties and each market selected what its consumers preferred. This point has a bearing upon the possibility of establishing new standards and new markets, and will be discussed later.

In discussing the different types of cure and the amounts of salt used, it is necessary first to give a general description of the actual process of curing.

Light Salted Fish

By far the greater part of the codfish catch of Newfoundland is "light salted." The idea behind the production of these lightly salted fish is this : the fish have not to lie long in salt bulk, and it is intended, and very necessary, that they should subsequently be dried to a low water content. This type of preservation gives a valuable product, and at the same time one which requires great care in the process of making because it is so perishable. Of all the salt fish types the light salted shore cure reverts back nearest to the original. When soaked in water it takes up a greater percentage of water than does the heavier salted article. It is the method suitable to the inshore fishery of the Island of Newfoundland, the prosecution of which is conducted almost entirely from land premises. The minimum amount of "light" salt used is about one hogshead per ten quintals. We shall see presently that the hogshead measure is a very unsatisfactory one, but it has been, and still is, the customary measure for salt in Newfoundland. The line fisherman working on a small scale may only leave his fish in salt bulk for ten days or a fortnight, and one hogshead per ten quintals suffices to delay decomposition for this short period until he commences drying. The trap fisherman, on the other hand, working on a larger scale, has to leave his fish in salt bulk for from four to eight weeks. He, therefore, uses around one hogshead of "light" salt to eight quintals of fish. The amount of salt, therefore, used for shore cure fish lies within the limits of one hogshead per ten quintals and one hogshead per eight quintals. Instances have been reported of the use of much less quantities, but inferior quality is bound to have resulted. Salts vary in weight from about 3·3 to 4·25 hogsheads per ton. The quantities given are for a light salt such as Cadiz. Unfortunately, the fishermen do not know how to apply proportionately a heavier salt, and only do so by guess work. The final shore cure product aimed at has an even and clean surface, free of blood spots at nape, and sound bone, perfectly split, with no salt showing on the face, and having no sour or tainted odour. The necessary conditions for the production of this product are (1) careful splitting and washing; (2) efficient salting; (3) thorough washing from salt bulk; (4) careful handling and "working" on the flakes; and (5) good drying conditions. By good drying conditions is meant a continuous process of drying uninterrupted by adverse weather conditions.

Heavy Salted Fish

Heavy salting is the method employed when the fish have to be kept a relatively long period in salt bulk. Originally the method was used for Labrador fish where the time available for the subsequnt period of drying was restricted. More water is removed by the use of salt and less by drying than in the case of the light salted cure. Roughly sixteen hogsheads of salt are used for one hundred quintals of fish, or, on the same standard as above, one hogshead of salt per six and one quarter quintals of fish. Subsequent drying is of shorter duration than for shore cured fish.

Intermediate Amounts of Salting

These two types of cure are the broad divisions into which the catch may be divided. There are degrees of salting intermediate between these divisions, and in the Straits of Belle Isle one hogshead of salt is used for from seven to eight quintals. Fish caught by the banking schooners are salted with one hogshead of salt to from six and one half to seven and one half quintals. The banks fish are, therefore, treated in a way almost intermediate between Straits cure and Labrador cure.

It is important to remark that fish caught on the Island of Newfoundland littoral proper are thicker fish than the thin Labrador fish, and that heavy salting of these fish does not produce the same product as Labrador cure.

The essentials of satisfactory production of the heavy-salted and medium-salted products are the same as for the lightly-salted product. It is not surprising that it is very difficult to obtain reliable information as to these salting methods. This is probably the first attempt at systematising the rule-of-thumb methods, and, as is usual amongst operators working under such methods, no fixed amount of salt is used in one type of fishery. In the Labrador fishery, for example, one operator may use as many as seventeen hogsheads of salt per hundred qunitals and whilst the resulting products may not be radically different, it is unfortunate that the newcomers to the industry cannot be given a definite figure. Another important differentiation has to be made. While the total amount of salt used may be one figure, the actual amount put on the fish may be appreciably different. Thus, information was obtained from a reliable source that, in the bank fishery, a schooner catching 1,200 quintals of fish would account for 200 hogsheads of salt. Whilst this figure appears to give a salt usage of one hogshead per six quintals, the salt actually in contact with the fish probably amounts to one hogshead per seven quintals. Again, a schooner working on Labrador caught about 1,875 quintals and accounted for 310 hogsheads of salt. This also works out to one hogshead per six quintals actually used, but probably the effective salting might have been not sixteen and one quarter hogsheads per hundred quintals, but around fifteen and three quarters. It is interesting to note at this stage that a high price of salt is likely to encourage its economical use, usually with bad effects. Recently a communication to the local press advocated the use of eighteen hogsheads of salt per one hundred quintals for Labrador cure. While it is distinctly possible that this amount is necessary, the point that stands out so clearly is the obviously conflicting opinions as to the correct amount.

It should be pointed out that, in talking of quintals of fish, the quantity means one quintal of the finished dried codfish. It is thus apparent that the salter has to judge not only the amount of salt to use, but also the amount of dried fish which the green fish will probably produce. Alternately, he has to judge the amount put on one fish according to its size. Such a degree of skill can only be acquired by long practice, and apprenticeship to such an occupation ought to be of long duration, involving clear instruction to the youthful pupil from the experienced operator. It is doubtful if this thorough apprenticeship prevails, and this state of affairs can be fixed upon as one very weak link in the chain of curing operations.

Amounts of Salt Necessary

The different types of salting may now be summarised. It must be understood that this is merely an attempt at recording the amount of salt which is used.

Fishery.	Type of Salting.	Quintals of Fish salted with 1 Hogshead of Salt.
Labrador	Heavy ..	6¼—6¾
Grand Bank .. .. .. Straits of Belle Isle	— .. Medium ..	6½—7½ 7—8
Inshore	Light ..	8—10

It cannot be too strongly emphasised that the method of preservation of codfish by salting and drying is, as will be explained below, essentially a removal of water. The ideal preservation would be that method which, while ensuring durability of the product by removal of sufficient water for that purpose, gave a product capable of reverting to the original or, in other words, capable of taking up the water which has been removed. This ideal reversibility is never attained, but light-salted shore-cure fish have a greater degree of reversibility than the heavier salted fish.

Market Categories

The products of the various fisheries are collected by the exporting business concerns, who ultimately select the fish to suit the requirements of their customers in the various countries. Not so many years ago fish were bought from the fisherman on the talqual basis. Briefly the method was this: The fisherman brought his fish to the buyer. He was generally limited to the man who supplied him on credit with his necessary outfit for the fishing season. This buyer had given that credit conditionally, not upon the fisherman paying his debt off the proceeds of his catch, but upon the fisherman selling his catch to the buyer. The buyer made a cursory inspection of the fish and declared a flat rate of so much per quintal for the lot. Nowadays there still exists in many cases the limitation as to whom the fisherman may take his fish for sale, but there is at least an attempt at a classification of sorts. There has been a change in the culling classification since 1932, but we must first consider the position of the industry at that time.

In the case of the shore cure the fish were graded into :—

(1) Merchantable ;
(2) Madeira ;
(3) Cullage.

The main distinction was between merchantable and cullage. The distinction was essentially a visual distinction. Into the cullage class were put inferior or spoiled fish, i.e. fish which were broken, slimy, or appeared to have too much salt ; also damp or insufficiently dried fish, and all fish which, because they would not sell in other markets, were shipped to the West Indian markets. The merchantable class comprised large and small fish of the best quality. They were well-cured, sound fish, with an even surface, free of blood spots at nape, and sound bone (presence of these blood spots did not always condemn the fish), perfectly split, with no salt showing on the face and having the characteristic yellow tinge. The Madeira class of fish was composed of those fish, which, whilst not up to the standard of merchantable fish, were obviously better than cullage. They were large and small fish which had, on the whole, a darker colour than the merchantable.

For the most part then, so far as the fishermen were concerned, these three were the usual classifications. Occasionally the buyer differentiated Spanish fish from the merchantable, paying more for this article, but the practice was not general.

The types of cure could be tabulated thus :

Heavy-Salted Labrador Cure : Large. Sometimes No. 1 and No. 2
Small. Sometimes No. 1 and No. 2.
Cullage.

Light and Medium Salted Shore Cure : Large Merchantable,
Small Merchantable,
Large Madeira,
Small Madeira,
Large West Indies,
Small West Indies.

After collection from the fishermen, and prior to export, the fish were culled into categories suitable to the various markets of the particular exporter. These subdivisions were largely of an arbitrary nature. Thus the thick fish necessary for the Spanish market could be divided into two or more grades. Hard-dried fish went to the Brazilian market. In each case there might or might not be more than one grade, and one exporter's second grade might, indeed, rival another exporter's first grade. The unusual amount of *laissez-faire* militated against a uniform quality being maintained in any one market, and this reacted to the detriment of the industry. It was said that there were at least twenty-three types of dried codfish exported from Newfoundland, and there are about eleven countries consuming these exports. The producing fishermen do not set themselves to cure fish in twenty-three different ways. They set themselves to cure fish by salting it and drying it all in the same way, and it is very evident that the standards ought to be set by the nature of the fish and by the degree of perfection attained in the curing, and not by the number of markets.

More recently regulations have been made laying down the following standards on which codfish must be purchased or sold.

Shore Codfish and Bank Codfish

(*a*) *Choice* (*or Number One*) *Spanish.*

Sound quality codfish, extra thick, light amber colour, even surface, thoroughly clean on both back and face, not showing blood stains, clots, liver, or gut ; well split, and not showing excessive salt on the face.

(*b*) *Prime* (*or Number Two*) *Spanish.*

Sound quality codfish, fair thickness, even surface, thoroughly clean on both back and face ; not showing excessive blood stains, clots, liver, or gut ; well split, and not showing excessive salt on the face.

(*c*) *Merchantable.*

Sound quality codfish, even surface, thoroughly clean on both back and face ; not showing salt on face ; well split, and not showing excessive blood stains, clots, liver, or gut.

(*d*) *Madeira.*

Any codfish not passing as choice prime or merchantable, rough in appearance but not oversalted, broken, sunburnt, slimy, dun, or otherwise defective.

(*e*) *West India.*

Codfish that is broken, sunburnt, slimy, dun, or oversalted or otherwise defective.

All Shore or Bank Codfish, to be classed as grades (*c*), (*d*), or (*e*), must be thoroughly Hard Dried. Fish otherwise of the description of fish of these grades, but not thoroughly dried, shall be classed as Damp Merchantable, Damp Madeira, or Damp West India, as the case may be.

All codfish caught on Labrador or in the Straits, and cured according to the requirements for Shore Cure Codfish, shall be described as Labrador Shore Cure Codfish or Straits Shore Cure Codfish, as the case may be. Such fish shall come under the same standards of cull as these applying to Shore Codfish and Bank Codfish.

The classification of sizes for all Shore and/or Bank Codfish, for local sale, must be as follows :—

(*a*) Tom-cods.	Codfish, not under eight inches and up to and including 11 inches in length.
(*b*) Small.	Codfish measuring over 11 inches and up to and including 18 inches in length.
(*c*) Medium.	Codfish over 18 inches and up to and including 20 inches in length.
(*d*) Large.	Codfish over 20 inches in length.

Genuine Labrador (Soft Cure) Codfish

The term "Genuine Labrador (Soft Cure) Codfish" shall be applied only to fish caught at and north of Blanc Sablon, off the coast of Labrador, and cured according to the following standards :—

(*a*) *Choice* (*or Number One*).

Sound quality, well split, thoroughly clean ; must show no excessive blood stains, clots, liver, or gut ; must be thoroughly salted and firm ; if not quite white on the face ; must have a clean, clear, even surface.

(*b*) *Prime* (*or Number Two*).

Badly split fish, extremely thin fish, and fish showing excessive blood or liver clots ; uneven surface, but in other respects similar to No. One.

(*c*) *Cullage.*

All fish not up to standard of Number One.

All Genuine Labrador (Soft Cure) Codfish shall be dried sufficiently to stand export shipment without loss of weight.

Heavy Salted (Soft Cure) Newfoundland Codfish

Codfish caught off the shore of the Island of Newfoundland, or codfish caught off the shores of Labrador south of Blanc Sablon, cured in Labrador style, shall be known as Heavy Salted Soft Cure Newfoundland Codfish, and shall be purchased or sold only as such.

Heavy Salted, Soft Cure Newfoundland Codfish are to be culled under the same standards as those applied to Genuine Labrador (Soft Cure) Codfish.

Salt Bulk or Wet Salted Fish.

(*a*) *Number One Wet-Salted.*

Sound quality, well split, must show no excessive blood stains, clots, liver, or gut ; must be thoroughly salted and firm ; must have a clear, even surface.

(*b*) *Number Two Wet-Salted.*

Badly split fish and fish showing excessive blood stains, clots, liver, or gut ; uneven surface, but in other respects similar to Number One.

(*c*) *Wet-Salted Cullage.*

All fish not up to the standard of Number Two.

