THE PRODUCTION OF DRIED FISH

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This paper was prepared for the Fish Production and Marketing Service of the FAO Department of Fisheries by Mr. J.J. Waterman on an authors contract. Its intention is to provide information on the principles of fish drying, together with practical aspects of simple drying techniques for use in the tropics. A comprehensive coverage has been attempted although it is appreciated that there are innumerable traditional methods of fish drying in use around the world.

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Contents

1. INTRODUCTION

Drying is one of the most important methods of preserving fish throughout the world. Although drying is regarded as a traditional, even primitive, method of fish preservation in many developed countries, it is still of vital importance in the less well developed regions of the world, and will remain so for a long time to come. For this reason alone it is highly desirable that the experience accumulated during centuries of dried fish production, together with the knowledge that has been gained in more recent years by experimental workers in many tropical countries, should be readily available to all those who are concerned with the expansion and development of fish processing, particularly in those regions of the world where an improvement in the fishery can have a marked effect on the standard of living of the people in the community.

In this review there is a brief survey of the history of the dried fish industry, its present size and scope and its possible future. The theory and practice of drying fish are then explained in some detail. The reader should not be frightened away by the dreadful word theory - although the section on principles does discuss such matters as water content, salt content and the physics of drying, the story has been kept simple enough for the layman to tackle; the intention is merely to outline in non-technical language what goes on when fish are dried, with or without the addition of salt before drying.

Perhaps the most important section for those who are contemplating the setting up of a fish drying installation is section 5, which describes in some detail a number of the methods that have been used in various parts of the world, gives advice on improving present practice, and suggests the employment of fairly simple pieces of equipment to make the process easier and more reliable. Some reference is made to more sophisticated machinery, but the main emphasis throughout is on methods and equipment that are practicable in the most primitive of tropical fisheries. Obviously it is not possible to describe one, or even ten, methods that will meet everyone's needs; different species, different climate and different consumer preferences have resulted in hundreds of regional 'recipes' for drying fish, but it is possible to give some general guidelines that can be applied to most fisheries when modified to suit local needs, together with a selection of particular processes in more detail.

It is hoped that the practical man engaged in the development of the industry will be able to pick out some of the information given in this review and turn it to his own advantage by adapting it to his own particular environment. Only in the most elaborate and expensive installations can the drying process be called scientific; in most corners of the world the drying of fish is still very much an art or a craft, and only by having a go, by trial and error, will it be possible to find the best way of turning a given supply of fresh fish into a marketable dried product. No amount of theory and calculation, however well worked out, will produce a perfect method. Some simple experiments, under commercial conditions rather than on the laboratory bench, will work wonders. Some mistakes will be made, some fish will be spoiled, but the man who never made scrap never made anything.

The next section of this review, on cost and economics of drying fish, is of necessity a sketchy one. In any guide of this kind it is impossible to relate the cost of doing something in one part of the world to the cost of doing something similar at another time in another place. The multiple components that make up the total cost of producing and distributing a food, items such as labour, raw material, water, power, heating, warehousing, transport and so on can vary so enormously from country to country or region to region. Furthermore, any firm financial evidence that could be quoted, even for a particular fishery, would be out of date in these inflationary times, long before this review appears in print. Nevertheless some financial information is given from one or two tropical drying installations that have been costed; although the answers to the sums may not have much meaning, the way in which the answers are arrived at may serve as a starting point for someone needing general guidance on assessment of profitability.

Section 7 is short and to the point. Overseas advisers are often asked about the suitability of the freeze drying and dehydration processes for tropical fisheries, and here the reader, after being given a summary of the two methods, is discouraged from applying them to a low priced raw material in the hope of making a modestly priced dried product.

In sections 8 and 9 attention is given to the storage, distribution and consumer acceptance of the dried product, again in relation to the tropical environment. Advice is included on packaging, pest infestation, contamination by moulds, and on shelf life of dried products. Other aspects of quality, the problems of marketing and the need for consumer education are also briefly discussed. Finally, in section 10 there is a list of definitions, of both drying terms and dried fish products.

The information in this review has been drawn from a variety of sources, too many to acknowledge individually, but in particular from reports made by experts who have worked on the problems of drying fish in tropical countries; much of the practical advice offered here is based on the knowledge and experience of those field workers who have built and operated simple drying plants in various parts of the world.

2. THE DRIED FISH INDUSTRY

Man has been drying fish as a means of preserving it ever since he first learned to fashion simple fishing implements from bone in paleolithic times, and a combination of salting and drying as a means of keeping lean fish had certainly become established by the Bronze Age. Sundried salted split fish was commonplace in ancient Egypt, and international trade in dried and salted fish was considerable in the Mediterranean and the Middle East several centuries before the beginning of the Christian era.

Stockfish and klipfish were important staple food commodities throughout Europe in the Middle Ages, dried salted cod was being made around Newfoundland soon after its discovery, and early voyagers to Asia brought back many accounts of dried and salted fish. It is possible to distinguish that certain methods of treatment had by that time been found to be more suited to a particular environment, sometimes because of the prevailing climate, and sometimes because the technological level was about right for that community. For example, minor local variations in methods of making stockfish and klipfish in the North Atlantic countries resulted in the development of characteristic regional cures, and the methods then remained virtually unchanged for the next five hundred years. Again, because France had plenty of solar salt available, her Newfoundland fishery came to depend on salt curing, while the dry, bright climate and rocky coastlines of Norway and Iceland encouraged the development of the stockfish industry; other examples could be cited of cures developed to meet local needs that have persisted to the present day. Broadly speaking, the right combinations of the traditional curing processes of drying, salting and smoking that best resist spoilage have survived, and they remain in use until the technical and economic background that produced them gives way to a more advanced organisation. It then frequently happens that when a certain point is reached the old techniques are rapidly replaced in a relatively short period of time by new methods that conform more closely with the new conditions.

Generally speaking there has not been too much difficulty in the past in introducing new forms of fish products, mostly based on species that are familiar in an area and are already eaten fresh, provided they were more pleasant to eat than fish that had suffered to severe treatments of hard drying or heavy salting; thus in the nineteenth century the rapid spread of rail and road networks in Europe, and the ready availability of ice and mechanical refrigeration, made it possible to introduce reasonably fresh fish throughout many developed or rapidly developing regions, and to oust the traditional dried products within a fairly short time. Those cured products that remained became milder and blander; for example in Britain the kipper, the bloater and the finnan haddock replaced the red herring, the pickle cured herring and the hard salted lean fish to which the people had been accustomed. It can be argued that it is more difficult to replace one heavily cured product with another that is less familiar to a community, simply because it keeps better under local storage conditions; certainly the tasks of education and marketing can prove formidable. Nevertheless the successful introduction of stockfish to Nigeria at the beginning of this century can be quoted to dispute this argument.

In many areas of the world where drying is still the principal means of preserving fish, the social and technological level of a community precludes the possibility of introducing more advanced methods of preservation, including radical changes in the drying method itself. Mechanized drying for example, except in countries producing for export to less developed ones, is often impracticable for the same reasons that the introduction of ice plants or cold stores is impracticable and, when a country is ready to change to a higher technology, it is perhaps more logical to consider changing the method than to prolong the production of traditional cured products by mechanising an obsolescent process. Dried fish is a cheap, durable, if sometimes a somewhat unattractive food product that will continue to be made of necessity but, when a community is advanced enough to be ready for change, not necessarily of choice.

It is impossible to be precise about the amount of dried fish produced in the world because the fragmentary nature of the industry, particularly in developing countries, makes the collection of meaningful statistics extremely difficult. However, some broad estimates of world activity in the production of dried fish can be made. About 8 million tons, that is 20-25 percent of the present world catch for human consumption in the mid-1970s, are dried, salted, smoked, or treated by some combination of these processes each year. It is estimated that more than half of this amount, 4-5 million tons live weight, is dried in some way, either without the addition of salt or after a preliminary salting treatment, to yield perhaps 2 million tons of dried fish products. Since there is no clearcut division between what may be called a dried product and what may be also described as salted or smoked products, it is not possible to be more precise about the amounts produced in each category; for example, some West African fish products are dried to such an extent while being smoked that drying can be regarded as equally important, if not the more important part, of the process.

The total amount of fish used for curing has remained fairly steady over the decade 1965-1975, although the weight of cured products has increased; an increase in the amount of smoked fish being made may account for this trend to some degree, but it may also be an indication that more dried salted products are being made at the expense of dried unsalted ones, since the weight of dried salted fish is normally greater than the weight of dried unsalted fish made from the same amount of raw material.

Most of the fish caught other than for human consumption is also submitted to a drying process in order to make byproducts, principally fish meal for animal feeding, but this survey deals only with dried products destined for human consumption.

Production of dried fish products in the 1970s has fallen in all the North Atlantic countries except Norway, where a decrease in stockfish production has been more or less counterbalanced by an increase in the production of dried salted lean fish. Production has fallen in some countries because other outlets have been developed, for example in Angola where freezing and cold storage facilities have been expanded in recent years, but production has increased in many developing countries in Africa and Asia, often as part of a general plan to increase food production from marine sources; for example the output of sundried fish in India doubled between 1966 and 1972.

World production of stockfish, that is dried unsalted products of cod and related species, has fallen markedly in recent years. The trend in the four leading producer countries is shown in Table 1.

The trend in the manufacture of dried salted products from cod and similar lean species of fish is less easy to follow because some of the production recorded as wet salted is in all probability subsequently dried, possibly not always in the country of origin. The total amount salted has remained more or less steady in recent years, but the indications are that the amount subsequently dried has considerably increased. Table 2 gives the approximate amounts that were dried salted in the principal producing countries between 1966 and 1974, together with the world production figures for salted cod; most of the balance was presumably marketed in the first instance as wet salted fish.

Dried products made from sardine, anchovy and similar species are made principally in the Far East and in West Africa; there has been a steady rise in production in the last few years. The recent trend is shown in Table 3.

The products in the three tables account perhaps for less than a third of the world's dried fish production; the remaining proportion of the world's production of dried fish does not fall into any clearcut category, either by species or by product. Among the 1½ million tons or so of miscellaneous dried or salted products there were probably well over 1 million tons in dried form, produced in several dozen tropical countries. Notable large producers include Indonesia, India, Japan, Philippines, Vietnam and Angola.

It is estimated that somewhere in the region of 200 000 tons of dried fish a year crosses national boundaries at the present time; the remainder of the 1½ to 2 million tons produced is used for domestic consumption. Movements of stockfish are from Norway and Iceland, mainly to the traditional outlets in Italy and Nigeria. Dried salted cod from Norway, Canada and Iceland are exported mainly to South and Central America and to Italy. Spain exports considerable amounts to Portugal and to South America.

Among the identifiable movements of dried fish products between developing tropical countries, the traffic from Angola, mainly to Zaire and Mozambique, and from India and Pakistan to Sri Lanka, are among the larger operations. The other main movements are probably between countries within Southeast Asia.

It seems inevitable that declining resources of cod and related species in the North Atlantic will in future result in less fish being available at an acceptable price in this area for salting and drying for export. Almost all of the catch will be in much demand as chilled or frozen fish in Europe and in North America. Little if any will be surplus to these needs during the next few years.

In the developing countries, although there will be some new outlets for chilled and frozen products as new coastal processing facilities are developed, it is likely that for some decades the absence of good inland communications and refrigerated storage will mean the continued dominance of traditional cured products; as financial and technical aid to the third world continues, so the catching power of many developing nations will increase, thus providing more raw material at the quayside. Drying will remain one of the most important means of preserving this large addition to the world's food supply, but the degree to which the time honoured methods of processing will be modified, for example by the introduction of salting treatments where none was used before, will depend largely on the extent to which consumer acceptance can be influenced. Alternatively, any increased supplies of fish, particularly of highly prized species, may be preserved by more sophisticated methods, not for home consumption, but for sale to developed markets overseas, and the ensuing revenue used directly or indirectly for the purchase of supplies of other foods that would be more readily acceptable to people who traditionally have not been eaters of fish.

Attempts to improve the quality of dried fish products, and also to increase output by mechanizing the process, have sometimes been successful, but mechanization in a developing country implies ready availability of engine fuel or electrical energy; if a community is able to buy the necessary capital equipment and supply enough power to remove water rapidly from fish under controlled conditions, then the producer probably has to demand a much higher price for his goods in the market place. But when buyers are able to pay more for the product, the community may be sufficiently well developed to justify closer examination of competitive processing methods like chilling and freezing, methods that change the nature of the raw material less radically; the affluent society eats very little dried fish, however efficiently it can be produced.

Table 1

Stockfish production 1966-74 ('000 tons)

	1966	1967	1968	1969	1970	1971	1972	1973	1974
World total	41.0	40.0	32.0	31.0	27.0	21.0	21.0	28.0	37.0
Norway	25.2	26.5	18.6	19.4	12.3	12.0	10.5	12.5	10.5
Japan	4.8	3.6	4.3	4.3	7.1	7.0	6.7	7.7	9.7
Korea	1.7	1.0	6.1	1.2	2.2	1.0	3.4	5.9	15.4
Iceland	8.0	8.3	2.2	5.8	4.8	0.5	0.5	1.7	1.2
	39.7	39.4	31.2	30.7	26.4	20.5	21.1	27.8	36.8
Percent World total	97	98	98	99	94	97	100	99	99

Table 2

Production of salted cod etc. 1966-74 ('000 tons)

	1966	1967	1968	1969	1970	1971	1972	1973	1974
World total	392.0	446.0	438.0	390.0	406.0	388.0	395.0	330.0	344.0
Approximate dried salted production in:									
Canada	45.9	68.3	45.3	42.5	33.6	33.8	29.5	20.8	27.0
Japan	10.8	10.2	11.8	10.1	11.7	15.5	13.2	12.0	12.9
Norway	35.0	37.7	38.5	35.9	45.2	53.4	52.5	58.9	56.7
Iceland	0.9	1.5	4.9	3.3	4.6	6.3	6.5	5.4	5.7
U.K.	3.8	3.4	4.3	3.2	3.4	2.9	2.8	1.2	0.7
	96.4	121.1	104.8	95.0	98.5	111.9	104.5	98.3	103.0
Approximate % World total dried salted	25	27	24	24	24	29	27	30	30

Balance presumably wet salted, some of which may subsequently have been dried.