Washed and Pressed Fish

The Standards for Grading "Washed-and-Pressed" shall be the same as those applied to Genuine Labrador (Soft Cure) Codfish.

When codfish is to be exported as "Washed-and-Pressed," the fish must be washed perfectly clean from Salt-Bulk and then pressed well to remove all surplus moisture before being graded.

II. THE INDUSTRY'S DIFFICULTIES: LOST MARKETS

Passing now to the difficulties of the industry—what are those difficulties, what are their causes and how can they be overcome ? The industry is losing sales in what are at least stationary, if not expanding, markets. This unfortunate state of affairs cannot be too strongly emphasised and some particulars must be given to illustrate the position. The decrease in sales is most alarming in the case of the Labrador cure, but it is not confined to that branch of the industry alone. There is an evident demand for high quality shore-cure fish which cannot be filled. In any case, the Labrador cod industry is merely a branch of the same system of production, entailing a difference in the method of salting. The cod are the same species as the inshore cod, with a variation in the skin pigment and in the feeding conditions. The ultimate chemical analyses of the tissue is for all practical purposes identical with that of the tissue of fish caught on the Newfoundland littoral, so that the principle of preservation is identical. It must be realised that the amount of salt used, as also the " thinness" of the fish, are the only factors which produce a cure different from the shore cure. There is, therefore, no necessity for considering the codfish industry of this country under two headings, any more than it is necessary to discuss Spanish fish and Italian fish under separate headings.

The following particulars of the codfish exports are taken from the Annual Report for 1932 of the Newfoundland Board of Trade.

NEWFOUNDLAND.[1]

Year.	Total Exports in Quintals.	Exports to West Indies in Quintals.	Percentage West Indies to Total.
1907	1,442,000	85,000	5·9
1928	1,380,000	160,000	11·6
1931	1,035,000	265,000	25·6
1932 (estimated)	1,092,000	270,000	24·7

Since the West Indies is the dumping ground for inferior fish, it is argued in this report that these figues should make it clear to everybody that the average standard of cure is getting worse. Actually this argument is insufficient, in that no regard is paid to the consumption in other markets. There is ample evidence that the standard of cure has not been becoming progressively inferior. A few excerpts from records will indicate how erroneous is the assumption that it is only to-day that the problem of inferior cure has existed.

Board of Trade Report, 1932.

"As everybody in the business is aware, the fishermen are producing more West India fish these years than twenty years ago."

Report of the Commission on Fishery Matters, 1915.

" Resolved : The deterioration in the cure of Newfoundland codfish, so noticeable in recent years, is one of the most serious factors—if not

[1] The production of dried codfish in Newfoundland has varied from one to one and a half million quintals since 1876, or as far back as figures are available.

the most serious factor—in the commercial life of the colony to-day. The effect upon the production and value of the Labrador fishery is already lamentable in the extreme."

Annual Report of the Newfoundland Department of Fisheries, 1894.

"The result has been that little or no improvement in the cure has taken place and that a good deal of our fish has been consumed by and sold at a low figure to the poorest class of people, or has been held over until the superior fish of our foreign competitors has been disposed of....".

It is also pertinent to compare the reasons given in 1894 and in 1932 for this inferior type of cure.

Annual Report, Department of Fisheries, 1894.

After discussing the large quantity of badly-split, badly-washed, and badly-salted fish, the report goes on: "We find further that a great part of our fish, after being salted and washed, is handled and made on the flakes by children and by women who, in many cases, have not the requisite knowledge of this work, have no idea whatever of the requirements of the various foreign markets, have large families, gardens, . . . and who, therefore, cannot spare the time to attend to this part of the cure as it should be done."

Board of Trade Report, 1932.

"The fishermen's families do not work at making fish the same as they did in the old days, and, therefore, the fish, while being cured, do not receive the proper care and attention."

There is ample evidence of a similar nature to show that the inferior fish were always a source of worry. The conflicting opinions indicate a failure to appreciate the real reason for narrowing markets and prices lower than those received by competitors. All the evidence points to the fact that the standards of the Newfoundland cure are not getting worse, but are remaining stationary while more and better standardised supplies are being produced elsewhere. This fact is borne out by a consideration of the production of cod in Iceland, where, since the War years, there has been an increase in production of one million quintals. This increase has found an outlet largely in the Newfoundland–Labrador markets.

ICELAND.

Year.	Production of Cod in Quintals of Dried Fish.
1907	300,000
1919	500,000
1929	1,300,000
1930	1,500,000

The figures are calculated roughly from the accurate statistics given by the International (European) Council for the Exploration of the Sea. The number of kilograms of fish landed are given ; taking one kilogram equal to 2 lbs. and one quintal as 112 lbs., the number of kilograms divided by 56 gives the number of quintals of green fish. Division by 3 gives approximately the final figures for dried-fish production. Actually not all of these dried codfish are cured in Iceland, since some of the catch is exported in salt bulk. The figures are, however, relatively sufficient for present purposes.

Writing in January, 1933, an important Greek business in Patras says : "Newfoundland–Labrador : We regret to report that, on account of the poor quality, the Newfoundland–Labrador is a drag on the market. The consumption of this commodity has been decreased by 60 per cent in comparison with last year's. Iceland fish is now selling freely over Greece at Drachms 19 per boka. This price is 4s. over and above the retail price of Newfoundland–Labrador. In spite of the low selling price for Newfoundland–Labrador, there is no demand for same. The Greek population is now accustomed to the Iceland fish because this fish is very clean and white in appearance, sound, and of uniform quality. On account of these latter facts, it is very difficult to sell Newfoundland Labrador except in small quantities at cheap prices."

Notice that the Greek population has become accustomed to the Icelandic product, and that, too, in the short space of five years, since previously Icelandic fish were unknown to Greece. The implication is that formerly the fish were not clean and white, indicating no previous superiority of Newfoundland fish over the present-day article. The letter finishes : " . . . about 40,000 bales of Iceland cure fish has been sold to Greece during the last two months as against 7,000 quintals of Newfoundland Labrador. If no improvement is made for next season, we fear that Greece is going to forget all about the Newfoundland."

A similar state of affairs has occurred in Genoa and Leghorn, from the markets of which Newfoundland has been almost completely driven out by the Icelandic product, superior in the eyes of the consumer, with whom it is useless to argue. Again, at Barcelona, Iceland finds a market for 100,000 quintals without a rival and at her own price. As long ago as 1894 Newfoundland products were fetching in Genoa prices considerably below those obtained by Norway and Iceland. Thus, on 26th November, 1894, "from the large quantity of fish imported from Norway, the stock only amounted to 50,000 kgs. Norwegian as against 400,000 kgs. Icelandic fish, and 500,000 kgs. Newfoundland and Labrador fish ; and further, the Norwegian fish sold readily at 55 lira, the Icelandic at from 54 to 56 lira, while our fish could only be slowly disposed of at a price ranging from 48 to 50 lira, all per 100 kilograms."

Sufficient has been said to illustrate the problem with which the industry is faced. It is not a question of competing with lower-priced products, produced at the expense of a lower standard of living. The consumers will pay a higher price, and there is a greater demand for a product of a quality superior to, or more reliable than, the Newfoundland product. The competition is becoming more one-sided as time goes on, and goes against Newfoundland. It is only recently that this has become alarmingly apparent.

During the past two years there has been a falling off in the number of complaints concerning quality. The argument is sometimes put forward that the improvement has been due to the fishermen taking greater care, but later it will be shown in discussing drying conditions that the intermittent complaints as to deterioration can probably be best accounted for as coinciding with wet seasons. So long as satisfactory means for artificial drying are not available, sooner or later a wet season will catch the industry napping.

Before discussing the technical aspects of the industry in detail, it will be instructive and useful to set out some particulars concerning preservation of tissue products generally, with special reference to the action of salt.

III. THE SPOILAGE OF PROTEIN OR FLESH FOOD PRODUCTS

After the death of a fish or an animal, the tissue or flesh soon starts to "go bad." This means that changes from the condition of the living tissue begin to become evident. These changes involve the breakdown of the complex chemical substances of the tissues into simpler chemical substances, accompanied in the later stages of breakdown by the evolution of evil smelling gases. This breakdown or decomposition of living tissue after death is brought about by *two distinct agencies. Bacterial decomposition* is one, and *autolytic decomposition or autolysis* is the other. Autolytic decomposition aids bacterial decomposition, which latter is the process of putrefaction.

Bacterial decomposition is the decomposition which is brought about by microscopic living things called bacteria. Bacteria live by sending out substances from themselves to produce their food just as human beings send out gastric juices to select and prepare their necessary food from what they eat. These bacteria are present on the tissue food product mostly as a result of contamination from outside sources, from he air, from already decaying matter, and from dirt of any kind, and they live and grow and multiply at the expense of the complex substances of the tissues, breaking them down and producing the substances of evil odour characteristic of decay. Because bacteria get into the product from outside sources mostly, and because they are to be found in any kind of dirty matter, and because their activity is half the cause of decomposition, it is very obvious that half the battle of successful preservation will be won if great care is taken to keep the product thoroughly clean and free from contact with dirt of any kind. This factor of bacterial decomposition cannot be too much emphasised, for, when it is understood, there is no excuse for any person failing to safeguard against it.

Since bacteria inhabit the air, and since they will undoubtedly get on the product in minute quantities despite every precaution, there is never any limit to the amount of cleanliness required. No time spent in ensuring a scrupulously clean protein food product is ever wasted. The more cleanly the methods, the less will be the contamination of the product with bacteria, and consequently the less the extent of possible bacterial decomposition.

The second agency at work in the destruction of the nature of living tissue after death does not arise from outside the product, but is the result of internal factors, uncontrolled and let loose as a result of death. Living tissue contains numerous substances called enzymes, whose purpose it is to control the supply and demand of the substances necessary for the correct working of the tissues. They can break down or build up complex substances as required. It is enzymes which prepare the food for bacteria just as it is enzymes in the gastric juices which prepare or digest the food for human beings. *Autolysis* of tissue is self digestion of the tissue brought about by the enzymes making merry, as it were, after the stoppage by death of nervous control. A certain degree of autolysis is often harmless and even desirous in that it produces flavouring or priming, but, eventually, it gives rise to substances with undesirable and so-called fishy smells. In addition, autolysis makes matters easier for bacteria, supplying them with their food ready made. For these reasons autolysis must be fought. The rate of autolysis is greatly *increased by warmth and decreased by cold*; bruising and crushing increase the rate, so that it is essential to avoid rough handling of the product. The two factors, then, which lead to the decomposition of protein food stuffs are bacterial action, resulting from infection largely from external sources, and self digestion or autolysis, by tissue enzymes within the tissue structure.

Preservation

There are two fundamental principles in the methods which can be used to prevent spoilage of protein foods. First, there is the *prevention* *of bacterial and enzyme action*; that is to say, conditions may be so arranged that these influences cannot function. Lowering of temperature, altering the acidity, or reducing the water content are three distinct methods available for this purpose. The first is exemplified by chilling, the second by pickling (pickling also reduces the water), and the third by drying and freezing. Because freezing solidifies the water of the tissue into ice, this method produces effects similar to drying, except that thawing-out of the frozen product replaces the water more effectively than soaking of the dried product.

The second method which can be employed for preservation is the *destruction of the bacteria and enzymes.* The usual methods employed are destruction by heat and by smoking. When a product is canned it is subjected to the action of heat to kill the bacteria and enzymes; this process is known as sterilisation, and it is the same principle the surgeon uses when he sterilises his instruments before an operation. The surgeon sterilises his instruments to prevent possible bacterial poisoning of the wounds, and surgery only became reliable when this principle became recognised. Preservation by canning is only reliable when sufficient heat sterilisation is given the product. Inside a can further contamination with bacteria is unlikely. Smoking is a much more temporary means of preservation.

Ideal Preservation

There is no doubt that the ideal method of preservation is that method which gives a final product capable of reverting to the original state of fresh material. In canning, the product is cooked fresh and kept in that condition, but the dried or forzen product has to be soaked or thawed: the ideal preservation in these latter cases would be accomplished if the final product, on soaking or on thawing, gave a product indistinguishable from the fresh. The protein material should be unchanged and there should be no loss of vitamins.

IV. METHODS OF PRESERVATION.

Drying and Smoking.

The simplest and oldest method of preserving tissue food material is by drying. The method was used by primitive peoples when, in a time of plenty, they desired to store the food against a time of scarcity. It is the method most suitable for hot, dry climates, but it was also used in temperate zones. It is possible that smoking of tissue products began accidentally in temperate zones: the use of the fire for drying in unfavourable weather probably resulted in the accidental production of a tasty smoked product (c.f. Beothuc Indians). Fish and venison were dried and smoked in early times and old records show arrangements for drying houses and smoking houses. The degree of preservation effected by smoking is small, and depends on the amount of drying and the disinfection of the surface of the product by the constituents of the smoke.

Salting and Drying.

Straight drying is so slow that considerable damage may be done before enough water is removed. In more advanced stages of civilisation, drying by heat alone is not, as a rule, used as a method of preservation. The abstraction of the water is, in the first stages, aided by the action of salt, either by dry salting or by brining ; subsequently, drying by sun action is used.

We have seen how it is necessary to prevent bacterial and enzyme action as one method of preservation. The withdrawal of water from the tissue can effect this since, in particular, enzymes require water solutions in which to function. We must, therefore, give some idea of how salt withdraws water.

In order to understand what is meant by the withdrawal of water from the tissues it is necessary to realise that animal or fish tissue is made up of microscopic units, called cells. Each cell is a separate and distinct unit, containing dissolved or suspended in water the chemical substances necessary for living processes. Roughly eighty per cent of the total weight of tissue is water. It has to be realised that this water is inside the cells. Each microscopic cell may be supposed to be surrounded by a membrane and, in order to prevent autolytic enzymes from working, the water inside the membrane must be withdrawn to the outside, away from the seat of chemical action. The water cannot be pressed out owing to the elastic nature of the cells, but it can be got outside by making use of salt and the properties of the cell membranes. Incidentally, the freezing of tissue removes the water from the seat of the chemical action by turning it into solid ice on the spot. The effect of salty food in producing thirst is an illustration of the removal of water from tissue cells by salt. The demand for water by the cells which have been dried up by salt results in the sensation called thirst. The process of removal of water through membranes by the action of salt is familiar to scientific people as an example of the principle of osmosis.

The Mechanism of the Extraction of Water by Salt.

Osmosis is an extremely important natural phenomenon found at work in all livng things, plant and animal. It is one of Nature's ingenious devices, and, for this reason, an explanation of it will be interesting. For a proper understanding of the effect of salt on fish a knowledge of the meaning of osmosis is essential.

Let us suppose we have a container divided into two compartments separated by a membrane. On each side of the membrane, in each compartment, that is, we have a solution of salt in water. We have at our disposal three different types of membrane. We can easily find a membrane that will not allow any intermixing of any of the substances, salt and water, on the two sides; such a membrane can be made, for example, with thin metal foil, and it is called an *impermeable membrane.* The solutions in each compartment separated by an impermeable membrane will remain exactly as we put them there. We can also use a fine silk membrane, but this kind of membrane will allow complete intermixing of these particular substances on either side; this kind of membrane is totally permeable. No matter what solutions we start with, in the end there will be the same amount of salt and the same amount of water in each compartment.

If we use an animal membrane we will find an extremely different behavior. If we start with the same concentration of salt in water on each side nothing will happen, but if one solution is stronger in salt than another there will be a flow of water from the side containing the weaker solution to the side having the stronger concentration. No salt will pass through the membrane but water will flow to the stronger solution until it is diluted down to the same strength as the weaker. There will be a difference in level between the surfaces of the water on the two sides; the compartment containing the more salt will contain the more water. This transfer of water towards the stronger salt solution is *osmosis*, and is due to the nature of the membrane. Wherever we come across a membrane exercising this selective action of allowing the liquid through and keeping back the dissolved solid, we are dealing with what is called a *semi-permeable membrane*, and we find osmosis possible.

The difference of level in the two compartments will give a measure of the osmotic force or pressure of the solution of stronger salt concentration. When the osmotic pressures of two solutions are equal nothing will happen at a membrane separating the two. When one solution has a greater osmotic pressure water will flow towards it, tending to dilute down its greater salt concentration, by virtue of which it has the greater osmotic pressure.

In considering the washing of fish we shall see that sea water is better than fresh water for washing, because fresh water softens the fish. This is a good example of osmosis. The explanation is that sea water has an osmotic pressure approximately equal to the osmotic pressure of the liquid of the fish cells, and no osmosis will occur. Fresh water, on the other hand, will tend to flow into the cells of the fish to dilute the salt of the cells ; the cells will swell, resulting in a softening of the fish.

It can now be understood how salt withdraws water from inside the tissue cells. The membranes of the cells act as semi-permeable membranes ; salt sprinkled on the fish immediately becomes wet, forming a strong salt solution of high osmotic pressure. Towards this solution water from the other side of the membrane will flow, tending to dilute it. If the cell membranes were ideally semi-permeable, that is to say, if the membranes allowed passage of water only, and absolutely kept back salt, then no salt would get inside the cells. The longer a fish, say, lies after death the more do the cell membranes lose their property of semi-permeability and the more salt will get inside the cells, and the more quickly. This explains why salt strikes through stale fish more quickly than through fresh fish. The necessity for preventing too much salt from getting inside by salting the fish as quickly as possible, will be seen on consideration of the impurities present in salt. An understanding of the principle of osmosis shows how both pickle salting and kench salting preserves fish tissue. *The essential action of salt is to withdraw water from the tissue cells, the seat of action of the chemical changes of autolysis or self-digestion.*

Pickling.

Pickling was one of the early methods of preserving food for long journeys and it can be done very cheaply. The idea behind this method is that raising the acidity inhibits the activity of enzymes and prevents bacterial and mould growth. In addition, brine pickle withdraws water from the flesh, and the surrounding fluid prevents, to a certain extent, contact with bacteria, as well as being an unsuitable medium for bacterial growth.

Chilling.

Chilling is that method of preservation in which the product is kept at a low temperature, cold enough to delay decomposition but not cold enough to freeze the article. Chilling is, of course, only satisfactory over a comparatively short period since, though the decomposition is delayed, it is not stopped and proceeds slowly, soon rendering the article unfit for food. The use of ice is an example of chilling ; its coldness slows down chemical and bacterial action, and, when the article is well packed, the ice helps to prevent any further bacterial action.

Freezing.

Freezing is equivalent to drying in that the water of the tissue is frozen solid, thereby preventing decomposition processes. The great advantage of this method lies in the fact that, on thawing, the water of tissue has a greater chance of being taken up, thus giving a product very like the original. Slow freezing leads to the formation of large ice crystals which tear and injure the texture of the tissue. The result is that, on thawing, a considerable quantity of drip results. On the other hand, rapid freezing turns the water of the tissue into very tiny crystals of ice and little damage is done to the texture. On thawing, there is much less drip than with the slowly frozen article. After freezing, the products can be kept for long periods if suitable storage temperatures are chosen and maintained.

The other important method is based upon the *destruction of bacteria and enzymes*. This is accomplished in the preservation method of canning.

Canning.

Bacteria and enzymes can be killed by the application of heat. This is the principle of sterilisation and is the method employed in canning. The can is prepared and sealed and thus, after sterilisation by heat, no further contamination can occur, and the product is preserved in the cooked state and will keep unchanged for long periods.

After this introductory resumé of preservation principles and methods, we can proceed to a more detailed discussion of the methods of the salt codfish industry.

V. THE PREPARATION OF CODFISH FOR SALTING

General.

Every fisherman knows that, after gutting, beheading, trimming, and splitting a fish, and before salting, the fish is washed to remove traces of blood, guts, and dirty matter. Every fisherman knows, too, that this process takes up a fair amount of time, but it is not every fisherman who realises that the time spent in the washing is every bit as important towards getting a good product as is the time spent, say, in drying the fish. For the most part the fisherman considers the important parts of preparing dried codfish as being the salting and the drying. He will take any amount of pains over drying the fish but he does not worry very much about the washing, a few hasty douses being the total precaution taken at this stage. Actually the care shown and time taken at this stage in cleansing the fish thoroughly of all traces of dirty matter will decide the final amount of bacterial decomposition, and, as we have seen, the successful control of this factor is half the battle to successful preservation. Time taken over the washing of the fish, then, is not time wasted. It is, of course, desirable to get the fish under salt as soon as ever possible, expecially in hot weather when, as everyone knows, decomposition works quicker.

It is now well known that bruising and crushing of the fish increases the rate of autolytic decomposition. There is absolutely no doubt but that rough handling of fish increases the rate of decomposition and makes it all the more difficult to get a successful cure. Fish should be carried about, not thrown about, and there is no justification for using pitchforks to toss fish from the boat to the wharf. However convenient a method the fork method is, it tends to encourage pitching and spoils the keeping qualities of the fish. In addition, the holes left by the fork in the fish tissue are splendid breeding grounds for bacteria and this accounts for the darkened appearance of the tissue round these holes. If forks are to be used the head should be pierced and the fish laid up on the wharf, but it would be advisable to use other means, such as fish baskets, to land the fish.

Gutting, Splitting, and Washing.

Blood and guts decompose more readily than the tissue because they are more prone to self-digestion and bacterial action. In addition, blood is objectionable because it darkens the final fish product. It is advisable, therefore, to bleed the fish by cutting the throat as soon as they are taken from the water. The impracticability of treating a haul from a trap in this way will be evident, but it should be the method used whenever possible. When the fish are landed water should be thrown over them to help to remove the blood and slime. The usual processes of throating, gutting, beheading, trimming, and splitting should be carried out as carefully as possible. That is to say, care must be taken to avoid gashes and tearing of the fish, for these, besides spoiling the appearance, become easy places for bacterial attack. In splitting, the point where the backbone is cut should be just far enough back to avoid leaving a blood spot, and the knife must not be allowed to slip deep into the flesh, forming a crevice where conditions become ideal for the activities of decomposition. A cut should be made into the part of the backbone that remains in the tail in order to remove any blood there. The final appearance of the fish should show the fish split evenly along the backbone from head to tail, with the backbone cut, not broken, about half way down, with no round tail and no ragged edges, no sliver and no gashes. At this stage the black skin of the belly wall is to be seen on the napes of the fish.

The leaving or removal of the black skin on the napes does not effect the preservation, but, on the whole, the improvement in appearance produced by whitenaping is such as to support the idea of removing the skin. Of course, there are market conditions to be considered here, and the individual operator will be the best judge. Generally speaking, however, whitenaping is advisable. If the fish are to be whitenaped the process should be done as part of the preparations necessary before salting and during the washing.

For the actual washing a plentiful supply of water is essential. Sea water is better than fresh water because fresh water tends to soften the fish. Where running water is not available keep renewing the still water. Still water accumulates debris and dirt and must be renewed, otherwise the washing develops into a process of contamination with pieces of the guts washed off other fish. A small scrubbing brush should be used for the back of the fish and all the slime removed, particular care being taken along the back fins. A brush should never be used for the face of the fish, for rough surfaces should be avoided, and this can be done with a cloth and plenty of water. The fish should be washed free of all blood and all pieces of gut; in fact, it should be in as clean a condition as it would be if it were being prepared for cooking; indeed it is more important that it should be thoroughly clean before preserving than before cooking, for the extent of the cleanliness affects the preservation more than it would affect the cooking and eating.

VI. THE SALTING OF CODFISH

Salt or common salt is a definite chemical compound composed of sodium and chlorine; its chemical name is sodium chloride and it occurs widely in Nature, in the sea and in deposits in the earth. It is obtained by mining or by evaporating sea water, but it is never directly obtained one hundred per cent pure. The commercial grades of salt used for salting fish have a content of sodium chloride which varies from about 94 per cent to 99 per cent. Sodium chloride is all that is necessary for extracting water by osmosis, and sodium chloride is not distasteful to the human palate, so that its presence on fish food is not disagreeable to the taste. Other substances are impurities, and it is desirable to find out what these impurities are and what their action is on the water extracting process and on the subsequent appearance and taste of the fish.

Where the salt has been obtained from mines there is every chance that it will contain lime salts, such as calcium sulphate (Plaster of Paris), or magnesium salts, such as magnesium sulphate (Epsom Salts), due to veins of these substances ocurring in the salt deposit. Where the salt has been obtained from sea water by evaporation, it will invariably contain a certain amount of lime or calcium and also of magnesium. Different samples of the same salt will contain varying amounts of calcium and magnesium and there will also be a certain amount of variation from pound to pound of the same sample. As a rule, in commercial samples, the amount of calcium and magnesium impurities exceeds ½ per cent and may even attain to as much as four or five per cent.

What is the effect of these unnecessary impurities, calcium and magnesium, on the process of salting fish ? In the first place, they delay the penetration of the salt into the fish. This delay in penetration allows the processes of autolytic decomposition to get busy in the interior of the fish before the water can be got out. Many years ago the United States Bureau of Fisheries did some work on this subject. It was found then that pure salt, pure sodium chloride, penetrated in less than five and one half days as deeply as did salt containing 4·7 per cent magnesium in seven days. The purer the salt used then the less the chance of autolytic decomposition, for the salt will penetrate more quickly and will all the sooner extract the water from the tissue cells.

Impurities in salt and, in particular, calcium or lime impurities, give a resulting fish product with a white, chalky appearance, and a firm consistency. Pure salt gives a softer and somewhat yellowish product. This yellowish appearance or yellow cast must not be confused with the dark colour of decomposition.

It was already mentioned that cell membranes were not ideally semi-permeable. They probably are so in life but they lose this property more and more the longer the fish has been dead. Consequently, they allow salt as well as water to pass through, and the salt, with its impurities, gets inside. Calcium impurities give to the fish a sharp or bitter taste and, because these impurities are held firmly by the fish protein, the fish will require a much more prolonged soaking before eating than if only pure salt were present. Indeed it will be difficult to remove the acrid taste.