Table 3

Production of dried or salted sardine etc. 1966-74 ('000 tons)

	1966	1967	1968	1969	1970	1971	1972	1973	1974
World total	257.0	290.0	261.0	326.0	332.0	305.0	367.0	375.0	370.0
Amount thought to be mainly dried or dried salted in:									
Japan	92.8	96.9	91.2	115.5	99.2	130.0	136.1	144.4	142.4
Ghana	52.2	72.3	65.9	98.1	127.3	72.8	120.6	-	-
Philippines	35.6	37.7	40.0	44.9	52.1	53.7	54.8	35.7	34.2
Korea	9.3	9.8	3.9	7.1	2.8	4.0	7.7	14.7	23.3
	189.9	216.7	201.0	265.6	281.4	260.5	319.2	194.8	199.9
Approximate % dried or dried salted	74	75	73	79	82	82	84	52	54

3. WHY DRY FISH?

As soon as a fish dies, spoilage begins. Spoilage is the result of a whole series of complicated changes brought about in the dead fish tissue by its own enzymes, by bacteria and by chemical action. Millions of bacteria and other microorganisms, many of them potential spoilers, are present on the surface of the fish, in the slime on the skin, on the gills, and in the intestines of the living fish. They do no harm because the natural resistance of a healthy fish keeps them at bay. Soon after the fish dies, however, bacteria begin to invade the tissues. Another important series of changes is brought about by the enzymes of the living fish which remain active after its death. Some of these enzyme reactions are involved in the flavour changes that occur in the first few days of storage, before bacterial action has supervened. In addition to the enzymic and bacterial actions, chemical changes involving oxygen from the air and the fat in the fish may produce rancid odours and flavours.

One of the most common ways of combating spoilage is to control the temperature at which the fish is kept; by sufficiently reducing the temperature the bacterial and enzymic actions in fish can be slowed down or stopped almost entirely. The chilling and freezing processes are based on this principle of preservation. On the other hand, if the temperature of the fish can be raised high enough, the enzymes and bacteria can be made permanently inactive; if the fish is then protected against re-infection, it will keep indefinitely. This is the principle on which the canning and other heat processing techniques are based.

However, the chilling, freezing and canning processes all require a certain amount of equipment, and chilled and frozen products have to be kept cold during storage and distribution. But control of temperature is not the only means whereby spoilage of the product can be retarded. The application of salt or of wood smoke to the fish, or the removal of water from the fish, are the most common long established ways of making products that can be kept for some time at ordinary temperatures.

Common salt, that is sodium chloride, if present in sufficient strength, will slow down or prevent bacterial spoilage of fish. This property of salt is used in salt curing to make products that will keep in good condition at ordinary temperatures for a long time. This traditional process is now less used in the developed countries than it was formerly, because there has been a general decline in the taste for heavily salted products, especially where the corresponding fresh and frozen commodities are much more readily available. There are two main types of salt curing. Dry salting is done by burying fish in salt and allowing the brine liquor to escape. After a period in salt, the product is then usually dried. Dry salting is suitable for lean fish such as cod, but cannot be used successfully for fatty fish such as sardine or anchovy. Pickle curing, in which the fish is preserved in airtight barrels in a strong pickle formed by salt dissolving in the body fluids, is used mainly for fatty fish. Immersion of fish in brine is also used as a preliminary treatment for many tropical species, both lean and fatty, before drying them or smoking them.

Some of the chemicals in wood smoke will destroy spoilage bacteria and this effect can also be used to advantage in preserving fish. But the production of wood smoke normally implies a fire and the generation of heat, and when the fish is subjected to the smoking process, it also becomes dried; in most smoking treatments the drying is often the more important part of the preservation process. Again in many traditional products salting was and is often a preliminary step to smoking, so that smoked products with a long storage life rarely owe their keeping qualitities to the preservative effect of wood smoke alone.

Water is essential for life, and microorganisms are no exception in requiring plenty of water for their growth and multiplication. Lack of water, or loss of it, can bring to a standstill the activities of the bacteria and moulds that spoil fish, and hence drying can be used as a means of preservation. Fish can be dried by the most primitive of methods, for example by merely hanging them in the sun and the wind, or over a fire; hence drying is a

Drying, like all the traditional methods, alters the nature of the raw material, often irreversibly. When water is again added to a hard dried fish product, and the reconstituted product is then cooked, the texture and the flavour of it are not those of the fresh fish from which it was made. The fibres in the flesh become tougher and more chewy, and some of the enzymatic changes that have gone on slowly during storage will have produced different, stronger flavours, even when all bacterial action has been stopped. Furthermore, any fat present in the flesh may become rancid during storage, and thus impart other less attractive flavours to the product. In spite of these changes, dried fish is still an acceptable food in many parts of the world. It is still a nutritious protein food, important in diets that would otherwise be protein deficient. Dried fish is usually preferable to badly spoiled fish, and its typically strong flavours are often preferred in some communities to the blander taste of chilled or frozen products.

To go back to the question asked at the beginning of this section - why dry fish? Dead fish, untreated in any way, will keep for only a very short time, a matter of days or even hours before they become inedible. In many tropical fisheries, methods of preservation that require complex equipment and a power supply are out of the question. Salting, smoking and drying are methods that can be applied with the minimum of equipment by relatively unskilled workers. Smoking is usually combined with one or both of the other methods, so that the choice perhaps lies between salting and drying. Both have their place in fish preservation and the choice between them may depend on the type of fish, the climate, the availability of salt, the tastes of the people who are to eat the product, the length of storage time required, the prevalence of pests and moulds and so on; often the best answer is a compromise, a combination of salting and drying, and perhaps smoking as well.

4. THE PRINCIPLES OF DRYING

The water content of fresh lean fish is typically about 80 percent. In fatty fish the water content is usually less, with the fat in the fish replacing an equivalent amount of water. Thus a sardine with 20 percent fat content for example would have a water content of about 60 percent.

When the water content of fish falls below 25 percent of the wet weight, bacterial action stops, and when the water content is further reduced to below 15 percent, moulds cease to grow. When salt is added to the fish before drying, less water needs to be removed to achieve the same effect, and a product with a water content of 35-45 percent, depending on the amount of salt present, is often dry enough to inhibit the growth of moulds and bacteria under most climatic conditions.

Traditionally, water content expressed as a percentage of the weight of the product has been the means of describing the dryness of a fish or fish product in relation to its resistance to spoilage. This term, water content, is used throughout this review, but research in recent years has indicated that a property known as water activity may be a more accurate guide, and the meaning of this term is given here in case the reader comes across it. Water activity, sometimes expressed as the equilibrium relative humidity erh, is a measure of the free or available water in a food. By this is meant the water that is not linked to other components of the food, and which is thus free either to react chemically or, in spoilage, to support the growth of microorganisms. The water activity of pure water is assigned the value of 1, and the water activity in a food is expressed as a fraction relative to pure water. For example, fresh fish has a water activity above 0.95. Most spoilage bacteria will cease to grow in a food whose water activity is below 0.9, the growth of moulds is inhibited below 0.8, and halophilic, that is saltloving, bacteria do not grow below 0.75.

The other term used, equilibrium relative humidity, is expressed as a percentage and is numerically equal to the water activity multiplied by 100. The erh can be directly measured to provide a single common index for the comparison of foods; for example a producer or distributor would be able, given the erh of each of a number of fish products with different salt and water contents, to assess the susceptibility of each product to spoilage in a particular climate, and be able to decide on the best means of packaging to give the required shelf life. Take for example a dried salted product whose water activity had been found to be 0.80, and its equivalent erh is 0.80 x 100 = 80 percent. The erh value tells us that when the product is kept in air with a relative humidity below the product erh, say 75 percent, the product will give up water to the air and become drier in store; on the other hand, if the relative humidity of the surrounding air were, say, 85 percent a product with an erh of 80 percent will then pick up water during storage, and would require to be protected by some kind of water resistant wrapper.

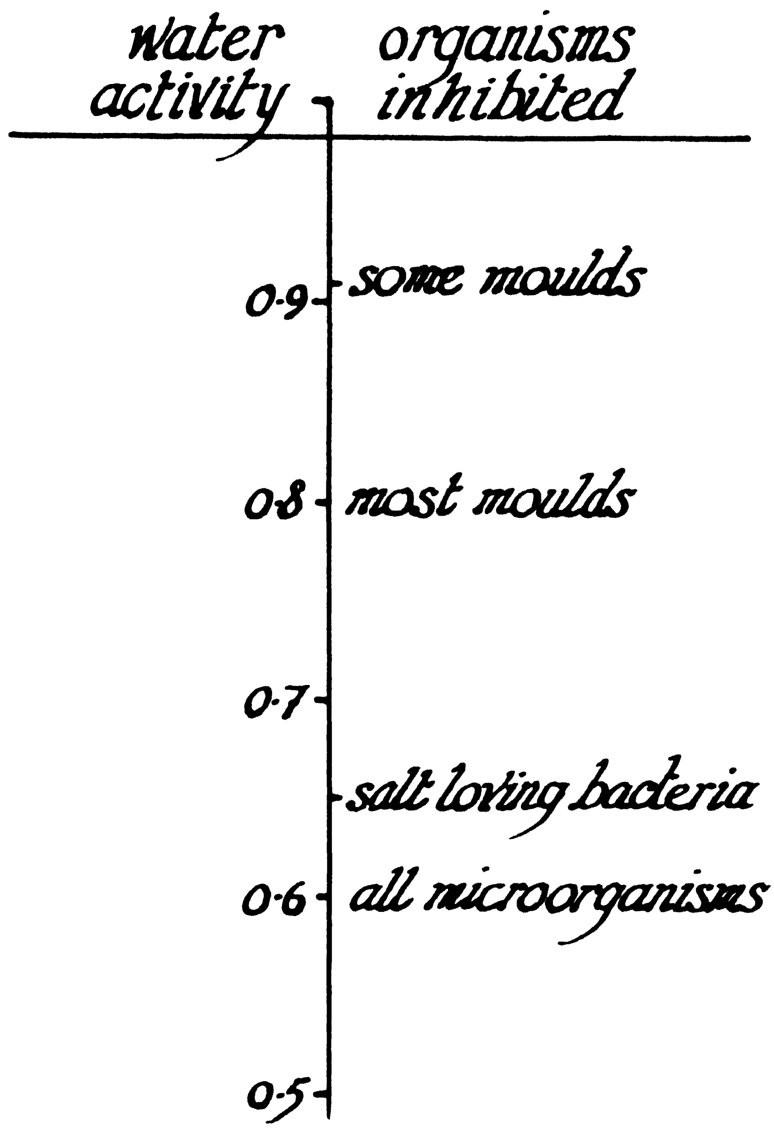


Fig. 1 Relationship between water activity and growth of micro-organisms

General adoption of the terms water activity and equilibrium relative humidity, instead of the more conventional term water content, is largely dependant on the perfection of suitably adapted measuring instruments, and such equipment is being developed, but until they are readily available commercially, the fish processing industry is likely to continue measuring water content. Since water content is sufficiently accurate for most commercial purposes this term is used throughout the rest of this review.

Water content is usually expressed on a wet weight basis, and this is the form in which the term is used here. However, the water content can be given in a number of ways, some of which are explained here, and whenever some information is being given about a process or a product, great care should be taken to ensure that the basis on which the water content has been measured is understood. This point is best explained by giving some examples of how the different forms of expressing water content are arrived at.

The percentage water content on a wet weight basis means the weight of water in a wet solid, divided by the weight of the wet solid, and multiplied by 100. Let us take a fishy example. A dried fish weighs 1 kg. The weight of water in it is measured, perhaps by heating the product in an oven until all the water has evaporated; the loss in weight, that is the weight of water in the product, is found to be 150 g. The percentage water content of the 1 kg fish, on a wet weight basis, is:

$$wc_{wb} = \frac{\text{weight of water in product}}{\text{wet weight of product}} \times 100 = \frac{150\ g}{1000\ g} \times 100 = 15\%$$

where wc_{wb} means water content, wet basis.

When percentage water content is expressed on dry weight basis, this is defined as the weight of water in the wet solid divided by the weight of the dry solid and multiplied by 100. Let us look again at the dried fish used in the first example, weight 1 kg, containing 150 g of water. Percentage water content on a dry basis is:

$$wc_{db} = \frac{\text{weight of water in product}}{\text{dry weight of product}} \times 100 = \frac{150\ g}{(1000 - 150)\ g} \times 100$$

$$\frac{150}{850} \times 100\ g = 17.6\%$$

Sometimes when a product has been salted as well as dried it is thought to give a better basis for comparison if the water content is expressed on a salt-free basis, using either the wet weight or more usually, the dry weight. How does this affect the calculation? Taking our 1 kg dried fish with 250 g of water still in the product and also 100 g of salt, the water content on a salt-free wet basis is determined like this:

$$wc_{sfwb} = \frac{\text{weight of water in product}}{\text{weight of wet solid} - \text{weight of salt}} \times 100$$

$$= \frac{250\ g}{(1000 - 100)\ g} \times 100 = \frac{250}{900} \times 100 = 27.8\%$$

where wc_{sfwb} = water content on a salt-free wet basis.

The water content of the same product, measured on a salt-free dry basis is:

$$wc_{sfdb} = \frac{\text{weight of water in product}}{\text{weight of dry solid} - \text{weight of salt}} \times 100$$

$$= \frac{250\ g}{((1000 - 250) - 100)\ g} \times 100 = \frac{250}{650} \times 100 = 38.5\%$$

If we repeat the water content calculations on a wet and a dry weight basis, but without paying any regard to the weight of salt present, the sums then look like this:

$$wc_{wb} = \frac{250\ g}{1000\ g} \times 100 = 25.0\% \qquad wc_{db} = \frac{250\ g}{(1000 - 250)\ g} \times 100 = 33.3\%$$

Thus in this simple example, for the same product in the same state of dryness, it is possible to quote the water content as being anything from 25-38.5 percent, depending on the basis on which the calculation is made. Therefore it is most important, when quoting a water content, to know how it was derived, so that it can be compared with other figures arrived at in the same way.

Just to complicate things further, yet another basis is sometimes used when the dried salted fish is also a fatty one. The water content may then be expressed on a salt-free, fat-free, usually dry weight basis. Using the same example yet again, a dried salted fish product containing 250 g of water, 100 g of salt and, in this instance, 50 g of fat, the water content on a salt-free, fat-free, dry basis, wc_{sffdb} then is:

$$wc_{sffdb} = \frac{\text{weight of water in product}}{\text{weight of dry solid} - \text{weight of salt} - \text{weight of fat}} \times 100$$

$$= \frac{250\ g}{(1000 - 250 - 100 - 50)\ g} \times 100 = \frac{250}{600} \times 100 = 41.7\%$$

The degree to which a product has been dried is sometimes described by quoting either the percentage loss of weight during drying, or by stating what percentage of the water has been removed. Let us examine the calculations involved, using our 1 kg dried fish containing 150 g of water. The amount of dry material in the product is therefore 850 g. If we assume the weight of dry material has remained unchanged during the process, and that the water content of the original fish was 80 percent, then the composition of the fish before and after drying was as follows:

850 g dry material +	3400 g water =	4250 g total weight at start	
20%	80%	100%	
850 g dry material +	150 g water =	1000 g total weight at finish	
85%	15%	100%	

The percentage of water lost is the difference between the weight of water at the start and the weight of water at the finish, divided by the original weight of water and multiplied by 100. The sum for the dried fish in the example is:

$$\%\ \text{water lost} = \frac{3400 - 150}{3400} \times 100 = \frac{3250}{3400} \times 100 = 95.5\%$$

The percentage weight loss in drying is the difference between the original weight of the fish and its weight at the finish, divided by the original weight and multiplied by 100.

For the example given, the percentage weight loss in drying is:

$$\frac{4250 - 1000}{4250} \times 100 = \frac{3250}{4250} \times 100 = 76.5\%$$

To sum up, the fish in the example has had its original water content of 80 percent reduced to 15 percent by drying; it has lost 95.5 percent of its water content in the process, and has lost 76.5 percent of its total weight.

Finally, the reduction in total weight can be expressed in another way as the yield. The yield of product, given as a percentage, is the final weight divided by the original weight, multiplied by 100. The original weight in the example was 4250 g, and the final weight was 1000 g.

$$\text{Yield} = \frac{1000}{4250} \times 100 = 23.5\%$$

The yield, 23.5 percent, plus the weight loss, 76.5 percent, of course, equals the original weight, 100 percent.

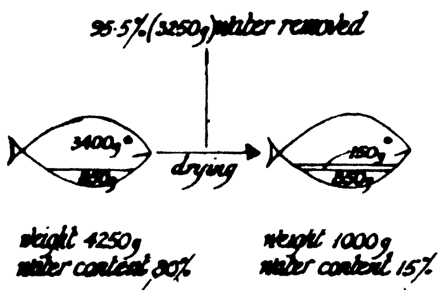
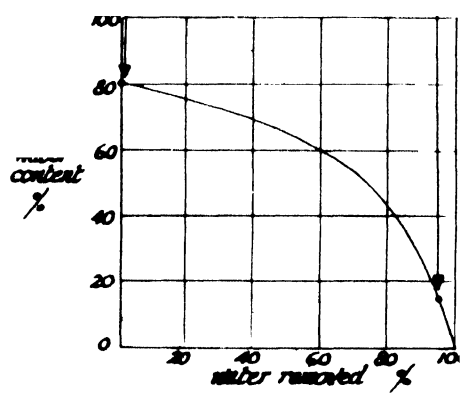


Fig. 2 Weight loss during drying



Already a number of terms like relative humidity have been mentioned; some of these are defined and explained in the text as we go along, but all of the terms commonly encountered in association with the fish drying process are listed and briefly defined in Section 10.

The term drying usually implies the removal of water by evaporation, but water can also be removed from fish by other methods, for example by applying pressure to it, by adding salt, or by using absorbent pads, but the term drying throughout this review normally means evapora-

When fish are dried in air, there are two distinct stages in the process; in the first stage, water on or close to the surface of the fish evaporates, and the drying rate depends only on the temperature, the speed of movement, and the relative humidity of the air. If the air conditions remain constant, then the drying rate remains constant. This is known as the constant rate period.

Once the surface water has evaporated, water can then evaporate only as fast as it can reach the surface of the fish from within. The rate of diffusion from the deeper lying parts of the fish becomes progressively slower as drying proceeds, and eventually the rate of evaporation no longer remains steady, but starts to fall. This second stage is known as the falling rate period

The principles of drying are somewhat different during the two stages, and the main principles for both the constant rate period and the falling rate period are given below. These have been deliberately oversimplified here for clarity, since the drying process is a rather complex one.

The first stage in drying is the constant rate period. During the constant rate period the following principles apply:

The higher the speed of the air flowing over the fish, the faster the water evaporates.

The higher the air temperature, the faster the water evaporates.

The drier the air, the faster the water evaporates. The rate of evaporation depends directly on the difference between the water vapour pressure in the air and the water vapour pressure at the surface of the fish. The dryness of the air is usually expressed as relative humidity, that is the weight of water vapour in it expressed as a percentage of the saturation weight at that temperature.

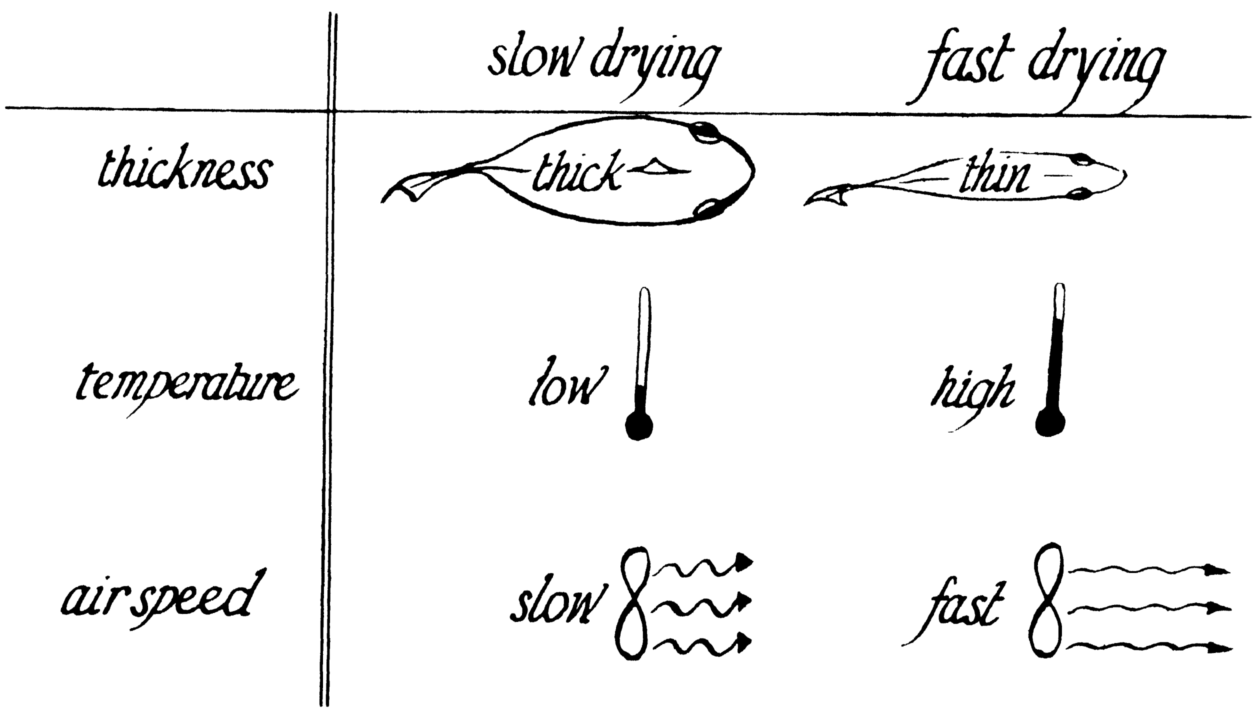


Fig. 3 Some of the factors affecting drying rate

A thin fish, or piece of fish, dries faster than a thick fish of the same weight, because the thin fish has a proportionately greater surface area.

The faster the water evaporates, the shorter will be the duration of the constant rate period; a greater proportion of the weight can be evaporated during the constant rate period when drying is slow.

The constant rate period is shorter for fatty fish than for lean fish of the same thickness.

The second stage in drying is the falling rate period. During the falling rate period, the following principles apply:

The faster the water diffuses from the layers beneath the surface of the fish, the faster the water evaporates.

The drying rate does not depend on the speed of the air passing over the fish.

The drying rate does not depend on the humidity of the air, provided the air is not saturated.

The higher the temperature of the air, the faster the water diffuses to the surface of the fish.

The leaner the fish, the faster the water diffuses to the surface of the fish.

The thinner the fish, the faster the fish dries, because the diffusion path to the surface is shorter.

The greater the amount of added salt, the more slowly the water diffuses to the surface.

There comes a point in any fish drying process when it is impossible to remove any more water from the fish. This point is dependent on the relative humidity of the air. The minimum water content obtainable at different relative humidities is shown in Table 4.

Table 4

Effect of humidity on final water content of lean fish

Relative humidity of the air %	Minimum water content obtainable in fish %
20	7
30	8
40	10
50	12
60	15
70	18
80	24

Thus it would be impossible to dry stockfish to below 15 percent water content in air that had a relative humidity of 60 percent. The minimum water content that can be achieved at a particular relative humidity is known as the equilibrium water content.

<u>Heat required for drying</u>. During evaporative drying, water leaves the fish in the form of water vapour. To change water into water vapour, heat is required. The required heat will be drawn from the surroundings and, if no additional heat is supplied, the surroundings will cool; the fish and the air around it will drop in temperature. Thus to maintain the drying process at constant temperature, the heat used for evaporation has to be put back into the process from some external source. In natural outdoor drying, the source of heat is the sun. In artificial drying, the extra heat has to be supplied by perhaps a fire, or a steam boiler or an electric heater, and the amount of heat to be added has to be known when designing the process. For every 1 kg of water that has to be evaporated, 550 kcal (2 300 kJ) of heat must be added to the system. Slightly more heat has to be added if the drying is being done from fish in the frozen state, as in freeze drying; 620 Kcal (2 600 kJ) of heat are required to change 1 kg of ice into water vapour.

<u>The presence of salt</u>. When salt is added to the fish before drying it, the drying process becomes more complex. The main feature of salting is the removal of some of the water from the flesh of the fish and its partial replacement by salt. The main factors affecting the rate of uptake of salt are as follows:

The higher the fat content of the fish, the more slowly is salt taken up and water lost.

The thicker the fish, the more slowly the salt diffuses into the flesh. The concentration of salt at the centre of a fillet 2.5 cm thick may reach say 10 percent after 24 hours in salt; it may take 3 days to reach the same concentration for a fillet of the same fish 5 cm thick.

The staler the fish, the quicker the uptake of salt and the greater the weight loss.

The higher the temperature, the quicker the uptake of salt.

Table 5 shows the effect of temperature on salt uptake in lean fillets:

<u>Table 5</u>

Percentage salt in lean fillets 2.5 cm thick

Temperature of process	Time in Salt		
	1 day	2 days	3 days
5°C	1.1	4.0	14.1
27°C	4.8	8.6	15.2

Pickle curing or immersion in brine is usually more suitable than packing in dry salt as a preliminary to drying in most tropical processes, and in pickle curing the weight changes are often complicated. With fatty fish like herring or sardine there is usually a marked loss of weight to begin with, accompanied by a rapid intake of salt into the flesh. Afterwards the fish gradually gain in weight again until, in temperate climates, the cured fish are back to the weight of the fresh fish after about 10 days in the pickle. The explanation for the complex weight changes during salting is not fully known.

The addition of salt to the fish before drying affects the drying process in the following ways:

The higher the concentration of salt, the greater has been the water loss before drying: hence less water remains to be removed during drying.