Another factor about salts is extremely important and this applies to solar salts, salts which have been obtained by the evaporation of sea water by the sun's heat. Very often solar salts contain a kind of bacteria which gives rise to that condition of fish known as " Red" or " Pink." Only fish heavily salted with solar salt will develop red, and only if the fish have been allowed to become warm. Fish that have been heavily salted with solar salt should be kept in a cool, well-ventilated store-room. The condition of fish known as " Dun" is due to an infective mould, and, though imported salt does not contain this mould, it is possible to contaminate the salt by keeping it in store-rooms where there has been an outbreak of " Dun." Calcium and magnesium impurities in salt will draw moisture from the air to the dried fish and moisture, combined with a warm temperature, favours the growth of " Dun." Thus we have another reason for using as pure a salt as possible.

To give some indication of how impurities in commercial salts run there is given below in Table 1 the results of the percentage analysis of twenty-two commercial salt samples arranged in order of sodium chloride content. The percentage chloride content is included in the last column of the table because it seems fairly reasonable to conclude that this value gives an idea of the purity of the salt. Thus a simple chloride determination would reveal whether a salt is of good, medium, or low purity. A chloride content of over 59·8 per cent shows a salt of good purity, one of between 59·3 and 59·8 per cent, a salt of medium purity, and one of below 59·3 per cent a salt of low purity, that is, as commercial salts go. In general, this approximate grouping would classify a good salt as being over 98 per cent pure, a medium salt as being between 97 and 98 per cent pure, and a comparatively poor salt as being less than 97 per cent pure.

Table 1.

Percentage Analysis of twenty-two Salt Samples arranged in order of purity.

NaCl.	$CaSO_4$.	$CaCl_2$.	$MgCl_2$.	$MgSO_4$.	Insoluble.	Chloride.
99·40	·5233	—	·0125	·1362	·1580	60·30
98·75	·1927	·4127	·1652	—	·0320	60·28
98·74	·8860	—	—	·1190	·0500	59·89
98·70	·5845	·1085	·8740	—	·0921	59·99
98·64	·7780	·6310	—	—	·0700	60·17
98·58	1·0010	—	·1950	·1190	·0700	59·95
98·35	·4614	—	·2788	·1633	·0480	59·83
98·14	·7115	·5926	·1533	—	·0679	60·03
97·93	1·0470	—	·2696	·0503	·0580	59·60
97·93	·9255	—	·0280	·2641	·0380	59·41
97·88	·2126	·2126	·1781	—	·0210	59·62
97·63	·9272	—	·1956	·1340	·0660	59·37
97·56	·8170	·4040	·0360	—	·0950	59·47
97·47	1·0340	—	·2280	·5000	·7290	59·30
97·36	·7140	·0180	·0050	—	·3100	59·08
97·22	1·3860	·0080	·0080	—	·3200	58·93
97·02	1·0890	—	·3670	·0580	·0900	57·80
96·84	·8840	—	·6730	·3780	·4000	57·64
96·73	·7193	—	·3030	·1590	·0669	58·89
96·58	·9413	—	·9098	·7217	·1270	59·24
96·48	·9620	·3392	·3305	—	·0550	58·97
96·15	1·3670	·4819	·0649	—	·0771	59·06

Table 2.

Average Analysis of twenty-two Salt Samples.

Constituent.	Average per cent.	Range per cent.
Sodium Chloride	97·73	96·15–99·40
Calcium Sulphate	0·83	0·21–1·39
Calcium Chloride	0·15	0·01–0·63
Magnesium Sulphate	0·13	0·05–0·72
Magnesium Chloride	0·24	0·01–0·91
Insoluble Matter	0·14	0·02–0·73

Table 3.

Average Analysis of Salt.

(Fisheries Experimental Station, Halifax, N.S.)

Constituent.	Eleven samples of Solar Salt. Average per cent.	Eleven samples of Mixed Salt. Average per cent.	Solar Salt. Range in per cent.	Mixed Salt. Range in per cent.
Salt (Sodium Chloride) ..	96·4	97·3	94·2–98·1	94·5–98·3
Gypsum (Calcium Sulphate)	1·09	1·20	0·33–2·88	0·04–1·76
Magnesium-Chloride ..	0·42	0·22	0·19–0·39	0·02–1·37
Calcium Chloride	0·22	0·05	0·02–0·72	0·00–0·13
Epsom Salts (Magnesium Sulphate)	0·18	0·15	—	—
Insoluble Matter	0·30	0·51	—	—

Table 3 gives in summarised form the results of the salt investigations of the Fisheries Experimental Station, Halifax. The average percentage of sodium chloride is lower for solar salts than for mixed salt, showing that the presence of a mineral salt raises the percentage purity. Reference to Table 2 reveals that the samples done in this laboratory gave a slightly higher value. This is undoubtedly because nearly as many as half of these salts of known origin were mineral salts and, therefore, the average value for purity is raised.

It is safe to say, as a result of all these analyses, that, in general, mineral salts are of higher purity than solar salts. As previously pointed out, however, in considering the practical advantages of this conclusion, care must be taken to bear in mind the differences in quantity used from fish to fish. No doubt equally satisfactory results have been obtained with solar salts because of this practical difficulty of obtaining uniformity in the application of salt. Any solution of the problem of standardising amounts of salt put on fish other than by better training of the operator who is applying the salt seems impossible.

At this point it is proper to introduce some remarks with regard to the question of the relative weights of different brands of salt. Fishermen and men in the trade generally talk of light salt and heavy salt without having any very clear idea as to what it signifies. Such loose expressions as "strength of salt," "safe salt to use," "evaporation of salt," are rather vaguely explained. And the reason is that, right down to the present day, the unit of measure of salt universally employed in Newfoundland is a volume, the hogshead, and not a weight. Now owing to the difference in the methods of manufacture and purification of salts, the texture and the size of grain from one salt to another will vary. One salt will pack or stow better than another, with the result that one measureful of one salt will not have the same weight as the same measureful of another. Conversely, one ton of one salt may turn out 4·25 hogsheads, whereas one ton of another may only run to 3·3 hogsheads. Here is a fairly reliable set of figures for the weights per hogshead of four different salts.

	Average Pounds per Hogshead.
Cadiz	510
Santa Pola	600
Torrevieja	625
Mineral	650

When the figures for the amount of salt used are recalled and when it is remembered that these figures are really the amounts of a light salt like Cadiz, it is easily understood how a change over to the use of a mineral salt may result in oversalting. One hogshead or 510 lbs. of Cadiz is necessary for say ten quintals of shore cure. One hogshead of mineral or 650 lbs. would salt twelve and three quarter quintals as effectively. Keeping to the hogshead measure, on the basis of one hogshead of Cadiz salting ten quintals, we have the following figures giving the same effects.

1 hogshead Cadiz salts 10 quintals.
1 hogshead Santa Pola salts 11·8 quintals.
1 hogshead Torrevieja salts 12·3 quintals.
1 hogshead Mineral salts 12·7 quintals.

The reason why Cadiz is regarded as a safe sale is because there is less chance of oversalting, for one handful of it weighs less than a handful of a heavier salt. Then, again, other salts are said to have more strength simply because there is more weight of salt in the same volume.

Now it is just as easy for a salter to learn how far to make 500 lbs. of salt go as it is for him to learn how far to make one hogshead go, so there is really no excuse for the continued use of this antiquated hogshead measure. Salt ought to be bought and sold by weight, an arrangement which will obviate disputes arising from shrinkage due to settling.

The Best Kind of Salt.

Someone may ask what is the best kind of salt to use. The answer to that is: the salt having the greatest amount of sodium chloride and the least amount of calcium and magnesium impurities. As to which commercial brand has this greatest purity it is difficult to say, for samples vary within themselves, and from time to time. California salt is nearly one hundred per cent sodium chloride and has been recommended despite the extra cost. With regard to the relative merits of mine salts and solar salts it should be pointed out that sometimes samples of mine salts may be obtained 99 per cent pure. Commercial solar salts will rarely be obtained with this degree of purity but the percentage composition will vary less.

The following conclusions can be drawn from a consideration of the question of the best kind of salt to use :

1. A sea salt of good sodium chloride content is very satisfactory provided due care is taken to avoid the consequences from the development of the pink organism. This necessitates, amongst other things, careful washing, but the risk is always there, especially in hot, damp weather. The expensive process of sterilising the salt is the only sure preventive, and this is out of the question from the point of view of cost.
2. The use of mineral salt, uncontaminated from contact with a solar salt, is a perfect guarantee against pink. A mineral salt of a high degree of purity is undoubtedly the best salt to use.

Points in the Actual Salting Process

Kench Salting of Cod.

When the fish are being piled in salt bulk care should be taken over one or two points. They should be piled with the flesh side up and more salt sprinkled on thick fish than on thin fish, with most salt over the thick part of each fish. Obviously the thickest part of the fish contains most water and most salt will be necessary to extract the water. The kench should be built in such a way that the pickle formed should drain off, and fish should be placed carefully on the pile so as to avoid kinks or folds. The kench should be built in a place where there is good drainage from the bottom.

The Amount of Salt used in Kench Salting.

The amount of salt used depends on the nature of the cure or product desired, upon weather conditions, and upon the length of time the fish is to remain in salt bulk. Unfortunately, considerable laxity prevails as to the amount of salt used. Whilst the resulting products may not be radically different, the desirability for uniformity is obvious.

Table 4 below gives a summary of necessary salt amounts, based upon figures obtained for a light salt such as Cadiz. The table includes some conclusions derived from particulars explained below in connection with loss in weight by salting and drying.

Table 4.

Type of Salting.	Suitable Fishery Locality.	Quintals of Codfish salted with		Lbs. of Dressed Green Fish salted with		Quintals salted with 500 lbs. Salt.	Lbs. of Salt applied per Finished Quintal.	Lbs. of Salt applied per 100 lbs. Dressed Green Fish.	Lbs. of Finished Fish produced from 100 lbs. Dressed Green Fish.
		One Hogshead Light Salt.	One Hogshead Heavy Salt.	One Hogshead Light Salt.	One Hogshead Heavy Salt.				
Light	Island of Nefoundland Inshore Banks	10–8	12·75 –10·2	3080 –2772	3927 –3142	10–8	50–63 Av. 56	16–20	36
Medium	Banks Straits of Belle Isle	8–6·75	10·2 –8·6	2772 –1755	3142 –2236	8–6·75	63–74	20–28	36–43
Heavy	Coast of Labrador Inshore	6·75 –6·25	8·6 –7·9	1755 –1625	2236 –2054	6·75 –6·25	74–80 Av. 77	28–31	43

The table is self-explanatory and column 7 gives the quantities of salt to be used on 100 lbs. of dressed green fish. Comment on the respective yields is reserved until after discussion of water and salt contents.

Length of Time in Kench.

The length of time in which codfish should remain in salt bulk, or in kench, is determined by the amount of salt which has been added to it, and the temperature of storage. In summer, for the lightest salting mentioned, about a fortnight is long enough, whilst in the case of the heaviest salting, probably ten weeks is an outside limit. Probably the necessary limits for the salt to "strike through" are ten days, and three to four weeks respectively. The hotter the weather the less time should the fish lie in salt bulk over these low limits.

Pickle Salting.

The method of pickle salting is a similar method to kench salting in that dry salt is used. The fish, however, in this case, are put in perfectly tight containers, so that the pickle does not drain away. For very lightly salted codfish a very small quantity of salt is used; four and one half quarts per 100 lbs. of fish is probably a good average figure, and three to five days in pickle is all that is necessary. It should be remarked that this small amount of salt is not sufficient to saturate the water in the fish tissue, and souring is possible owing to the pickle losing strength. A product of this kind must be very carefully watched, and in any case is not very durable when finished. However, by adding more salt to the container from time to time a more durable heavy-salted article can be made.

VII. WATER CONTENT, SALT CONTENT, AND YIELD OF FINISHED PRODUCT

In view of the table of salt quantities just given, particulars of water contents, salt contents, and yields of the different finished products may conveniently be given at this stage.

Water Content of Fresh Codfish.

The water content of fresh codfish tissue may be given at 81 per cent as the nearest whole number. It is quite remarkable how little variation there is from fish to fish.

Percentage Waste in preparing Codfish for Salting.

In Table 5 below are given some collected weighings of the loss in weight when fish from the sea are dressed ready for salting. The average loss is 38·5 per cent.

PERCENTAGE WASTE WEIGHT OF COD IN DRIED FISH INDUSTRY

Table 5

Grand Banks, March, 1934.

Weight of Fish from Sea.	Weight without Heads.	% Heads.	Weight of Split Fish.	% Total Waste.
192 lbs.	124 lbs.	35	102 lbs.	47
158 ,,	130 ,,	17·7	112 ,,	29
321 ,,	222 ,,	30·8	189 ,,	41
144 ,,	108 ,,	25	94 ,,	34·8
178 ,,	116 ,,	34·8	101 ,,	43
183 ,,	120 ,,	34·5	103 ,,	43·5
165 ,,	109 ,,	34	93 ,,	43·5
181 ,,	149 ,,	17·7	131 ,,	27·6
179 ,,	123 ,,	31·3	103 ,,	42·5
188 ,,	126 ,,	33	105 ,,	44
163 ,,	121 ,,	25·4	98 ,,	39·4

Grand Banks, April, 1934.