The higher the concentration of salt, the less need there is to remove water, because the additional preservative effect of the salt will give a partially dried product the same storage life as its unsalted but more heavily dried counterpart.

The higher the concentration of salt, the more slowly the fish will dry.

The presence of salt reduces the water vapour pressure in the fish, because a salt solution has a lower vapour pressure than pure water. This means in practice that most salted fish will not dry readily in air whose relative humidity is higher than 75 percent, because the salt will absorb water vapour from the surrounding air.

The effect of drying in a vacuum. Water evaporates more quickly in a vacuum. Rapid evaporation keeps the product cool, thereby reducing bacterial and enzymic spoilage during drying. Since little or no oxygen is present there is also no undesirable oxidation of fat in the fish during drying. If the pressure in the vacuum cabinet is sufficiently low the fish freezes and remains frozen whilst it dries. This process, known as freeze drying, has a further advantage that the material, having been dried in a frozen state, retains an open structure that encourages reconstitution more readily than fish dried in air. The advantages and disadvantages of vacuum drying and freeze drying are commented on further in section 7.

Optimum conditions for natural drying. For successful production of naturally dried products in tropical climates, the following conditions should apply:

The air temperature should be high enough to ensure rapid drying, but not so high that the outside of the fish becomes scorched or casehardened before the inside has dried sufficiently; a temperature above 35°C can sometimes cause difficulties, but temperatures of up to 43°C have been used in some tropical trials without too great an amount of damage, as described in section 5.

The air should be dry enough to permit drying of the fish to a water content below 25 percent to prevent bacterial spoilage, and preferably to below 15 percent to prevent growth of moulds. A higher final water content may be acceptable when some salt is present. It is difficult to make a durable product or to store it in air with a relative humidity above 75 percent.

The raw material should be lean rather than fatty, unless the consumer is prepared to accept some degree of rancidity in the dried product.

Unless the whole fish is thin, it should be cut into thin pieces, or split open and laid flat, to permit rapid drying, and should in any event be gutted and cleaned to reduce spoilage during the drying process. Procedures should be as hygienic as possible, and some attempt should be made to reduce insect infestation.

Where the consumer is prepared to accept the presence of some salt in the finished product, a preliminary salting treatment will shorten the drying time without reducing the shelf life, and in some circumstances the combined preservative effect of salting and drying, coupled with reduced opportunity for spoilage during the drying process, may give a longer storage life for the product.

If a preliminary salting step is introduced, the following conditions should apply.

The fish should be immersed in brine rather than in dry salt; the required concentration will be achieved in a shorter time with less risk of spoilage.

Where necessary the fish should be cut into thick pieces, or split open and laid flat to permit rapid salting; the thin pieces or split fish will then also be in a form suitable for subsequent drying.

Lean fish are preferable to fatty fish, since they take up the salt and lose water more quickly; if fatty fish are used, air should be excluded during the brining process to reduce rancidity; keep the fish completely covered with brine throughout.

Wherever possible use a full-strength brine, that is a saturated solution, and control the salt uptake solely by time of immersion. This makes procedure easier for the operator than attempting to vary the brine strength, and makes it easier to compare one trial process with another when trying to establish the optimum.

Although stale fish take up salt more quickly than fresh ones, fish for salting and drying should always be as fresh as possible; poor initial quality will inevitably result in poor products.

Use a well aged salt for making the brine; there will be less chance of introducing harmful spoilage microorganisms.

The brine should be kept as clean as possible, and changed as frequently as the cost of the process will allow.

In general, in salting as in drying the higher the temperature, the faster the process, but a balance has to be achieved because the higher the temperature the faster the fish spoils during processing, and the harder it becomes to maintain the equipment and its surroundings in a clean condition; only practical experiment can determine whether any attempt has to be made to conduct the salting process in a cool place.

Optimum conditions for controlled drying. The optimum air conditions for drying salted lean fish at a constant temperature in a temperate climate are well established. Whilst these conditions cannot be transferred without adjustment to any tropical environment, they can serve as a guide and reference point from which to start finding out the best local processing conditions. For most tropical applications, simple control of temperature with the object of keeping it steady throughout the process may be all that can be hoped for, but in some installations controlled change of temperature during the process may also be possible. Control of humidity may be much less feasible, but the waterholding capacity of the air may sometimes be increased simply by raising the temperature to the maximum the raw material will stand.

The speed of the air passing over the fish should be 1–2 m/s; a higher air speed will improve the initial drying rate, but will inevitably shorten the first stage of drying, the constant rate period. Once the second stage is reached, the drying rate falls, and in practice there is unlikely to be any reduction of the total drying time as a result of speeding up the air flow; higher air speed also means greater fan power and thus higher running costs.

In temperate climates, an air temperature of 25-30°C, with an optimum of 27°C, has been found by experience to give the best results. There seems every indication that in many tropical situations the raw material can be subjected to a higher air temperature without making the product too unattractive to the consumer. Temperatures up to 43°C in field trials have been claimed to be workable without visible damage to the fish; the main advantage is that in humid climates the waterholding capacity of the air is much increased without the need for expensive dehumidifying devices.

The relative humidity of the air should be between 45 and 55 percent at the inlet of the dryer; a lower rh may result in premature casehardening of the fish, thus preventing diffusion of water from the deeper lying parts of the fish to the surface. Too high a relative humidity reduces the drying rate; drying time then becomes so long that spoilage becomes unacceptably excessive before the process is completed. The drying of salt fish often becomes impossible when the relative humidity exceeds 73 percent.

In temperate zones, the technique of press piling of the fish between periods of drying in a tunnel shortens the total drying time for salt fish. Press piling allows diffusion of water to the surface to continue outside the dryer so that the water can be removed during the next tunnel drying stage. Unless cool, clean storage space were readily available, it is likely that the introduction of a press piling step into the process of drying salt fish in the tropics would merely provide a further opportunity for spoilage and infestation to occur without offering much material advantage.

5. PRACTICAL DRYING IN THE TROPICS

This section is concerned with practical evaporative drying in a hot climate; the drying of both salted and unsalted fish products is discussed, and the techniques of salting as a means of removing water prior to drying are also mentioned where these preliminaries are a key part of the whole process. Preservation by salting alone is not dealt with.

There are hundreds of different dried fish products in the world, and a great number of ways of making them. Some of the products are highly prized, some are tolerably pleasant, while others are barely acceptable except as an alternative to starvation. The intention here is not to persuade producers of dried fish to make standard products; the raw material, the climatic conditions and the markets are all so different in different regions that uniformity is neither possible nor desirable. Some of the principles to be observed have been outlined already. Here the intention is to give existing producers, particularly those operating on a modest scale in the tropics, some suggestions for improving their methods at small expense, and to help those who are planning or advising on the establishment of a dried fish industry of some kind. The information is aimed particularly at remote communities where good power supplies, advanced technical skills and good communications are the exception rather than the rule.

Of the many accounts of regional methods on record, it is unfortunate that all too often the essential details are missing that make all the difference between haphazard procedure dependent largely on luck, and a controlled reproducible method. This is rarely the fault of the recorder; in all probability the process times and temperatures, brine strength, water content and other factors have never been measured, let alone set down on paper.

Therefore it is difficult to tell others how to use such methods, or to comment on how they might be improved. But of those tropical drying processes that have been reasonably well documented, a selection has been made and the details presented here, so that intending processors elsewhere can attempt some variation of them to suit their own local conditions.

Dried fish products may be divided into groups in several different ways, for example into those that are dried without salting, as opposed to those where drying is combined with salting or smoking; the products can be divided on the basis of the raw material, for instance those made from lean fish and those made from fatty fish, or products made in temperate climates can be separated from those made in tropical climates. The only division made here is between naturally dried products and artificially dried ones.

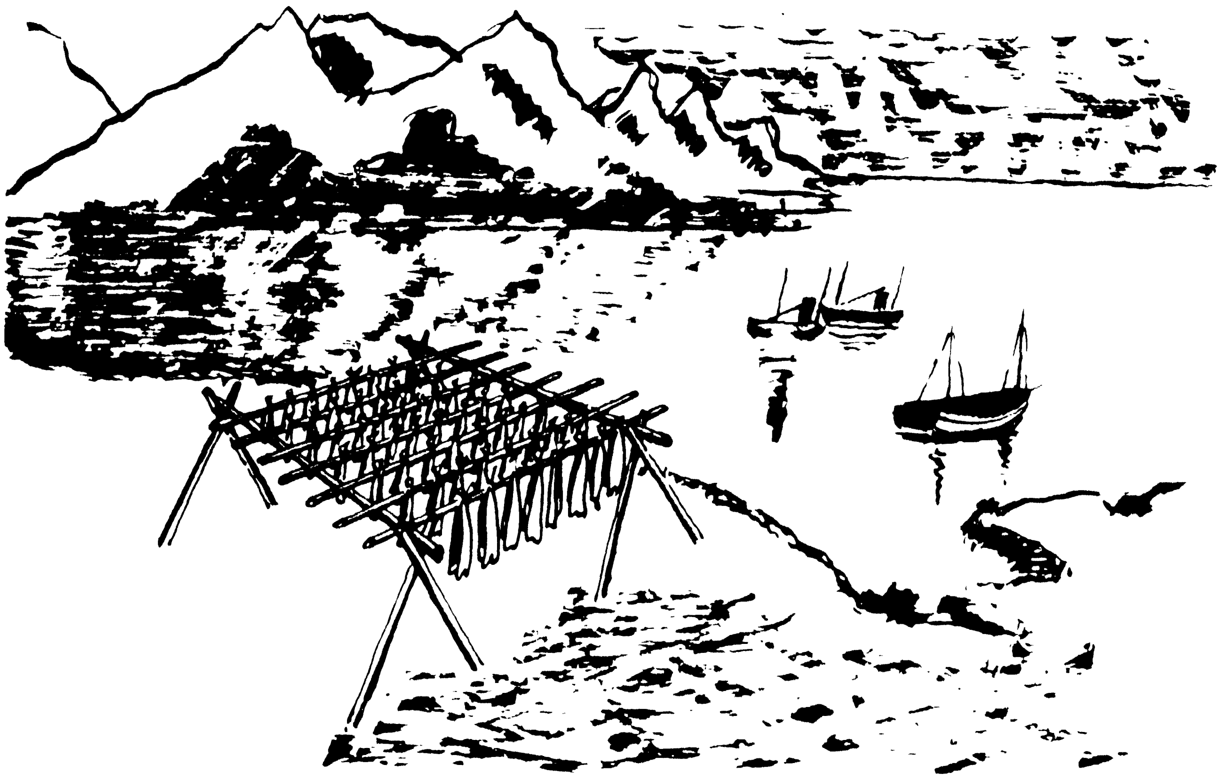


Fig. 4 Drying stockfish in Norway

Naturally dried fish products. The two best known products from temperate climates are the stockfish and the klipfish and, although this survey is about drying in the tropics it would be a mistake to ignore completely the well documented methods by which they are made; many of the practical steps, and much of the code of practice by which they are made, are relevant to similar operations in less well developed areas.

Stockfish is made from a number of species of lean fish of the cod family, notably cod, ling, tusk, haddock and saithe, by splitting them open and hanging them in the open air to dry until the water content is less than 15 percent. Similar products are made in South Africa from hake, and in Japan and Korea from Pacific cod and Alaska pollack.

The Norwegian procedure is as follows. The fish are beheaded, gutted, split open from vent to tail, tried in pairs by the tail and hung over poles or lines to dry for up to 6 weeks in the open air. Small fish are usually split almost to the tail, large fish completely. The dried fish, reduced to about 20 percent of the weight of the original fish, are usually moved into dry, well ventilated warehouses for storage up to 1 year or more before being graded, compressed in a hydraulic press and packed in bales of 45–50 kg, wrapped in hessian for shipment. Since the relative humidity in Norwegian coastal areas is often higher than 70 percent, the stockfish sometimes pick up water during transport and storage until the water content rises again to about 20 percent; some moulds can then grow, and these, mainly on the surface of the dried product, have to be brushed off; the fish may also possibly be redried before shipment to bring the water content down to 15 percent. Other contributory causes of spoilage include inadequate gutting or incomplete splitting, which give rise to damp patches on the dried fish which also encourage the growth of moulds. There is also some damage by blowfly larvae at certain times of the year.

The finished product is typical of many unsalted dried products in all parts of the world, temperate and tropical. It is a good source of protein, but it is not very convenient to handle and use and is unappetizing to many consumers. Its shape and structure make it almost impossible to pack well enough to prevent uptake of water, and some spoilage and insect infestation is almost inevitable during storage in the tropics. Some of the suggestions that have been made from time to time for making stockfish more readily acceptable as a food include the manufacture of compressed blocks of milled, bonefree stockfish flesh, suitably wrapped in moistureproof packs with insecticide powder between the wrapping layers, and the use of the dried milled powder as a basic ingredient of packaged soup mixes. Elaborate wrappings, milling and compressing treatments, bone separation and seiving all add some cost to the process and the product, and the producer aiming at the market in a developing country usually has to compromise; he has to find out what the customer can afford, and settle for a product that is perhaps less than ideal, durable enough to reach the consumer in reasonably palatable condition without too much loss of damage en route, but not so elegantly processed and expensively wrapped that, although it has few blemishes and will last for months without spoilage, is nevertheless beyond the pocket of those for whom it was intended.

The equipment for making stockfish in Norway and Iceland is fairly rudimentary; apart from the racks themselves, the only other equipment is the baling and strapping machinery; mechanical dryers are rarely if ever used.

Some of the most useful information that tropical processors can glean from this simple process is the way in which operations and equipment are inspected and controlled by government staff to ensure as high a standard of production as possible. The following are some of the points that are watched for:

The raw material has to be of the same high quality as fish that is destined for chilling and freezing for the home market, and has to be handled just as carefully. Failure to recognise that poor fish make poor products of any kind is a common error in most fisheries; all too often, in developed as well as developing countries, fish considered to be unsuitable for distribution as fresh fish is diverted to a salting or a drying process, for which it is regarded as good enough. While it may be true that the characteristically strong flavours generally associated with dried fish may mask some of the off flavours of stale raw material, the drying process should never be regarded as an outlet, a dumping ground even, for fish that is unwanted for any other purpose.

The fish is not allowed to be left lying for more than a few hours without proper cooling before being prepared for drying. Again, this ruling needs to be applied even more stringently in hotter climates.

The backbone has to be removed to three joints below the vent; the purpose here is to remove as much bone as possible so that the fish can be opened and exposed for drying, but leaving some bone at the tail to give strength during subsequent handling.

The split fish has to be washed in clean running water, and all loose particles of gut, liver, remnants of blood, the gall bladder and any other impurities have to be removed. Again this is common sense if spoilage is to be reduced as much as possible.

Species with well developed scales, such as saithe, have to be handled separately from other fish, and the scales removed as far as possible before drying begins; this is to prevent the scales being transferred to the flesh of the split fish and thus blemishing the dried product.

The fish have to be moved in clean boxes or in clean vehicles with suitable partitions from the fishing vessel to the drying area. Dirty boxes or carts will contaminate the fish.

The fish have to be handled carefully, and not thrown about or dropped, in a manner that will reduce their quality.

Fish waiting to be hung on a rack must not be laid directly on the ground, but must be laid in clean boxes, on tarpaulins or on shelves. Again, simple hygiene can do nothing but enhance the value of the product.

Fish have to be sorted roughly by size before being hung, and must not be hung so closely together that drying is impeded. One of the essentials of open air drying is that all the fish are as much exposed as possible to the warm air around them. No self respecting housewife hangs out her washing to dry with the clothes overlapping; she know they will not dry properly.

Fish that touch each other may stick together; not only will they dry more slowly, but they may also stick together and cause stains to appear on the flesh. Any fish that have adhered to each other must be separated.

Racks have to be staggered, so that fish on one pole or line do not drip onto fish on the pole or line below, and the lowermost pole has to be at least 2.5 m above ground level, so that the chances of contamination are reduced. Other hygienic restrictions on the siting of racks are that the ground beneath them must be dry and clean, the racks must be at least 5 m away from other buildings and at least 10 m away from dwelling houses and roads. Offal must not be dried, or kept, in the vicinity of racks used for drying fish. While the distances quoted here do not have to be copied slavishly in other drying installations, it makes good sense to dry the fish well away from any other activity that may contaminate the product in any way.

The dried fish when they are taken down must not be exposed to rain, nor polluted in any way, before being stored. Obviously if hard dried fish gets wet, it will quickly take up water again, thus rendering useless much of the effort expended in drying. Protection against rain is a particularly difficult problem in many tropical installations during the wet season; either a great deal of labour is required to take the fish indoors whenever it rains, if drying has not been completed, and then putting them out again, or some rapid method of covering the fish has to be provided; covers for racks in the tropics are discussed later in this section.

The dried fish have to be stored in spacious, dry, airy stores. Dry, well-ventilated storage space may not be easily come by in many tropical areas, but obviously this is the ideal to aim for. It is not permissible to store dried stockfish in places where salted dried products are being prepared, to avoid any cross contamination of spoilage organisms.

Stockfish must not be loaded, unloaded or transported when rain is likely to damage the product or the wrapping round the product, and any vehicle used for moving the finished product must be equipped with tarpaulins or other suitable covers.

Preservatives or insecticides are not permitted for use on stockfish unless they have been officially approved for use.

Klipfish. Round lean fish of the cod family are gutted, split and salted and then dried in the open air to make what are known in Scandinavia as klipfish. The species used include cod, haddock, saithe, ling, whiting and catfish. Countries active in the industry include Norway, Iceland and Faroe in particular; hard dried salt fish are also produced in Canada, Belgium and, using Pacific species, in Japan. Although the traditional klipfish is a naturally dried product, the drying process in the open air is such a slow process that it is now generally uneconomic, and a high proportion of the hard dried salt fish is mechanically dried; the equipment used for drying artificially is discussed later.

The salting process prior to drying is briefly as follows, although there are numerous local variations of the technique both in North America and Northern Europe. The split fish are usually stacked in layers with dry crystal salt of an acceptable food grade to form piles about 2 m high, from which the pickle coming out of the fish can drain away freely. With this method, known as kench curing, the amount of salt to fish may vary from 1 unit of salt to 8 of fish by weight for light curing, to 1 unit of salt to 2 of split fish for heavy curing; the time in the salt may range from 6–8 days for light salting to 21–30 days for heavy salting. Heavy salting is also sometimes done at sea on the catching vessel. Alternatively the split fish can be pickle cured in dry salt in tanks or vats; rather less salt is used than in kench curing, and the time in the vat is usually less, 3–4 days for light salted fish and 12–18 days for heavily salted fish. Salting by either method is best done at a temperature of 5–7°C to prevent the flesh going sour before the salt has penetrated the fish. The salted fish are washed to remove excess surface salt, stacked again about 0.5 m high to drain, and are then ready as wet salted fish for drying. Wet salted fish can be stored at chill temperature, 5–7°C, for several months before drying.

The salted fish are laid skin downwards in a single layer on drying platforms, often nowadays made of plastics coated wire mesh stretched across wooden or metal frames. Dry windy weather with a temperature of about 20°C is most suitable. The fish have to be moved indoors if there is any likelihood of rain or a sharp overnight fall in temperature with a danger of condensation. Normally 7–8 days outdoors is sufficient to dry the fish to a water content of 36–40 percent, but since hard dried products usually have a water content below 30 percent, with a salt content of perhaps 25–35 percent, the drying time for these can be very much longer, as the drying process enters the falling rate period.

A total drying time of 6–8 weeks is not uncommon for klipfish, broken up into as many as 5–6 drying periods, with the fish stacked in press piles for a few days between each drying period to bring more water to the surface of the fish. This makes the process so labour intensive that it becomes uneconomic, and successful completion of the process depends on long spells of suitable drying weather. Recommendations made to the World Food Programme on the storage of packaged dried salt fish in humid tropical climates state that the water content of the product, on a salt free wet basis, should be less than 28 percent if the product is required to be kept for several months; this would mean drying to a water content of about 20 percent on a wet basis for a product that had a final salt content of about 28 percent.

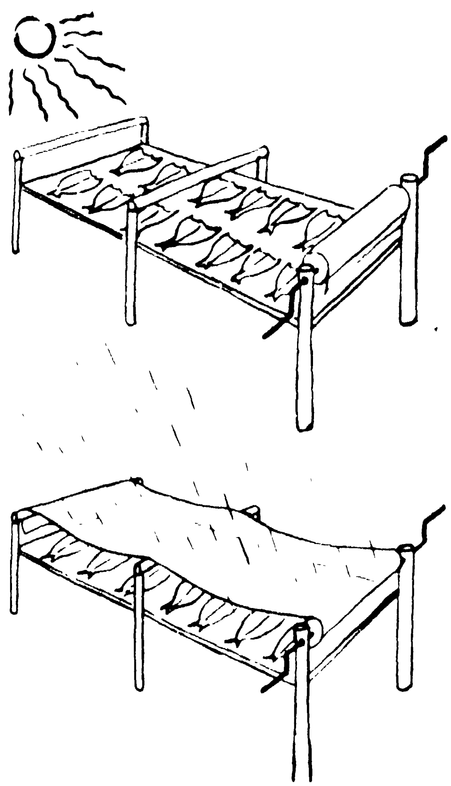


Fig. 5 Prevention of contamination by keeping the fish off the ground with polyethylene covers to prevent rain damage

Sundried tropical fish. In developing tropical countries a great number of species of fish, both freshwater and saltwater, are dried in the sun; the method may be no more than laying out the small whole fish on the sand or the rocks along the shore, or there may be more careful preparation of the raw material and some use of mats or racking and awnings to protect the product. Drying time and final water content are largely unspecified, but anything from 3–10 days in the sun are typical times quoted for small fish. Larger fish are often cut up in some way, perhaps into steaks, strips of flesh, or as split fish, in order to provide thin pieces that will dry before they spoil too much.

The simplest of improvements that can be made in the more primitive drying processes are getting the fish up off the ground and onto racks to reduce infestation and contamination, and the provision of some form of protection against rain. The experimental work done in Zambia to improve the drying of freshwater sardine from Lake Tanganyika will serve as a first example of what can be achieved in practice under tropical conditions.

The fish concerned, Limnothrissa and Stolothrissa species, are 5-7 cm long. The traditional method of drying is to lay them out in the sun on a sandy beach for a few days, then to gather them into heaps and pack them, along with adhering sand, and small stones, into jute bags for transport and storage. They often become mouldy very quickly, become infested with beetles, and are strongly off flavour. The improvements were designed to be as simple as possible, so that a minimum amount of expenditure and training would be necessary to implement them. Efforts were also made to prepare products that were likely to meet the taste of local consumers.

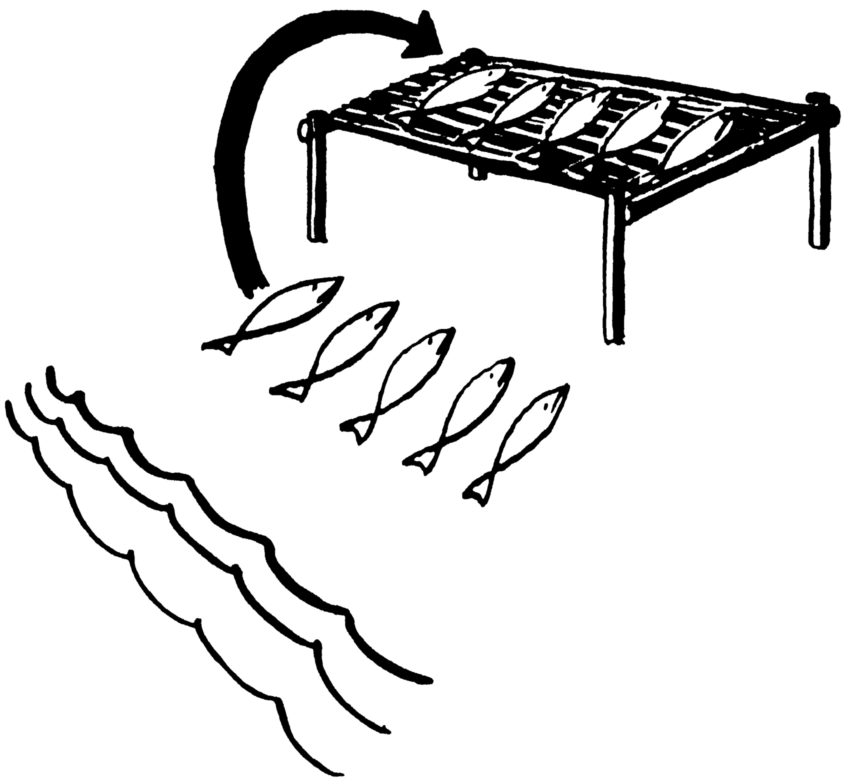


Fig. 6 Getting the fish up off the ground

In the first instance racks were built to prevent the mixing of fish with sand and stones, and also to reduce drying time by exposing each fish more completely to the warmth of the sun. Wherever possible local materials were used for making the racks. The legs were wooden poles, and the platform of the rack was made from wire mosquito netting fastened along the tops of the poles. At the end of each row of racks was a simple roller, turned by hand, on which was wrapped a length of plastic film sheeting, so that whenever rain threatened the sheeting could be pulled out over the racks to protect the fish. When the weather improved again, the sheeting was wound back and exposed drying continued, thus eliminating the labour of carrying all the fish from the racks to put them under cover, or allowing them to become wet and having to repeat a great deal of the drying effort. In the dry season in this area the relative humidity is between 20-70 percent from May to October, and in the wet season from November to March the relative humidity is between 65 and 95 percent.

One of the main recommendations made for improving this particular fishery was that a preliminary salting would improve the quality and would make a product that would be acceptable to local people. Sardine-like fishes usually have a fair amount of fat in them, and a prolonged drying period inevitably results in some brown discoloration and some rancidity; one of the main purposes of adding salt was to remove some of the water at this stage and so reduce the drying time and thus the spoilage. The brining time adopted was a 15 minute dip in saturated brine. The small whole fish on the racks were also turned at frequent intervals to speed drying. During the dry season the salted fish dried faster than the unsalted ones during the first day on the racks; weight loss was 62-67 percent. In the wet season the salted fish gained weight overnight between the first and second day of drying, and several hours of additional drying during the daytime on the second day were required to reduce the weight again to the level achieved on the first day.

The drying time was expected to be shorter during the dry season, but in practice the drying time turned out to be the same in both wet and dry seasons because the fish were bigger and had a higher fat content in the dry season. Using the traditional process, the weight loss obtained over 2 days in the dry season had usually been about 75 percent; local processors found that the salted dried fish, losing 62-67 percent in one day, were preferable to the previously unsalted dried product dried for 2 days, and were able to reduce the number of drying racks by half.