Weight of Fish from Sea.	Weight without Heads.	% Heads.	Weight of Split Fish.	% Total Waste.
168 lbs.	115 lbs.	31·5	100 lbs.	40·5
175 ,,	122 ,,	30·3	94 ,,	46·3
199 ,,	126 ,,	36·7	105 ,,	47·2
107 ,,	68 ,,	36·4	59 ,,	44·8
161 ,,	111 ,,	31	99 ,,	38·5
188 ,,	124 ,,	34	103 ,,	45·2
123 ,,	74 ,,	39·9	62 ,,	49·6
154 ,,	109 ,,	29·2	97 ,,	37
169 ,,	105 ,,	38	93 ,,	44·9
120 ,,	73 ,,	38·1	60 ,,	50

Bay Bulls, October, 1934.

126 lbs.	—	—	78 lbs.	38
122 ,,	96 lbs.	22·9	73 ,,	40·1

Water Content of Shore Cure Fish.

The light-salted shore cure dried codfish product has a water content which varies over a range of roughly about eight per cent. From the many samples examined by the writer an average of 41 per cent can be taken as reliable.

Water Content of Heavily-Salted Labrador Fish.

Heavy, salted fish are dried largely by extracting water with salt. It becomes more dificult to dry out the remaining water. As a result, this type of product has usually a somewhat higher percentage of water, although samples are found just as dry as the shore cure product. The average figure obtained for the final water content of Labrador cure is 47 per cent.

The water content of dried fish, apart from consideration of preservation and calculation of yield, is of practical interest because we shall see later that, in Porto Rico, a water content line of demarquation is set for duty purposes.

Salt Content of Shore Cure Fish.

Taking an average of the percentage of salt in the dried weight of shore cure fish, the figure is 19·94 per cent. Using the average water content of 41 per cent given above, we have that the percentage of salt in the dried shore cure fish product is 11·76. Since there is 11·76 lbs. of salt in every 100 lbs. of product, it follows that one quintal (112 lbs.) of finished shore cure contains 13·17 lbs. of salt. These calculations have been made by disregarding the bone weight content of the article. Of course the salt does not penetrate the bone to any great extent, and the correctness of the calculation, therefore, depends on how far it is justifiable to neglect the weight of bone. Experiments were conducted to destroy the flesh and leave the bone. The percentage of bone found was from two to four per cent. This has, therefore, been omitted as complicating the calculations without gaining much in accuracy, since average figures have been used.

Salt Content of Labrador Cure.

The average percentage of salt in the dry weight of Labrador cure is 33·37. The percentage of salt in the commercial product, therefore, averages 17·69. In other words, one quintal (112 lbs.) of Labrador cure contains 19·8 lbs. of salt, or about one and a half times as much as the shore cure.

Yields of Dried Product.

With the foregoing data, it is possible to calculate and tabulate some very useful information concerning the industry.

Effect of Final Water Content.

It is very obvious that the final water content of the product will determine the weight of yield of product to a great extent. Now, as already stated, in actual commercial practice there is a variation in the final water content. For shore cure, the variation is about eight per cent from 37–45. The following figures show up the effect of this final variation on the quantity of salt bulk and dressed green fish required. In calculating the green fish care must be taken to eliminate the salt, but the same elimination is made in each case here, so that the difference in yield is entirely due to the difference in the final percentage of water.

Finished Product.			Corresponding weights of Salt Bulk.		Corresponding weights of Dressed Green Fish.	
Weight.	Water content.	Total wt. of salt.	Weight.	Water content.	Weight.	Water content.
112 lbs.	37%	13 lbs.	235 lbs.	70%	298 lbs.	81%
112 ,,	41%	13 ,,	220 ,,	70%	279 ,,	81%
112 ,,	45%	13 ,,	205 ,,	70%	260 ,,	81%

Where the fish are dried to a water content of 45 per cent the original quantity of green fish (260 lbs.) is 38 lbs. less than when the final water content is 37 per cent. Though the actual figures given may be rather low for reasons given later, the relative effect is as calculated.

Effect of Final Salt Content.

Again the total weight of salt actually taken up by the fish will affect the yield. As a matter of fact not only do heavily-salted fish gain in weight as compared with lightly-salted fish from the salt uptake, but also they have, in general, a higher final water content than lightly-salted fish. As has already been said, the more water is removed by drying the more difficult it is to dry off the water remaining, hence the final water content is generally higher. Meantime, for purposes of illustration, we can take two examples of the same water content but of different salt contents.

Finished Product.			Salt Bulk.		Dressed Green Fish.	
Weight.	Water content.	Total wt. of salt.	Weight.	Water content.	Weight.	Water content.
112 lbs.	45%	19·89 lbs.	140	56%	218	81%
112 ,,	45%	13 ,,	205	70%	260	81%

The relative salt bulk weights differ more than the relative green fish weights because of the effect of salt in taking out more water. At the same time, the difference in original weights of fish necessary, owing to the use of different quantities of salt, is considerable.

Combined Effects of Final Salt and Water Contents.

In the different types of cure of the industry, actually both the final water and salt contents differ, so that the effect on the yield is twofold. Before setting forth a tabulated account of the actual effects an explanation of the method of calculation is necessary. Whilst the calculation is straightforward, it is, nevertheless, beset with many pitfalls.

Calculation for Shore Cure using Average Values

1. *Finished Product to Salt Bulk.*

Take first the number of pounds of salt bulk fish necessary to produce 112 lbs. of shore cure fish averaging 41 per cent water and 11·76 per cent salt. At the salt bulk stage the water content is 70 per cent.

The amount of salt really does not effect this calculation if it is assumed (and this is quite justifiable) that the total quantity of salt in the salt bulk fish remains in the fish at the dried stage. Note that the percentage of salt will be different at the salt bulk stage from the finished stage because there is more water; so also the perecentage of fish solids will differ at the two stages. However, in corresponding quantities at the salt bulk stage and at the finished stage the total actual quantities of salt and fish solids remain the same.

At the finished stage, since there is 41 per cent water, 41 lbs. water are associated with 59 lbs. solids in 100 lbs. fish.

At the salt bulk stage, since there is 70 per cent water, 70 lbs. water are associated with 30 lbs. solids.

Now, there is in the final 100 lbs. of fish 50 lbs. of solids, so that these 59 lbs. at the salt bulk stage must have been 30 per cent of the total weight.

Hence a total salt bulk weight of 196·6 lbs., containing 59 lbs. of solids, and 137·6 lbs. water (i.e. seven per cent water) will give rise to 100 lbs. of finished fish containing still 59 lbs. of solids, but now only 41 lbs. of water (i.e. 41 per cent water).

Since 196·6 lbs. salt bulk produce 100 lbs. finished fish of average water content, 220 lbs. is necessary to produce 112 lbs., or one quintal.

2. *Finished Product to Dressed Green Fish.*

In passing from the finished product to the dressed green fish, it is essential to know the salt content of the product because, of course, the salt has to be eliminated in the calculation. A sufficient accuracy is obtained by assuming no salt in fresh fish.

At the dried fish stage in 100 lbs.,

11·76 lbs. are salt,
41 lbs. are water,
and 47·24 lbs. are fish solids.

The 47·24 lbs. of fish solids represent 19 per cent of the original dressed green fish, from which these 100 lbs. were obtained. The total weight, therefore, of dressed green fish necessary to produce 100 lbs. finished fish of average salt and water content is 249 lbs. Therefore, one quintal (112 lbs.) is derived from 279 lbs. dressed green fish.

Labrador Cure.

The calculations for this type of cure are similar to those just given. For the sake of emphasis, the method of calculating from the finished product to dressed green fish is repeated for this type of cure.

At the dried fish stage in 100 lbs.,

17·69 lbs. are salt,
47 lbs. are water,
and 35·31 lbs. are fish solids.

Since the water content of green fish is 81 per cent, and there is no salt, the remaining 19 per cent is fish solids.

Therefore, 35·31 lbs. of fish solids were originally associated with water to the extent that they represented 19 per cent of the total weight. The total weight was, therefore, 186 lbs. That is to say, 186 lbs. dressed green fish gave rise to 100 lbs. finished fish.

Hence one quintal (112 lbs.) Labrador Cure comes from 208 lbs. dressed green fish.

The relationship between the weight of dressed green fish and the weight of fish from sea has already been given, as well as the quantities of salt used, and all the available information can now be collected in tabular form. Table 6 gives this information.

TABLE 6

		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
		Percentage water.	Percentage salt.	*Pounds of split fish producing 112 lbs. cured fish	*Pounds of fish from sea producing 112 lbs. cured fish	Pounds of split fish producing 100 lbs. cured fish	Pounds of fish from sea producing 100 lbs. finished fish	Pounds of salt applied to original weight of fish producing 112 lbs. cured	Pounds of salt applied per 100 lbs. split fish	Pounds of cured fish from 100 lbs. of split fish	Weight of salt bulk from split fish producing 112 lbs. finished fish	Weight of salt bulk from split fish producing 100 lbs. finished fish	Percentage water in salt bulk
Shore Cure	Actual (approx.)	41	11·76	308	500	275	447	56±6	18±2	36	224	200	70
	§Calculated			279	454	249	405		20±2	40	220	196	
Labrador Cure	Actual (approx.)	47	17·69	260	423	232	377	77±3	29·5±1	43	130	123	57
	§Calculated			208	338	186	302		36±2	53	140	125	

*Percentage water in fresh fish 81.
Percentage waste in dressing the catch ready for salting 38·5.
§Calculated values must be considered in relation to the reservations mentioned in the text.

An approximate idea of the actual weights necessary can be had from the experience of those in the trade, with the turn-out of green fish bought "from the knife." Sometimes fish "from the knife," that is dressed green fish or split fish ready for salting, are bought up and the amount paid for the purchase has to be calculated from the expected yield of cured fish. It has been found that a quantity of split fish between 300 lbs. and 320 lbs. is necessary to produce one quintal of Shore Cure fish, and probably around 250 lbs. for Labrador Cure. These actual quantities are higher than the calculated ones given. On the other hand, on comparing the accepted actual quantities of salt bulk fish necessary for one finished quintal (224 lbs. for Shore Cure and 138 lbs. for Labrador), with the corresponding calulated figures (220 lbs. and 140 lbs.), the agreement indicates that the assumption that the loss in weight from salt bulk to cured fish is due entirely to loss of water is correct. The discrepancy between actual and calculated values for the weight of green fish necessary for one quintal of cured fish shows that, in addition to loss of water and uptake of salt, there is a third loss—the loss of solid fish material. When the brine drains away from the kenches, it takes with it considerable quantities of proteinaceous matter. According to experiments by Harden Taylor, as much as 1 to 2½ lbs. of equivalent food fish flesh are lost in each gallon of brine. It must also be remembered that the lighter the salting the more the changes in the cell structure and the greater the penetration of salt and extraction of solid. It is likely, too, that light salting tends to extract more protein than heavy salting.

It is of great interest to consider the respective yields in the case of light salting and of heavy salting. Almost 450 lbs. of fish from sea are required in the light salted method to produce 100 lbs., whereas 375 lbs. produce 100 lbs. Labrador Cure. American figures (A. W. Bitting, U.S. Department of Agriculture, Bureau of Chemistry Bulletin No. 133, 1911), which obviously apply to heavier salted fish than Labrador, because most of the water is removed by salt action, are as follows:

Loss of weight in dressing, 40 per cent.

Loss in salting, 40 per cent of what remained after dressing.

Loss in drying on flakes, nine per cent of the salted fish.

Thus starting with 300 lbs. of fish from sea, 40 per cent is lost, leaving 180 lbs. dressed green fish. A 40 per cent loss in this weight leaves 108 lbs. salt bulk. Nine per cent of the salted fish is 9·72 lbs., which leaves 98·28 lbs. finished fish. Thus 305 lbs. produces 100 lbs. cured, according to this investigator. The figures probably apply to the yields in the boneless codfish industry, but probably also to French yields, where heavy salting is favoured.