Samples of salted and unsalted fish prepared in the wet season and dried for 16 to 34 hours respectively were packed in plastic film and stored for up to 6 months. After 3 months the unsalted fish were rotten, regardless of drying time, and the unsalted fish that had had only 16 hours drying were mouldy within a week. The salted dried samples were still edible after 6 months.

Unsalted samples prepared in the dry season and dried for 16 hours were spoiled by mould after 3 months, and the salted ones were of a fair quality after 6 months. Both the unsalted and the salted fish, dried for 34 hours, were good after 6 months, with little to choose between them.

The experimental work on this simple Zambian fishery resulted in the field workers making the following recommendations for improving the drying of Lake Tanganyika sardine.

1. Salt the fish by dipping in saturated brine, 10 minutes for 5 cm fish and up to 20 minutes for 7 cm fish. This gives in the final product a salt content of 8-10 percent, a water content of 13-25 percent, and a yield of 33-38 percent.

2. Dry the fish on elevated racks for 16-18 hours including night time at the initial drying stage. Smoke them lightly after drying if required to suit local preference.

3. Pack the fish in plastic bags (pvc gauge 200 was used in the trial) to prevent overdrying during storage in the dry season and to give protection against contamination and infestation. The product keeps for 3 months in good condition at 20-35°C, and for 6 months in fair condition.

A brief indication of the cost of this improved process is given in Section 6. The foregoing account indicates not only the importance of improving and shortening the processing stage, but also emphasizes the need to protect the product against infestation and contamination. Packaging, storage and pest control are as important as the drying method itself.

Another example of tropical drying is the operation around Lake Chad in West Africa; the following summary of the traditional method of preparation and transport of dried fish from Lake Chad to Nigerian markets and other neighbouring countries serves to highlight the serious shortcomings of primitive techniques and the enormous difficulties encountered in a hostile environment.

A wide range of species of freshwater fish are taken from Lake Chad, and these are usually either burned in a flame and then smoked to make banda, or are sundried. Banda is a name applied in West Africa to many kinds of meat, from animals as well as fish, when it is subjected to a smoke drying process. The larger specimens of fish are descaled, gutted, cut into chunks and spread out to dry on the sand or on wooden racks. The smaller specimens, for example fish of the Alestes or Tilapia species, are first dried on the surface and then covered with grass or papyrus which is then set on fire. The fish become scorched and blackened, thus presenting a hard protective outer surface. Some of the fish may be also smoked on a grid or over a fire, and in a few instances simple kilns are used. Processing may take 3–6 days. The dried fish are packed in sacks or in bales wrapped in rushes, ready for a long overland journey by camel, donkey or oxen, or a water journey by canoe. The journey of several weeks is often made in stages, with perhaps further drying and smoking between stages before a final haul by road or rail to the coast. The strong tasting product is popular, and the demand is unlikely to be quickly transferred to fresh or frozen fish products. However the smoking and drying offer little control against insect attack. The wet fish is attacked by blowflies which lay eggs in the flesh before and during drying, and the heat of sundrying does not penetrate deeply enough to kill the larvae. Cracks in the casehardened surface of the fish also permit further attacks by flies. Even when the temperature of the fish on the sand rises high enough to kill insects during the day, the larvae can survive in the comparatively cool area underneath the fish and reinfest them at night when the temperature falls. The flies are deterred from laying eggs during the smoking period, but larvae already present penetrate the deeper regions of the fish where the smoke and heat cannot reach them. As the fish dries it becomes less attractive to flies, but becomes more appealing to beetles. A Dermestes beetle can lay up to 300 eggs in cracks and fissures in the fish during drying; the larvae hatch in 1–2 days and eat through the dried fish, leaving tunnels for further egg laying and pupation. The fish is already highly infested by the time the journey begins, and uncontrolled infestation increases rapidly during the long journey until at the end the fish may be completely hollowed out. As much as half the weight of the product may be lost, and much of what remains is bone; even the small remaining amounts of protein are of doubtful nutritive value. Some experimental attempts have been made to reduce drying time, including the introduction of a salting stage, and thus reduce the risk of infestation, but the inevitable gradual increase in water content during the long period in transit and storage makes improvement an almost impossible task.

In the same area of the world a practical attempt to introduce an improved drying system for the products of a lake fishery has met with some success; workers on the United Nations Volta Lake project in Ghana introduced a drying technique which although fairly simple yielded locally acceptable products with a reasonably long shelf life. The catch is 50 percent Tilapia together with a mixture of larger species such as Lates and Alestes, up to 5 kg or more in weight. Again, the approach was to be by using a combination of salting, drying and smoking.

In the procedure that was adopted, Tilapia were descaled, split, washed and brined in saturated brine; the time in brine ranged from ½ hour for a 0.2 kg fish to 6–8 hours for a 2 kg fish, to give roughly a 10 percent salt content in the finished product. There were three stages in drying, first a predrying period in the open air to reduce the weight to 70–80 percent of the initial weight, a warm smoking period in a single drum smoker at 40–60°C, and finally a further drying period on the open air racks until the yield was about 40 percent; the whole process took 24–36 hours in the dry season and 40–70 hours in the wet season, depending on the size of the fish. The products were superior to locally smoked fish, and could be stored at 28–35°C for at least 1 month in polyethylene bags.

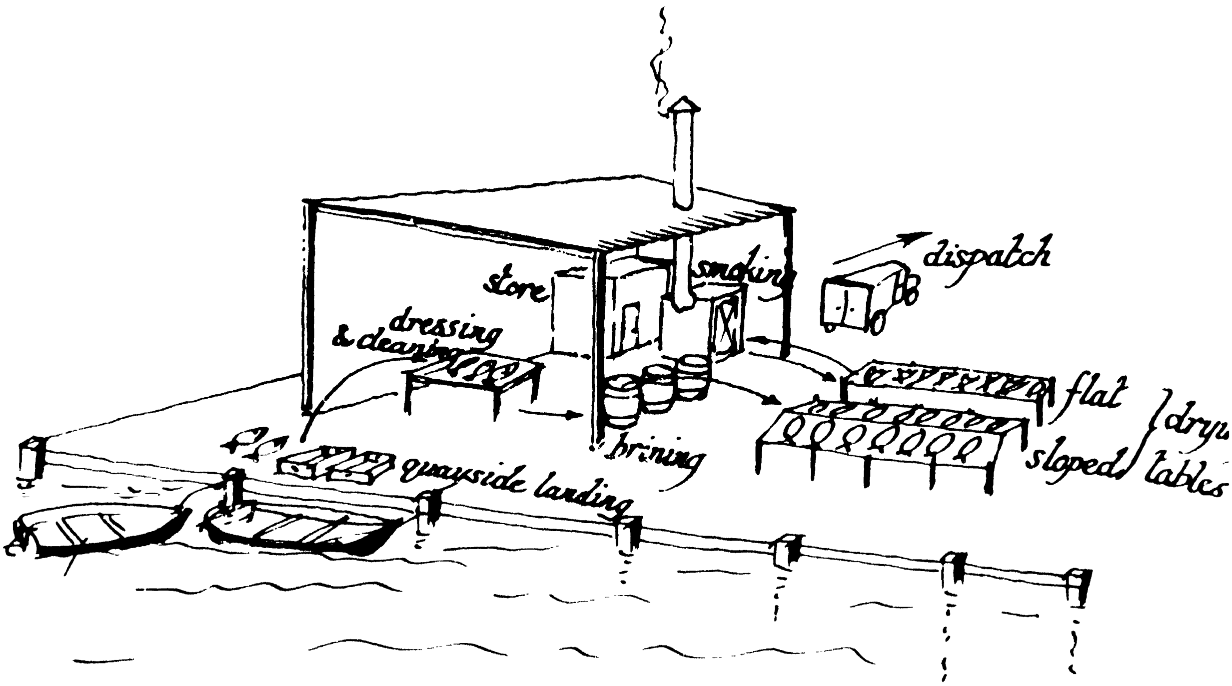


Fig. 7 Layout of the Volta Lake project

The larger fish proved to be a problem, especially in the rainy season; spoilage during processing was more rapid because the thicker and fattier flesh made salt penetration much slower. To speed the brining and drying stages, the fish had to be cut into steaks which were then brined for times ranging from 6 hours for steaks from 2 kg fish up to as long as 30 hours for steaks from 5 kg fish, the steaks all being cut about 5–8 cm thick. The final salt content was 10–15 percent and the water content about 40 percent. Since the new product was more akin to Ghanaian salted products than to the locally dried and smoked fish, special cooking instructions had to be given to give the right saltiness to the cooked dish without losing too much of the flavour and nutritive value.

This example of smoke drying combined with sundrying is really a hybrid method, requiring as it does a simple kiln for the smoking stage. In the full smoke drying process, where all of the drying is completed within a kiln or oven, the fish are artificially dried, and descriptions of such methods fall more properly in the next part of this section.

Artificially dried fish products. Natural drying in the open air is subject to the vagaries of the weather, is often difficult and sometimes impossible to achieve in humid conditions, and usually exposes the product to spoilage and infestation over a period of several days or even weeks. Salting will remove some of the water, so that less water has to be removed by subsequent drying, but the presence of salt in the flesh in turn reduces the rate at which water diffuses through the fish, and so again increases the drying time. Thus for many tropical products, whether salted or unsalted, dependence on natural drying may result in excessive spoilage because the time required for drying is too long in the particular climatic conditions.

Many attempts have been made to control the drying process by using some kind of artificial dryer, both in temperate and tropical climates. The sun and the wind are not easily controllable, but the source of energy is undeniably cheap. Any form of artificial drying costs money to operate, and in many situations in unsophisticated fisheries there is a limit, usually a financial one, to the degree of mechanization that can be introduced. It is perfectly feasible, given freedom to choose the plant and the method, without regard to cost, to dry fish rapidly, but it is usually sound policy in all but the most developed of communities to examine the possibilities of the simplest types of dryer before embarking on any elaborate installation. Because the consumer in developing countries is often prepared to accept and even relish dried products with a strong flavour, and because many tropical species have been reported as being able to withstand more severe heat treatment than those from temperate waters, it is often practicable to employ cruder designs of drying tunnel operating at higher temperatures than would be acceptable elsewhere.

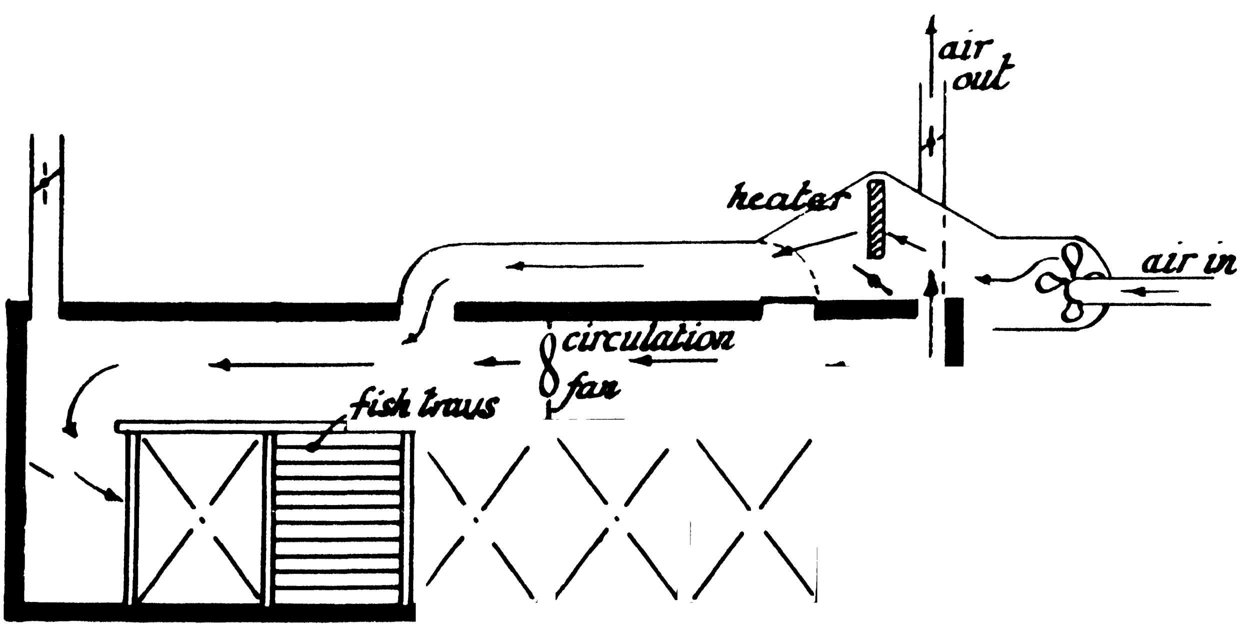
Before describing some examples of tunnels that have been tried in the tropics with some success, it would be useful to examine how artificial drying has developed in temperate regions. There have been three stages in the development of drying artificially under controlled conditions, mostly as a result of work on lean fish and more particularly for salted cod and related species. The first step was simply to bring the fish indoors and hold them in a heated room, the heat being generated in a very simple manner, typically from wood or coke fires, with little or no control of temperature or humidity, but at least avoiding the excesses of change in the outdoor climate. The second stage was the use of a kiln or tunnel through which the air could be directed over the fish at constant speed and at a fairly steady temperature; some degree of control over humidity was also possible, though at extra cost, for example by the use of dehumidifiers. A large proportion of dried salt fish is today still made commercially in tunnels of this kind. The main disadvantage of the constant temperature tunnel is that drying becomes inefficient once the falling rate period has begun, and a third generation of dryers has been developed in which the air conditions can be changed as drying proceeds. The higher degree of control that is possible with programmed temperature control means higher output and a more uniform, better quality product but, because the capital and maintenance costs of such equipment are almost always higher than for the more simple tunnels, the method has not yet been generally adopted commercially.

The optimum air conditions for constant temperature drying of salted lean fish in temperate zones are well-established, and are repeated here as a basis on which to work. The air speed should be 1–2 m/s; higher air speeds improve the initial drying rate, but shorten the constant rate period so that there is little or no reduction in the total drying time. Air temperatures should be maintained at 25–30°C, with the ideal at about 27°C. The relative humidity should be 45–55 percent, at the inlet of the dryer. A lower relative humidity may result in casehardening of the fish, and any increase in the relative humidity reduces the drying rate until at about 73 percent relative humidity the drying of salt fish becomes impossible. For salt fish, drying time in a constant temperature dryer is shorter if the fish are press piled between periods in the tunnel instead of attempting to complete the drying in one continuous run in the tunnel. Press piling allows diffusion of water to the surface to continue outside the dryer so that it can be readily removed by a subsequent spell in the dryer. A typical sequence for light salted fish might be an initial drying period in the tunnel to reduce the water content from 75 to 55 percent, followed by alternate press piling and 12 hour periods of tunnel drying until a final water content of about 36 percent is reached after a total time of 60 hours. The same process might take as long as 120 hours with continuous drying. A mechanical pressing stage, using press plates or rollers, is a refinement that has been introduced in some Norwegian and Belgian equipment to eliminate the labour involved in loading and unloading the dryer for press piling.

Most forms of heating have been used at some time or other in tunnel dryers; hot water or steam are most typical, but electric and infrared heating have also been tried. Incidentally in some tropical countries it is not always possible to maintain an initial air temperature below 30°C without introducing some form of cooling. However in some tropical areas experimental runs with tunnels at temperatures higher than 30°C have produced a locally acceptable product; in Brazil for example a tunnel operating at 35–40°C was found to work well, and temperatures above 40°C have been tried elsewhere.

The experiments in Brazil, although conducted some years ago, bear closer examination. As in other hot and humid countries the application of sundrying is restricted, chiefly because the sun is often too hot for direct drying in summer, the climate is generally too humid at other times of the year, and spoilage is rapid due to infection by moulds and salt-loving bacteria. In general, the species being salted were fattier than cod, so that some of the products had a final fat content of up to 5 percent. Nevertheless it was found that although the fat might become somewhat rancid, the salted dried products were still compared favourably with many of the traditional products on the market.

One of the important claims made by the experimenters was that Brazilian fish remained firm at a temperature of 35°C and higher, and that there was not the same problem of early spoilage encountered in northern climates, apart from some souring. Pickle salting in tanks was considered preferable to kench curing, that is dry salting in open stacks, because attack by red halophilic, that is saltloving, bacteria could be so severe as to spoil the fish in 4–5 days in summer. There were no particular difficulties in salting the fish in pickle at any time of the year. Preliminary trials with a small experimental tunnel dryer were sufficiently encouraging to go on to the building of a commercial scale dryer. Corvina was dried many times at a temperature of 38–40°C without visible heat damage, and other species, including sharks, rays and hake, were all dried at 39°C without heat damage. Dehumidifiers were found to be unnecessary in southern Brazil, since at 39°C there were many days in the year when the relative humidity was in the region of 50 percent, and in other more humid parts of the country the tunnel could also often be operated successfully at the same high temperature. It was also claimed that corvina was repeatedly dried in less than 1 day without press piling, fillets of small sharks and rays were fried in 1 day, and fillets of larger fish were processed in 2 days, but the final water and salt contents were not specified.



The main features of the commercial tunnel dryer, shown in the diagram, were as follows. The tunnel body was constructed entirely of wood, with 5 sections of racks, each with its own loading door. Galvanised wire mesh used for the supporting trays was found to be unsuitable in Brasil, because the material became badly rusted within 3 months, and it also proved difficult to find a suitable alternative that was locally available; bamboo strips or painted wire were suggested as possibilities. The dryer took 2 hours to load, and 200 m^3 of air a minute were circulated by a 2 hp fan located in the return duct. The fan motor was reversed half way through the drying period, and a linked set of dampers were reversed at the same time. A 3/4 hp centrifugal fan, capable of delivering 60 m^3 a minute, was used to introduce fresh air when activated by a simple paper strip humidistat set to operate at 55–60 percent relative humidity. A thermostat set at 36°C was located between the second and third drying sections, and this operated a motor driven damper that forced the incoming air to pass through a steam heated finned tube section when required. While it is not suggested that the design of this tunnel could be taken without modification and used anywhere else with any guarantee of success, it indicates the kind of construction and control system that could be adapted and experimented with by a practical man until by trial and error a workable version was obtained.

Experiments with tunnels in India are also claimed to have shown that fish such as sardine and mackerel can be tunnel dried at temperatures up to 45°C. Drying times for unsalted fish of 30 hours have been reported, and for salted fish a drying time of 24 hours reduced the water content to 25 percent from an initial water content of 60–65 percent.

The successful use of a high tunnel drying temperature was also exemplified by work in Cambodia, where a drying temperature of 43°C was used without marked injury to the product, and a simple and economical 2 ton dryer was designed on this basis. In the traditional local process, stable dried products were being made from split salted fish, dried for about 48 hours on bamboo racks at the landing point, transported to an inland depot and then given a further 6 hours drying. However during the 4 months of the rainy season, up to 3 days drying at the central warehouse was needed, and there were considerable losses due to the onset of bacterial spoilage, particularly reddening from saltloving bacteria.

When designing the dryer it was argued that a tunnel should be developed that did not need expensive external dehumidifiers. It was proposed that since the air can hold more water vapour when its temperature is raised, the tunnel should be made to operate at the highest possible temperature to give faster drying and to reduce the amount of fresh air that needed to be introduced.

Samples of Cambodian fish, already given a preliminary drying treatment equivalent to that given at the landing place, were artificially dried to determine the most suitable air conditions. A temperature of 43°C was found not to damage the product, and a constant relative humidity of 50–55 percent was selected as being a suitable average throughout the drying period. The air speed selected was about 1.8 m/s. In Cambodia the relative humidity of the outside air was 65–72 percent in the dry season and 81–83 percent in the wet season. It was calculated that the air, when heated to 43°C in the dryer, would have a relative humidity of about 36 percent for much of the year, low enough to permit good drying of the fish without dehumidification.

The 2 ton drying plant was designed on simple lines, with provision for expansion by the addition of more units as required. The basic elements were a 6 station drying tunnel, a fan and a steam heater. Since the inlet air was always likely to be moist, and the outlet air after passing over the fish would have an even higher water content, no attempt was made to recirculate any of the air. The only instrumentation was a temperature controller set at 43°C; this was located at the inlet to the tunnel. Each section had 20 trays about 2 m x 1.3 m, and each tray was estimated to hold about 16 kg of fish to give the desired 2 t capacity. The trays were spaced at about 10 cm vertical intervals, thus making the tunnel height about 2.1 m. Calculations showed that the volume of air required was likely to be about 370 m^3 per minute; this was delivered by a 0.75 kw (1 hp) motorized fan, and the heating requirement of 103 000 kcal/hr (120 kw) was met by a steam heater. The layout of the tunnel is shown in the diagram.

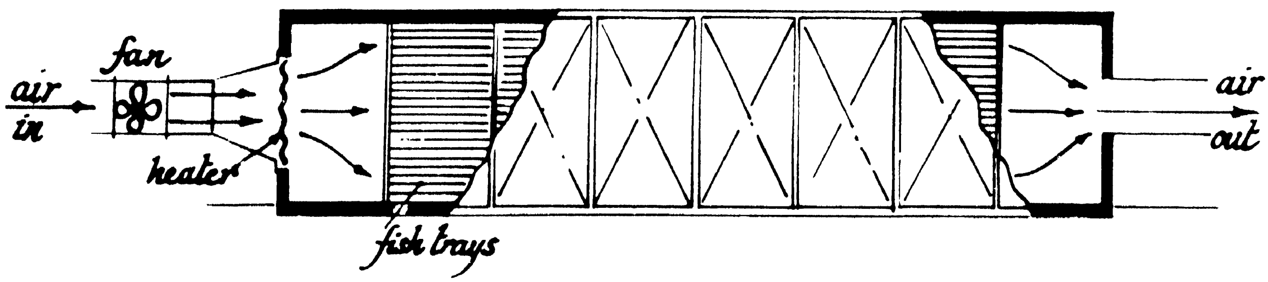


Fig. 9 Tunnel dryer in Cambodia without recirculation

No attempt was made to improve the design by adding more instrumentation or by making it more complex; simplicity of construction and operation were considered to be more important than more efficient performance. On the assumption that it was not possible to vary the operating conditions as the fish dried, one of the ways of improving performance was to maintain a fairly constant load in the tunnel at all times. This can be done fairly readily in a sectional batch tunnel by loading each section in rotation so that the amount of wet fish, partially dried fish and fully dried fish in the tunnel is always about the same. Alternatively, if a tunnel with trucks is used, a truck of wet fish can be pushed in one end of the tunnel and a truck of dry fish taken out of the other end at fixed intervals. In this type of tunnel it is sensible to put the wet fish in at the end where the fresh air enters the tunnel, so that the wet fish encounters the air with the lowest relative humidity.

Yet another experiment with mechanical drying, this time on mackerel in India, again pointed to the possibility of using higher temperatures than are deemed to be practicable in temperate zones for cod. A temperature of 45°C was found to be suitable, with air at a relative humidity of 50 percent. An even higher temperature, 50°C, caused some unacceptable yellowing and cooking of the fish. Unsalted split mackerel were tried, but were considered unsuitable for drying; prolonged drying proved to be necessary, up to 4 days, in spite of the higher drying rate for unsalted fish, and during this time there was extensive browning as the fat in the flesh oxidised. The salted split mackerel, about 1 cm thick and with a fat content of about 7 percent, took about 12 hours to reach a water content of 34 percent. The suggestion was made that 6 hours in the dryer should be followed by 6 hours in the sun under reasonably hygienic conditions as a cheaper alternative.

Finally, the smoking kiln or smoking oven can be used to make a smoked, dried product in regions where smoked fish is acceptable. The main preservative effect in most smoke drying processes in the tropics is the removal of water from the product, and this can be done cheaply and effectively by using the heat from wood fire, with the hot air and smoke moving over the fish either by natural convection or aided by means of a fan. The smoke drying of bonga, Ethmalosa species, in tropical Africa is described in considerable detail in another FAO publication, Fisheries Technical Paper 104, "Equipment and methods for improved smoke drying of bonga", published in 1971. Two simple types of kiln are described and drawn in great detail in this publication, the drum type and the simple version of the Altona oven, and the reader is referred to this booklet if he wishes to adapt smoke drying equipment to suit his process. The temperatures used in the production of bonga, 80–110°C during the smoking period, are much higher than have been quoted here for the drying of salted or unsalted fish; the product is cooked at this temperature, and the final water content is as low as 8–12 percent. Yield ranges from 22–30 percent of the weight before smoking. Smoke drying time for a weight loss of 75 percent was found to be about 15 hours, and uniformity is obtained by reversing the order of trays of fish in the kiln, moving the top fish to the bottom and the bottom fish to the top at intervals during the process. The keeping time of hot-smoked bonga in humid conditions can vary from only a few days to over a month.

To close this section on the practice of drying in the tropics, it must again be emphasized that there is no simple theory, no infallible set of rules, that will work in any climate, on any fish, to give an indestructible product; trial and error under local prevailing conditions is the only sure way of devising a suitable process. Even when a good cheap product can be produced, it is still essential to find a distribution and storage system to match.

6. THE COST OF DRYING

How much does it cost to dry fish? There can never be one universal answer to that question. It may not even be the right question to ask. Perhaps the question should be how much will the consumer pay for the finished product? The answer to that may well determine what the maximum processing cost is to be for raw material at a given price.

To remove water from fish requires the application of heat, and provision of heat requires an energy source, either natural or man made. The first question inevitably is whether or not use can be made of the heat of the sun – all the year round, for part of the year, or for part of each day, because removal of water from fish other than by natural drying is a costly business; where natural heat is available, no matter how difficult it may be to control its application, the chance to use that heat should not be ignored without very serious consideration. Can the process depend on natural convection, or are fans needed to move the air over the fish? Are there plenty of people available at modest cost to move the fish frequently, turning them as they dry, or taking them into shelter when the weather is unsuitable, or will it be cheaper to provide mechanical assistance or reduce the labour content of the process? This same simple kind of question must be applied to each of the many factors affecting the design and operation, and therefore the cost, of a drying installation. The very process of planning the method and the equipment necessary to turn the available raw material into a marketable product will yield a rough costing for the enterprise, even in the next village, because the circumstances are never exactly alike.