Assuming the same cost of production per unit weight of catch in each case, it follows that the respective prices necessary for equal return in the various types of fishery would be on the basis of yield in the ratio of 9 Shore Cure, 7·5 Labrador, and 6 for the apparently heavier salted American type referred to. *When it is recalled that the heavier salting procedure means less spoilage, and that only a fraction of the light salted cure turns out first class, fetching top price, the possibility arises that the heavier salting may actually be a more profitable method of prosecuting the industry.*

VIII. THE DRYING OF CODFISH

We have seen that salt, as a result of the osmosis produced, withdraws water from the inside of the tissue cells. Now, some of this water runs away as brine, but there is still 70 per cent water left in the Shore Cure bulk, and 57 per cent in the Labrador Cure. The water contents in the final products are 41 and 47 per cent respectively, so that there is a considerable amount of water still to be got rid of. The time honoured method of doing this is to dry off or evaporate the water, to "make the fish," by using the sun's rays and the general drying properties of the atmosphere. Briefly, the making of the fish is done as follows: Open work platforms or "flakes," constructed of wood and floored with boughs, are erected, and on these flakes the salt bulk fish, first washed and pressed, are spread to dry. At night the fish are gathered into piles or bundles or faggots, and generally protected with some sort of cover, if not taken inside the storage shed. The weight of the pile helps towards producing an even surface, as well as assisting the drying by allowing inside juices to come to the surface, to be dried off again next day. Considerable importance attaches to the details of the drying process. The more care is taken at each step, the more likely is the final product to be of high quality. When the fish are being washed from salt bulk, care should be taken to use clean salt water, to take each fish singly, and to make sure it is as clean as possible without soaking it too much. The salt is removed from the face of the fish in this way, and there is also a certain amount of wetness on the surface. This renders the surface prone to bacterial attack, so that cleanliness is all the more necessary to prevent development of bacterial decomposition. After washing comes the process of "waterhorsing." This consists of stacking the washed fish in large piles back up, so as to press out as much brine as possible. Light salted fish cannot be left for long in waterhorse during the heat of the summer months. If the weather gets bad, causing too much delay in spreading on the flakes, it is usual and necessary to give a light sprinkle of salt.

The process of waterhorsing not only helps to get rid of water, but also gives the fish a smoother surface, due to the pressure of the pile.

The "making" process conducted on the drying flakes requires good drying conditions. The more uninterrupted the good drying conditions, the better the finished product. However, a certain amount of "working" of the fish is necessary for satisfactory results. Working consists in piling and repiling to press out the juices and to produce an even surface. When the fish become moist on the surface by piling, they are said to "give up." This moisture has to be dried off again. The piles in the first stages are small, only consisting of little more than half a dozen fish, but gradually as the drying proceeds, the piles are increased in size. Care is also taken to spread the fish back up to dry the backs. "Sunburn" is an affect which has to be avoided. It is generally associated with too intense direct sun rays in the absence of a cooling breeze, and results in its worst stages in the product crumbling and falling to pieces. It is probably a heat effect, as we shall see presently. Fish are said to be "slimy" when, as a result of prolonged bad drying weather and an insufficiency of salt for the length of time without further air drying, decomposition sets in, manifesting itself as a "slimy" effect. "Salt-burn" is an expression sometimes used, which seems to be almost a pronounced sunburned effect. It is quite probable that an excess of salt aids the sunburning process, a point which will be mentioned below. Under satisfactory drying conditions, and provided the fish have been brought to the drying stage in a satisfactory way, none of these effects are encountered. This brings forward the question of the general principles underlying evaporation, and a consideration of optimum drying conditions.

Principles of Evaporation.

For our purpose, evaporation can be defined as the process whereby a liquid is converted into a vapour, which is carried off in the atmosphere. In dealing with a solution of solids in liquid, it is only the liquid portion that will evaporate; the dissolved solids give off no vapour. Liquids give off vapour for this reason; the molecules of the liquid are in a continued state of irregular motion, and when in their irregular motion they reach the surface of the liquid, they fly off into the space above. Now, if the air above the surface contains molecules of water vapour, these also will be in irregular motion, and some of them will hit the body of liquid. If as many molecules hit the surface as leave the surface, the volume of liquid will remain the same. This is what happens when the air is saturated. At any particular temperature the vapour pressure or tension of water, say (as the tendency of a liquid to lose molecules is called), can be measured by the pressure of saturated vapour above the water. Evaporation will go on until saturation of the air is reached, when the back vapour pressure of the saturated aqueous vapour equals the vapour pressure of the liquid, when evaporation ceases. By the application of heat to a liquid, however, that is, by raising the temperature, the speed of the molecules increases, the vapour pressure increases, and a new set of conditions control the extent of evaporation. If the temperature of the atmosphere above the surface is not the same as that of the liquid, evaporation can proceed despite saturation of the atmosphere; for example, water may be boiled in a heavy fog. Under conditions affecting the drying of fish, however, the temperatures of the fish and surrounding atmosphere will be nearly always the same.

The rate of drying, that is, the rate of evaporation, is determined by two factors; first, the speed at which the molecules are moving and leave the surface, or the vapour pressure; and second, the receptive power of the air. The receptive power of the atmosphere depends upon (1) the difference in level between the forward vapour pressure of the liquid and the backward vapour pressure of the aqueous air; in other words, the *humidity of the air*, on (2) the temperature of the air on which depends the total amount of water vapour it can contain, on (3) the the amount of air movement, since wind blowing over the surfaces, at which evaporation takes place, constantly provides a new supply of drier air to take up the vapour, and on (4) the amount of direct sunlight.

1. The humidity of the atmosphere is the amount of water vapour present in it at any particular temperature. No evaporation of water will occur if the air is saturated. The more the condition of the atmosphere is removed from this saturated condition, the drier the air is, that is to say, the more the amount of evaporation possible, the more quickly it will take place. Humidity is conveniently standardised for measurement by relating it to the humidity of saturation. It is then called Relative Humidity. A Relative Humidity of 100 means that the atmosphere is saturated, whilst lower values, as for example 50, signifies the percentage extent of moisture relative to saturation.
2. The amount of water vapour which the atmosphere can hold depends upon the temperature of the atmosphere. Cold air does not take up so much vapour as warm air. The higher the temperature of the air, therefore, the more the evaporation and the quicker.
3. Air movement plays an important part in the amount of evaporation taking place and in increasing the rate of evaporation. The explanation is that new supplies of air are constantly being provided, so that instead of the air over the liquid becoming more moist, the humidity over the liquid actually remains stationary. The more air movement the more the evaporation and the greater the speed of evaporation.

4. The influence of direct sunlight on evaporation is only imperfectly understood, but it has been shown that a liquid will evaporate more quickly in the direct rays of the sun than in the shade at the same temperature.

One of the biggest problems of the cod curing industry in Newfoundland is the question of the control of the drying conditions. The operator has to depend on a means of drying which he cannot control. If that means were consistently uniform, the production of a standard article would be possible. But atmospheric conditions in Newfoundland from week to week and from season to season during the summer months are not uniform.

The following table will serve to show the extent of variation in the humidity from one day to another during the summer of 1934. It gives the number of hours each day for which the humidity stayed at the stated levels. Similar daily variations were noted in previous years.

Day Midnight to Midnight	No. of hours during which the relative humidity was					
	0–50	50–60	60–70	70–80	80–90	90–100
10/7/34	13	2	2·75	·25	·25	5·75
11/7/34	12	2	5	5	0	0
12/7/34	5	7	6	2	3	1
13/7/34	0	0	4·5	1·5	7·0	11
14/7/34	12·5	1	2·5	4	3	1
15/7/34	0	0	4·5	3·25	5·25	11
25/7/34	0	0	0	0	2	22
26/7/34	2·5	6·5	1·5	2	1	10·5
27/7/34	0	3	2·75	3·25	4·5	11
28/7/34	0	4	5	6	3	6
29/7/34	0	0	0	2	5·5	16·5
31/7/34	7·5	·5	2·5	·5	1	12
1/8/34	0	0	1	3	8	12
2/8/34	0	2	8	1	6	7
3/8/34	10	1·5	1	·5	4	7
8/8/34	11·5	·5	1	2	4·75	4·25
9/8/34	10	1·5	1	1·5	5	5
10/8/34	6	2·5	3·5	2	4	6
21/8/34	0	0	0	2	5	17
22/8/34	10	1	1	5	3	4
23/8/34	2	2	·25	2·25	5·5	12
24/8/34	·5	7·5	2	3	6	5
25/8/34	0	2	2	1·5	6·5	12
26/8/34	10·5	1	5	1	·5	6
4/9/34	0	2·5	4·5	4	12	1
5/9/34	5	2	1	2·5	3·5	10
6/9/34	0	1	6·5	1·5	4	11
7/9/34	3	2	2·5	4	9	3·5
8/9/34	1·5	2·5	1·5	5·5	2	11
	4·22	1·98	2·69	2·48	4·28	8·33

Suppose we consider the average values from one season to another, for 1932, 1933, and 1934.

	No. of hours during which relative humidity was					
	0–50	50–60	60–70	70–80	80–90	90–100
1932	1·6	1·2	2·4	3·1	5·6	9·9
1933	3·1	2·6	2·9	3·1	7·1	5·2
1934	4·2	2·0	2·7	2·5	4·3	8·3

During 1933 and 1934 the Relative Humidity fell below 50 twice, and over twice as many hours per day as in 1932. There was also in these two years considerably more time during which the Relative Humidity was between 50 and 60. By adding the first and second columns, we get the number of hours per day on the average during which the Relative Humidity remained below 60. In 1932, the extent of the period was 2·8 hours, in 1933 it was 5·7, and in 1934 6·2 hours.

When it is recalled that these figures for 1933 and 1934 represent splendid drying conditions for six hours daily, from say 11 a.m. to 5 p.m., as compared with at most three hours, say from 11 a.m. to 2 p.m., in 1932, it becomes evident that, by comparison with 1933 and 1934, 1932 was a poor drying year. Actually, complaints were numerous of inferior cure during that year, and a general outcry was apparent concerning deterioration in quality and the large percentage of the cure shipped to the West Indies. It is significant that, in 1933 and 1934, it was generally agreed that a pronounced improvement in quality had taken place. Whilst the tendency on the part of the trade was to attribute improvement in 1933 and 1934 to a generally better standard of care by the fishermen, it is highly improbable that one, or even two years, would produce such a reformation in human failures. When it is recalled that a survey of the past reveals periodic outbursts on this subject of deterioration, it is distinctly possible that the failures of the past may be attributed to bad drying conditions. The important lesson to be learned is that at some not distant future date, when another bad season arises, control of the drying process by artificial means will be necessary, and provision should have been made to make that control possible.

Effects of Bad Drying Conditions.

Some of the effects of unsatisfactory drying conditions were already mentioned. A better understanding of these bad effects is now possible. "Slimy" fish are simply fish that have started to decompose, owing to the fact that the water on the surface is not dried off quickly enough. "Sunburnt" fish are fish in which the protein of the flesh has been coagulated by heat, in a manner similar to the effect of boiling on the white of an egg.

It is probable that much sunburning takes place on days when it is warm but humid. Little evaporation is going on and, therefore, there is no cooling effect ; the temperature of the fish rises to a degree sufficiently high to produce physical changes in the protein of the flesh—changes which are characterised by the brittle and crumbly nature of the protein.

Sometimes dried codfish become infected with a condition known as "dun." Dun is a mouldy, dust-like fungus which, in its advanced stages of development, spreads over the entire fish, and causes putrefactive decomposition. The fungus is first seen as a dust-like spore powder covering the fish with white spots. As it develops, the fungus becomes dun-coloured, and gradually produces decomposition of the tissue. It grows best at a temperature of 25°C., requires a certain amount of moisture, and is most favoured by a nourishing medium containing 10% salt. As with other low forms of life, the growth of dun is doubtless encouraged and made easier when it received its nutrient food in the form of degraded tissue material. In other words, growth is favoured by the presence of substances arising from very slight decomposition. Once again satisfactory drying conditions, producing a satisfactory finished article, lessen the chances of dun infection even under the most adverse conditions of hot moist weather. The fact that the fish must first become contaminated with the spore powder makes it imperative to disinfect all fish premises and utensils regularly. Sulphur fumigation and liming will lessen the chances of dun infection as well as generally improve the hygienic conditions under which fish are processed. "Pink" or "red" infection of dried fish, characterised by the surface of the fish becoming red and by subsequent putrefaction of the tissue, is due to contamination with a bacteria from solar sea salt. The most effective method of preventing infection is to sterilise the solar salt at a temperature of 212°F. This method is not economically feasible, so that there is generally risk of "pink" infection from solar sea salt. The risk is, however, minimised if the conditions of satisfactory processing have been observed. When it is realised that satisfactory processing is impossible under bad weather conditions, the possibility of devising some satisfactory means of artificial drying to cope with these conditions becomes a matter for intensive investigation.

IX. THE ARTIFICIAL DRYING OF CODFISH.

The usual objections to the artificially dried product are that the fish is "case-hardened" and that salt "comes out," showing on the face. The surface is generally uneven, and has a "stringy" appearance. All these faults indicate that the drying has been too intense and of too short a duration. The water content of such fish is not so very much less than usual, varying around 39 per cent, but the surface is usually very dry. A similar effect can be obtained by taking a normal finished fish into a heated room in the winter time, when the inside air is intensely dry, and the surface drying leaves solid salt deposited there and produces cracks in the even surface. The whole difficulty seems to be due to a too rapid drying, brought about by too much air movement and an unnecessarily dry air inside the chamber. Just how many methods of artificial drying have been or are being used it is difficult to say, but one exceedingly common method seems to be the use of a blast of hot dry air. This attempt to speed up drying cannot but prove fatal to the production of a good cure. Methods are used in which the entering air is passed over chilled pipe condensers, thereby cooling the air and depositing water. Upon heating such an air the Relative Humidity becomes very low. An idea of how dry such an air can be is had on consideration of the effect of temperature on humidity.

For this purpose a chart has been drawn to show the effect on Relative Humidity of air of raising its temperature by heating. This is equivalent to calculating from dew points the corresponding humdities at higher temperatures.

Thus the simple process of raising the temperature of saturated air (i.e. air of Relative Humidity 100) from 35°F. to 75°F. causes a lowering of the Relative Humidity to 28. At lower initial temperatures the effect is still more pronounced. In a drying chamber the original source of air is the outside atmosphere. Air of certain temperature and humidity enters, and is heated. Towards the end of the year an atmospheric temperature of 35°F. and Relative Humidity of 100 is a not unusual condition, so that it is readily seen how intensely dry such an air will be rendered on heating for admittance to a drying chamber. Much of the "case-hardening" of artificially dried fish is probably due to the production in this way of too dry an atmosphere inside the drier. Of course, a lessening of the intensity of dryness is brought about because of the mixing of the moisture, given off by the fish, with the entering air.

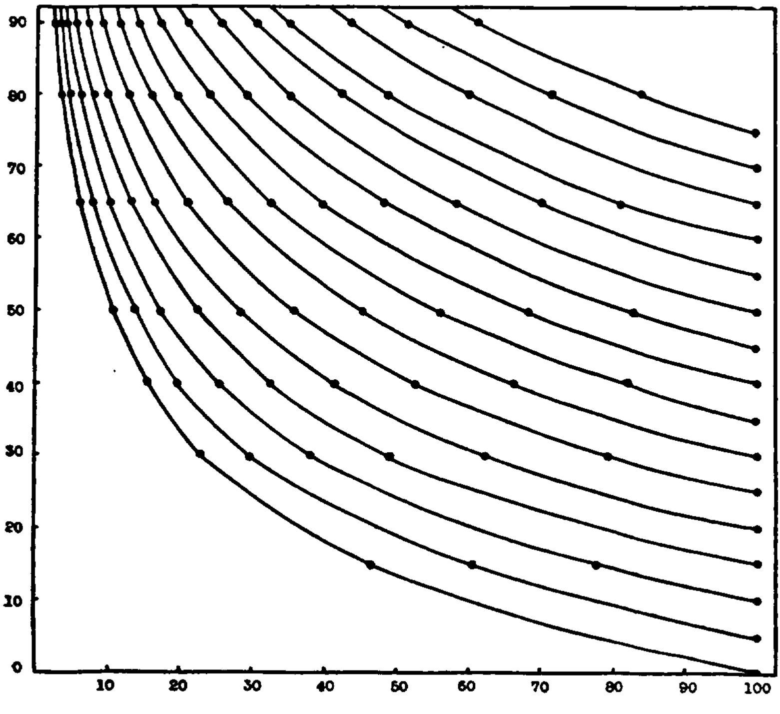
Table 7 gives the calculated values of Relative Humidity at different temperatures, and corresponding to the same actual given amounts of water vapour present. The method of calculation may be illustrated by example. The weights of water vapour present in air under various conditions of temperature and Relative Humidity are those obtained from tables.

At 30°F. the weight of vapour in saturated aqueous vapour is 1·943 grains. Raise the temperature to 90°F ; in the same volume will be 1·943 grains, less what has been expanded away according to ordinary gas laws ; it will, in fact, be

$$\frac{271 \cdot 9}{288 \cdot 0} \times 1 \cdot 943$$

Now the weight of vapour in saturation at 90°F. is 14·96 grains. Hence Relative Humidity—the percentage of the actual weight of vapour to the weight of vapour in saturation—is

$$\frac{271 \cdot 9}{288 \cdot 0} \times \frac{1 \cdot 943 \times 100}{14 \cdot 96} \text{ or } 11 \cdot 6$$



Relative Humidity

FIG. 1.

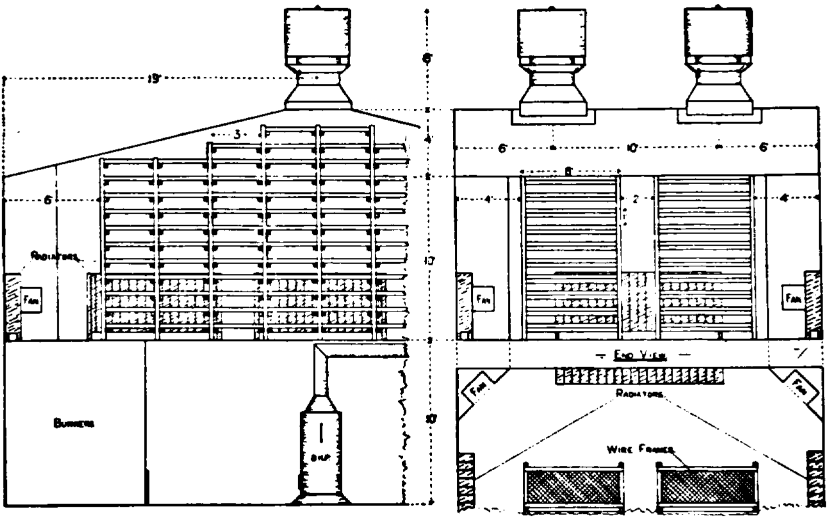
The calculated values given in the table form the basis for the accompanying graph (Fig. 1). Each line gives the Relative Humidity of air at temperatures above its dewpoint. It is evident that the raising of the temperature of any atmospheric air, saturated or unsaturated, from temperatures at and below 60°F., to temperatures of 80°F. or over, will produce Relative Humidity values of less than 50. It is further evident, therefore, that the production of a dry air is easy when the outside conditions are cool, say below 60°F., and that under such circumstances the

Table 7

Initial temperature of a saturated air	Resultant relative humidity at various higher temperatures																	
	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
0°F.	100			46·5			22·8		15·1		10·4			6·0			3·6		2·6
5°F.		100		60·4			29·6		19·7		13·4			7·8			4·7		3·4
10°F.			100	70·8			38·1		25·3		17·3			10·1			6·1		4·4
15°F.				100			49·0		32·5		22·2			13·0			7·8		5·7
20°F.					100		62·4		41·4		28·3			16·5			9·9		7·2
25°F.						100	79·2		52·6		35·9			21·0			12·6		9·2
30°F.							100		66·4	54·8	45·4		32·7	26·5		18·8	15·9		11·6
35°F.								100	82·1		56·1			32·7			19·7		14·3
40°F.									100		68·4			39·9			24·0		17·4
45°F.										100	82·9			48·3			29·1		21·1
50°F.											100			58·3			35·1		25·5
55°F.												100		70·1			42·2		30·6
60°F.													100	81·1			48·8		35·4
65°F.														100			60·2		43·7
70°F.															100		71·6		51·9
75°F.																100	84·7		61·5

danger lies in producing too dry an air. It is distinctly probable that unsatisfactory artificial drying is unsatisfactory for this very reason. With saturated outside air at temperatures over 60°F. it is impossible by warming to 80°F. to lower the Relative Humidity to 50, or to values below 50. This does not necessarily mean, however, that the introduction of such heated air into a drier will produce conditions too moist for drying, since the former conditions may probably be too dry.

As a means of producing in a drier a moderate degree of air movement, combined with control of the air conditions, it was considered that a drying chamber designed on lines somewhat similar to the style of a fish smoking



— Side View (Section). — — Plan (Section). —

kiln might offer possibilities. A source of heat at the base would cause the hot air to rise through the fish above. In picking up moisture as it rose, the air would became lighter, thereby helping the upward movement. Ventilator outlets at the top would take care of the egress of the moist air. It was thought to be very desirable to have heating inside the chamber, as it seemed easier to control the air of the chamber in this way. It seemed easier to regulate the mixture of heated outside air and moisture from fish on the spot than to regulate the entering air before mixing with an amount of moisture from the fish, which is very difficult to determine.

With these points in mind, the laboratory supervised the design and erection of a fish drying room for a local fish merchant. An existing room was utilised for the purpose, and any available building of a size to suit the quantity of fish an operator would wish to dry at one time can be adapted to the purpose. The room, approximately 35 feet long by 20 feet wide by 9 feet high at the sides, rising to about 14 feet at the centre, was fitted for tiers of wire netting trays in the centre, a clear space for working purposes being left all around and a narrow corridor running up the centre between the trays. As a source of heat, an 8 h.p. boiler was placed in a suitable location underneath, and steam was circulated to six pipe coil wall radiators, one at each end and two at each side. On the roof, two large ventilators were installed and inside the chamber four 14 inch oscillating electric fans were arranged, one at each corner, circulating air towards the centre and upwards. With regard to the entrance of outside air it may be pointed out that this is never a difficult matter. However, small sliding air inlet doors were made behind the end radiators and these could be opened or closed according to conditions. With regard to the capacity of this drier, the trays (just over one hundred, each 3 feet by 6 feet), were capable of taking around thirty-five qunitals of fish. However, as time went on, in view of the success attained, fish were hung up wherever space was available, and usually as many as seventy quintals were in the drier at one time. Simple plans of this experimental drier are attached to this text.

At the outset, the method of working the drier was as follows: The drier was loaded with partially-dried fish and, towards the end of this operation, steam was got up. A temperature of around 80°F. to 85°F. was considered best, but it may be remarked that an occasional higher temperature of short duration will not harm; the fish will not reach the temperature of the air for a considerable time later, and it is the temperature of the fish that matters. It is harmful to the fish if they rise to a temperature over 80°F. At six o'clock the heating and fans were stopped but the fish were left all night on the trays. The humidity overnight attained almost saturation point. Next morning steam was got up and the fans started, but it was generally after 10 o'clock before a temperature of 70°F. was reached. Thus, it was afternoon before the air in the drier was at its driest, a state of affairs corresponding to outside conditions. As the afternoon advanced, the dry air picked up moisture from the fish and the humidity gradually rose, and this tendency was aided after six o'clock by the cooling of the air. In this way of operating it was possible to get a fair degree of approximation to good average outside conditions and the final product was very satisfactory. At the outset of the experiments no attempt was made to dry fish without outside drying, but very satisfactory results were obtained in the case of the nearest attempt, where the fish had been outside for only two to three days.

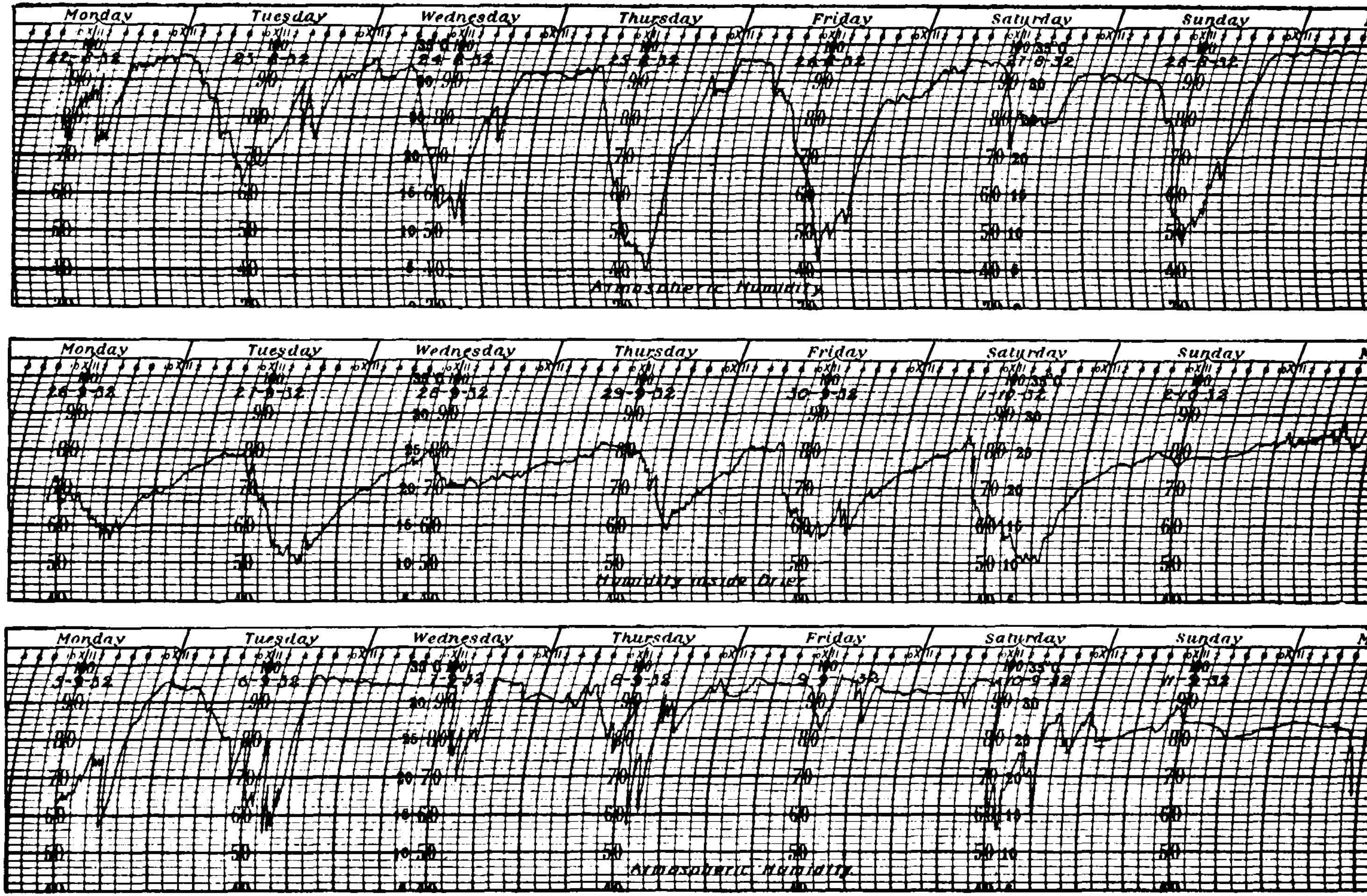

Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Atmospheric Humidity
Humidity inside Drier
Atmospheric Humidity

FIG. 2.

To illustrate how the air conditions inside the drier approximate to outside conditions, a reproduction is made of the record charts of a hydrograph for outside humidity and for humidity inside the drying room (Fig 2). It is apparent from a consideration of the three charts that the centre one showing the humidity inside the drier lies intermediate between the fairly good outside drying conditions represented in the first and the bad conditions of the third. In other words, humidity conditions inside the drier strike an average and maintain this average within narrow limits. It is of particular interest to follow the humidity conditions in the drying room as the fish dry. Thus, referring to the chart, on Wednesday the drier was loaded and the humidity that day did not fall below 70; on Thursday the humidity fell to 60, but did not remain at that value for long, while on Friday, the value 60 was maintained for several hours. The fish were getting drier, and on Saturday, the air in the drier reached the low moisture value of 50. Actually, the fish were removed on Monday morning as being satisfactorily dried. It is possible to read from the charts when fish were put in the drier and when removed. The chart reproduced shows the conditions for the last two days of the previous run, on Monday and on Tuesday. On Tuesday, the humidity value had fallen to 50 and the drying process was completed.

Fish at various stages of dryness were tried in the drier with satisfactory results and an attempt was then made to prolong the daily heating up to midnight, so as to reduce the drying period if possible. Satisfactory results were obtained even when operating night and day. One batch of fish had been on the outside flakes for only two days in the month of December, and the superior final qualities produced gave ample compensation for the increased cost of the drying. The most important feature of this drier is that it has demonstrated the advantages and, by its successful operation, the necessity of having such a method to which resort may confidently be had in the event of weather conditions being bad. It is, of course, highly improbable that fish need be dried entirely by artificial means. Although the added cost of such a procedure might indeed be justified by the production of a higher priced better average quality, it is certain that there will be spells of satisfactory outside weather conditions which should be availed of.

CONTROL OF CONDITIONS INSIDE THE DRIER.

We have already discussed the factors affecting evaporation, and, from experience with the experimental drier described, it would appear that satisfactory drying of fish is concerned with the rate of evaporation. Satisfactory results can be had when drying is more gradual than has been customary. We have seen, too, that neither high wind not direct sunshine is essential for evaporation, so that there is left for consideration the two factors of humidity and temperature. In considering the evaporation of water from fish, the general principles are the same as for pure water. There are differences in vapour pressure and probably the fish will not take the temperature of the surrounding air as soon as pure water, but general effects are the same in both cases.

We have already seen that, at any particular temperature, water exerts a definite vapour pressure or tension tending to change the liquid into the vapour state; a measure of this vapour tension is the pressure of the saturated aqueous vapour above the liquid, and evaporation will go on ûntil the back pressure of the surrounding aqueous vapour attains this value. In general, the atmosphere surrounding evaporating water already contains a certain amount of moisture which, of course, possesses a definite pressure. At any particular temperature, the difference between the vapour pressure of the moist air and the vapour pressure of the saturated air will give a gradient, on the steepness of which will depend the rate of evaporation.

At a higher temperature, the water will have an increased vapour tension, hence, to keep the gradient (and, therefore, the rate of evaporation) the same, the surrounding atmosphere will have to possess a similarly increased vapour pressure. This means that, in order to maintain the same rate of evaporation at a higher temperature as at a lower temperature, the humidity of the surrounding atmosphere must be greater. The effect of heat in a drier not only raises the vapour pressure of the evaporating liquid, but also raises the temperature of the surrounding air, thereby lowering the humidity and, therefore, the back vapour-pressure of the atmospheric aqueous vapour. The gradient is increased, and so the rate of drying is similarly increased. Fish become hard and over-dry on the surface probably owing to the progressively increasing rate of drying usually employed.

The accompanying chart (Fig 3), shows the relationship between temperature and humidity which will give the same rate of drying, assuming no air movement or constant air movement. It was compiled in this way: Various values for relative humidity at 65°F. were chosen. The differences between the vapour tension of water and the vapour pressure of air of the particular humidity at those temperatures were noted. To establish the corresponding humidities necessary to give the same pressure gradient at other temperatures, the differences between the vapour pressure of water at the new temperatures and the first established pressure differences gave the values for the necessary vapour pressures of the atmosphere. With the atmospheric vapour pressure values known, the corresponding relative humidity values were found:

Example :—

Choose a Relative Humidity of 50 at 65°F.

The vapour pressure of water at 65°F. is 15·83 mm.

The vapour pressure of air at 65°F. of Relative Humidity 50 is 7·8 mm.

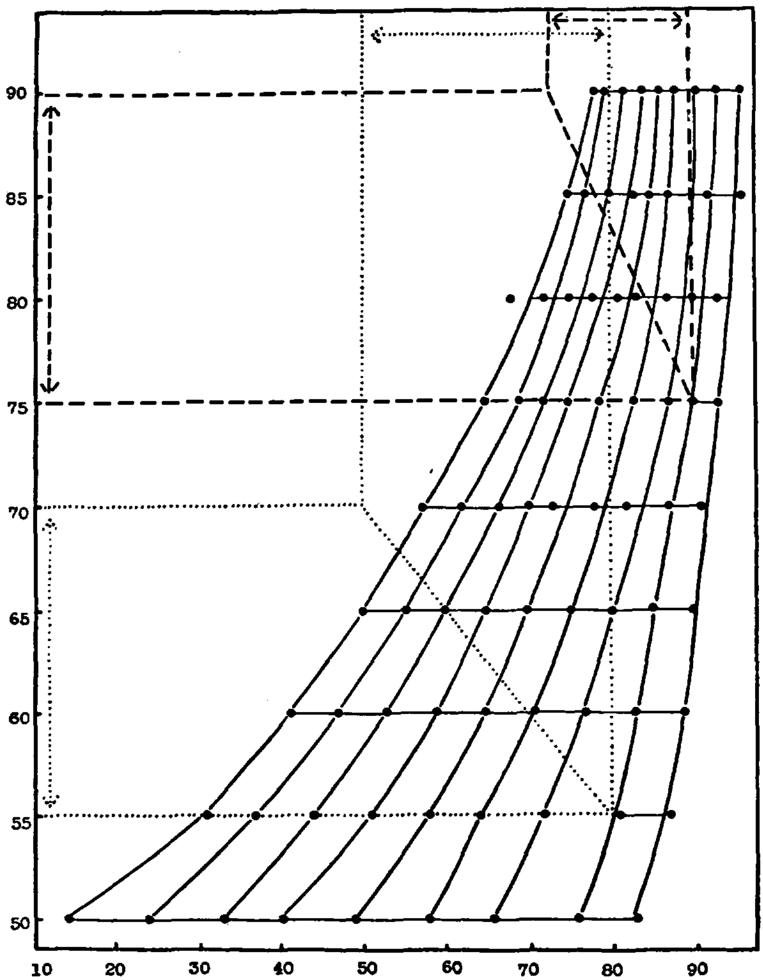


FIG. 3.

The difference, or gradient determining the rate of evaporation, is 8·03 mm.

Now take a temperature of 90°F. It is desired to find a Relative Humidity value giving the same gradient as before.

The vapour pressure of water at 90°F. is 35·72 mm.

The gradient desired is 8·03 mm.

Hence the desired vapour pressure of the atmosphere is 27·89 mm.
The Relative Humidity of an atmosphere with vapour pressure 27·89 at 90°F. is 78.

Thus, assuming the same degree of air movement, an atmosphere with a relative humidity of 78 at 90°F., should produce the same rate of evaporation as one of Relative Humidity 50 at the lower temperature 65°F. Other values were derived in a similar way, and are recorded in the table showing corresponding values of Relative Humidity at different temperatures giving the same " Driving Force of Evaporation."

Corresponding Values of Relative Humidity at Different Temperatures giving same " Driving Force of Evaporation."

50F.	55F.	60F.	65F.	70F.	75F.	80F.	85F.	90F.
14	31	41	50	57	65	68	75	78
24	37	47	55	62	69	72	77	79
33	44	53	60	67	72	75	80	81
40	51	59	65	70	75	78	83	83
49	58	65	70	73	79	81	85	86
58	64	71	75	78	83	83	87	89
66	72	77	80	82	86	87	90	92
76	81	83	85	87	90	90	92	(95)
83	87	89	90	91	93	93	(96)	(98)

The results of our investigations, therefore, show that there are theoretical reasons for maintaining fairly high humidities inside heated drying chambers. Good results have been obtained here in practice under conditions approximating to the theoretical, and it seems reasonable to attempt to obtain in the atmosphere of a heated drying room that humidity which gives the same rate of drying *as the observed lower humidity of a good cool day under outside conditions.*

When the fish are in the wet or green state the atmosphere of the drier will be very moist. There are, therefore, two methods available to increase the rate of drying to a degree comparable with good outside conditions.

These are :—

1. Keep the temperature low and raise the speed of air movement.
2. Allow the temperature to rise, leaving the air movement the same, and thus giving high temperature and high humidity.

The air movement in the drier can be maintained constant and, therefore, the second method seems more feasible, although slides could be adjusted over the ventilator openings. As the fish dry the atmosphere will become less moist. Therefore, in order to maintain the same rate of drying, it is necessary to adjust the temperature to a lower value.

Now, when speaking of good outside conditions, the minimum of humidity is the condition referred to, but it must not be forgotten that the variation is from approximately 80 at 8 a.m. to 50 at 2 p.m., with a rise again to 80 at 8 p.m. The range over a twelve-hour period is, therefore, 80–50–80, at a temperature ranging from say 55° to 70° and back to 55°.

Adjusting the temperature to 75°–90°–75°, the corresponding R.H. range is roughly 90–70–90.

The control of a drier would, therefore, appear to consist of :—

1. Maintaining a gentle air movement similar to outside air movement.
2. Maintaining a humidity range of 90–70–90 over a temperature range of 75°–90°–75°, so as to approximate to good outside conditions of 80–50–80 over a temperature range of 55°–70°–55°.

Note—A constant check should be kept on the humidity and the temperature adjusted accordingly.

Control of Conditions.

Control over the first effect is comparatively easy. In order to obtain the second effect, control must be exercised over two distinct factors.

1. Control must be kept on the appropriate conditions of temperature and humidity inside the drying chamber, by adjusting the temperature to suit the humidity according to the chart in Fig. 3.
2. Control must be kept on the humidity and temperature of the inflowing air according to the chart in Fig.1.

Thus, the question narrows down to a consideration of how the control of these two factors can be effected. It is doubtful if the heating of inflowing air is enough for this purpose. Thus, supposing air conditions in the drier become humid ; it is necessary to raise the temperature, and this can only be done by heating the inflowing air ; unfortunately, this heating will render the inflowing air less humid, and this, in turn, will help to dry the air in the drier, defeating the purpose of raising the temperature ; indeed, as a result of increased temperature and decreased humidity, the rate of drying will probably be increased to the very extent we are trying to avoid. While it may, even so, be possible to adjust things suitably, greater control in the shape of heating equipment inside the drier seems more possible and desirable. Under these conditions the procedure would involve the use of the outside heat to bring the inflowing air to a good degree of dryness, and then maintaining it at this constant humidity value, irrespective of outside conditions. Subsequent control in the drier might be maintained by radiators inside the chamber.

The ideal method of working would, therefore, appear to be as follows :—

A. Ascertain the outside temperature and humidity.
B. Raise the temperature of the inflowing air to such a degree that the humidity will have the agreed constant value, say 55. Use Fig. 1.
C. Allow this air to mix with the vapour in the drier.
D. Ascertain the temperature and humidity in the drier.
E. Adjust the temperature to suit the humidity according to Fig. 3.

As the fish get drier it may be advisable to raise the humidity of the inflowing air to perhaps 60 or 70. This is done, of course, by suitably adjusting the temperature. Once again, further and more effective control could be had with heaters inside the chambers.