Begin with the market, because when the product does not meet the needs of the market, there is no point in making it - childishly obvious, but all to often a product is designed and made and only then does the producer begin to seek some place to sell it. Next design a process that gives a product that suits the market. The elementary questions that affect viability are formulated as the outline of the venture evolves. How far away is the market from the source of the raw material? Is the supply of fish steady or seasonal? Does the product need to be kept for weeks or only for a matter of days? Are storage and transport costs high in relation to those of processing? Is packaging necessary? These and dozens more questions have to be answered, and some of the answers will in turn modify some of the questions that have to be asked again until a compromise is reached between unprocessed fish that will never reach the consumer in edible condition and a well preserved, hygienically wrapped, indestructible, delectable product that nobody can afford to buy. The business of arriving at a reasonably accurate costing is to some extent a self regulating process, with each step of the process being costed at the design stage, and the answer being fed back in. It must be emphasized that the least satisfactory way of determining costs is to do the sums after the method and equipment have been decided on; the answer is more than likely to be a disappointment! It makes much more sense to estimate cost as the project is being designed. so that whenever a particular step appears to be disproportionately expensive, it can be re-examined and perhaps modified or even dispensed with. A searching financial examination of the need for doing things a particular way can often result in savings at the feasibility stage before there are heavy, irreversible commitments in plant or premises.

All that can be done with figures here is to quote a couple of sample costings that have been made on real drying installations by workers in the field to show the steps in the procedure. The figures quoted were probably out of date in this inflationary world before they ever appeared in print for the first time; nevertheless the relative costs, and the way the cost of the product is arrived at, may prove a useful reminder to those about to embark on something similar of the kinds of things that must be taken account of in arriving at a realistic estimate.

A few examples of costings of production of dried fish have been prepared based on data obtained from practical commercial or pilot scale operations. These costings provide some dimensions of production costs under different conditions, illustrate the significant differences in production costs from case to case, and show, in rough terms, how some operational parameters may influence dried fish production costs.

Example 1: Mechanical versus natural drying of small fish

High investment costs and cost of energy input for mechanical dryers command higher production costs than for natural drying in a country with relatively low wages.

Investment costs
(in U.S.$)

Drying method	Mechanical	Natural
Land (M: 500 m^2) (N: 1800 m^2) x $ 1	500	1 800
Store 20 m^2 x $ 75, capacity 10 t	1 500	1 500
Processing and/or office buildings M: 100 m^2; N: 10 m^2 x $ 75	7 500	750
Mechanized dryer with accessories, installed	9 000	-
Drying racks 600 m^2 x $ 1.20	-	720
Miscellaneous equipment + contingencies	1 500	1 230

Annual production costs
(in U.S. $)

Type of drying	Per daily batch Mechanical	Per daily batch Natural	Mechanical	Natural
Fixed:				
Depreciation: building 4%, equipment 10%, drying racks 100%, miscellaneous and contingencies 10%			1 410	930
Interest on capital: 8% on investment costs			1 600	480
Insurance: 2% of investment cost except for land			390	84
Maintenance and repairs: 6% of investment cost			1 200	360
Administration: manager ($ 1000/y) + clerk ($ 500/y)			1 500	1 500
Permanent labour: 3 guards x $ 0.30/day			330	330
Total fixed			6 430	3 684
Variable:				
Fresh fish 654 + 33 kg waste x $ 0.06	41.22	41.22		
Electricity 36 kWh x $ 0.05	1.80	-		
Fuel oil 84 l x $ 0.19	15.96	-		
Labour (M = 5) + (N = 10) x $ 0.30/day	1.50	3.00		
Total variable	60.48	44.22	15 120	11 055
Total production costs			21 550	14 739
Cost per ton of dried small fish (total annual $/53 t)			406	278

Cost structure

Drying method	Mechanical		Natural	
	U.S. $	%	U.S. $	%
Fixed costs	121	30	70	25
Raw material	194	48	194	70
Other variable costs	91	22	14	5
	406	100	278	100

Explanatory note on the calculation: Small freshwater fish in an East African country dried in a mechanized fish dryer or naturally in the sun. Assumed production at full capacity for 250 days a year, 12 hours each day, daily raw material input, yield of 32.5 percent, production of 53 t of product per year, product sold in bulk without packaging, and wages are identical for both mechanical and natural. Mechanized drying is carried out in a diesel-oil indirectly heated, small-scale drying tunnel with forced air circulation, and the drying cycle lasts for 12 hours. Sun-drying is carried out on drying racks constructed of timber and wire-mesh, with useful life of one year, slightly over 5 kg of fish is spread on 1 m^2 of the drying rack and the drying cycle lasts for 5 days.

Example 2: Simple drying/smoking and capacity utilization

The higher the rate of utilization the lower are the production costs. In Example 2, differences in production costs are relatively small since investment costs, reflected in fixed costs, are low. The cost of raw material governs the cost of the product, but packaging material has also a significant influence on the cost.

Investments costs

	U.S. $
Construction of drying and smoking plant	22 000
Equipment (scales, sealing machine, generator, water pump, miscellaneous)	8 000
Total investment	30 000

Annual production costs

	U.S. $
Fixed:	
Depreciation: construction (10 years life)	2 200
equipment (5 years life)	1 600
Interest on capital invested (5%)	1 500
Maintenance (fixed part)	170
Plant supervisor, per year	1 430
Foreman, per year	910
Clerk/storekeeper, per year	650
Permanent labourers (10 x $ 0.98/8h)	2 940
Total fixed	11 400

	U.S.$/24h	%
Variable:		
Raw material 4.3 t x 195 $/t)	838.50	77.9
Packaging material (5 800 polybags x 1,30 $/100 + 116 cartons x 32.40 $/100)	113.00	10.5
Salt (430 kg x 182 $/t)	78.26	7.3
Wastage of fish (2%)	16.77	1.6
15 direct labourers x $ 0.78/7h	11.70	1.1
Wood (3 m^3 x $ 1.3)	3.90	0.4
Maintenance (variable part)	2.20	0.2
Miscellaneous	11.20	1.0
Total variable	1 075.53	100.0

Variable costs per t of product ($ 1 075.53/1.16 t) = 927 $/t

Total production costs

Capacity utilization rate	25%	50%	75%	100%
Production (t/year)	64	128	191	255
	($/t)	($/t)	($/t)	($/t)
Fixed Costs	178	89	60	45
Variable costs	927	927	927	927
	1 105	1 106	987	972

Explanatory note on the calculation: Based on commercial processing of small freshwater, sardine-like fish (Stolothrisa tanganicae) in an East African country. Fish is brined (10 percent salt to fresh fish), sundried on racks for about 10 h, then smoked in a non-mechanized kiln for 4 h, packed in polyethylene bags of 200 g content and 50 bags in a carton. Daily capacity 4.3 t of raw material input, yield 27 percent, and maximum number of production days 220 days/year.

Example 3: Highly mechanized drying of salted fillets in small and large-scale dryers.

The smaller capacity of the dryer the higher the production costs. In Example 3 only investment in machinery and energy consumption are accounted for. Depreciation and interest on investment are mainly responsible for the difference in absolute costs of products, followed by energy consumption. Cost structure is practically identical for the two productions.

	Large dryer		Small dryer	
Investment cost (dryers only) U.S. $	190 000		8 000	
	Per ton of product			
	U.S. $	%	U.S. $	%
Depreciation (10 years' life)	29	32	57	32.5
Interest on capital (10%)	29	32	57	32.5
Maintenance (2%)	6	7	11	6
Fixed costs	64	71	125	71
Electricity (520 or 1 000 kWh) x $ 0.05	26	29	50	29
Production costs/t of product	90	100	175	100

Explanatory note on the calculation: Based on data on commercial dryer for 655 t of dried salted cod fillets/year dryer with built-in conveyer belt, rubber rollers which exercise periodic pressure on salted cod fillets, a fan for forced air circulation and thermostatically controlled electric heaters operated in Europe compared with a pilot scale (14 t dried salted shark fillets/year) dryer with built-in fan for forced air circulation and an electrically driven "heat-pump" air heater/dehumidifier (condensing unit) operated in a Central American country. Depreciation and maintenance rates were reported to be identical, and interest on capital, capacity utilization of 100% and 250 working days per year were assumed to be identical in both cases.

<u>Guide for preparation of simple cost estimates.</u> To obtain an indication of the economic viability of a commercial fish drying venture, production costs per ton of product should be estimated and compared with the prevailing market prices. Whenever a larger scale venture is contemplated or under investigation, appropriate expertise should be sought to recommend the economically optimum solution. For exploring small-scale operations, an approximate cost estimate may be prepared (also by people with limited experience in making feasibility studies) by suitable application of locally available information on the guide given below. The guide should be used as a kind of check-list which can be extended or shortened to meet the actual needs of a specific case.

To use the guide for a given process, accurate information or estimates should be provided on the volume and regularity of supply of raw material, expected production days in a year, yield of products, expected useful life of buildings and equipment etc. The figures in the guide should be filled in and costs entered in local currency. The guide is prepared for making cost estimates over a year; cost estimates may however be prepared over any other long period of production.

<u>Investment costs (for ... t of product/year)</u>

	$
Land	....
Access roads, parking area, etc.	....
Building (processing premises, stores, offices, fences, etc.)	....
Mechanized equipment (mech. driers, power generatores, etc. including freight and installation)	....
Drying racks	....
Vehicles for in-part transportation	....
Accessories, small equipment and tools	....
Engineering costs	....
Contingencies	....
Total investment costs	

Annual production costs

Fixed:	$
Interest on capital (...% of investment costs)	....
Depreciation (...% roads, etc. + ...% buildings + + ...% mechanized equipment + ...% drying racks + ...% accessories, etc. + ...% vehicles)	....
Maintenance and repairs (...% of investment costs, or broken down similarly as for depreciation)	....
Insurance (...% of investment costs for items that need to be insured)	....
Taxes (...% of investment costs liable to taxation)	....
Interest on working capital (...% over ... months)	....
Permanent labour (supervisor(s), engineers(s), driver(s), guards(s), etc. and administrative staff such as manager, bookkeeper, clerk(s),etc. yearly salaries)	....
Other overheads (stationery, lighting, etc.)	....
Contingencies (estimated lump sum)	....
Sub-total fixed costs	

Variable:	Per batch or per day $	$
Raw material: (... t of fresh fish x ... $/t delivered to processing premises, including all costs such as ice, transport, chilled storage, etc.)	....	
Electricity (... kWh x ... $/kWh)	....	
Fuel for processing (... litres x ... $/l)	....	
Water (... m^3 x ... $/$m^3$)	....	
Salt (... kg x ... $/kg)	....	
Packaging material (... plastic bags x ... $/bag + ... master cartons x ... $/carton)	....	
Director labour (... operators x ... $/day or batch + ... semi-skilled labourers x ... $/day + unskilled labourers x ... $/day)	....	
Variable costs per batch or day	....	
Variable costs per year (... batches or days/year x ... $/batch or day)		....
Total annual production costs:		....
Total annual production (... t fresh fish per year x x ...% yield/100) ... t of product		....

Cost per ton of dried production (total ... $/total ... ton

In addition to the information contained in the form under annual production costs, it is emphasized that they can conveniently be divided into fixed costs, which are constant regardless of the volume of production, and variable costs, which are proportional to the quantity of goods produced. Single variable costs can normally be expressed first as those to be incurred per batch of product, working day, shift, or similar smaller unit, and their sum converted into the amount to be incurred over a year.

7. OTHER DRYING METHODS

Natural drying and artificial drying in warm air have been discussed in some detail. There are other methods of evaporative drying that have been applied to fish from time to time, and two of these are briefly reviewed in this section, if only to dismiss them as being of little direct interest to the would be fish processor in a developing tropical country.

Vacuum drying. Serious attempts were made in Western Europe, mainly in the 1950s to develop a process that would yield a dried product that could be stored at room temperature, and that when reconstituted would closely resemble fresh fish. Layers of fish fillets about 2 cm thick were dried by putting them on steam heated plates inside a vacuum chamber. Water evaporated quickly, and the rate of evaporation was high enough to keep the fish cool and so retard spoilage during drying. Furthermore the absence of air prevented any undesirable oxidation of the fat in the flesh. The dried product, with a water content of about 15 percent, was then compressed into a laminated block and subjected to further drying until the water content fell to 5 percent. The final product was known as pressfisk, and was produced experimentally in Denmark and the United Kingdom; about 1 ton fillets could be fully dried in 7 hours. The process was not perfect, since there were still differences in taste and texture between reconstituted pressfisk and fresh fish that were readily detectable by the consumer. The process was further improved by reducing the pressure in the vacuum chamber still more until the fish froze and remained frozen during drying. A process known as accelerated freeze drying was evolved, and the product was much superior to the earlier versions, but still it remained distinguishable from fresh or frozen fish of good quality. Moreover the process was costly, and required considerable skill on the part of the operators; for these reasons it was never adopted commercially for fish except for some highly priced raw materials like shrimp. The process of freezing and cold storage provides a suitable means of keeping products like shrimp for as long as they need to be kept in countries that have a cold chain, without any significant change in texture or eating quality. The only commercial outlet, as yet small, for freeze dried shellfish meats in developed countries is in prepared speciality dishes as one of many ingredients; the packeted product is distributed dried for subsequent reconstitution by the consumer during preparation for the table. In general there seems to be little evidence in favour of the freeze dried product when compared with the cheaper, conventionally dried form or the more versatile frozen form, even in developed countries. Therefore there is no reason to advocate the use of freeze drying in countries where a raw material has to be processed and marketed at low cost.

Dehydration. Dehydration simply means removal of water, and by this definition all of the drying methods previously referred to in this review could properly be called dehydration. In fish technology, however, the term dehydration has come to mean principally those methods by which fish flesh is dried after a preliminary cooking and mincing stage. The final product is typically in granular or powdered form. Methods of making dehydrated products from herring and from lean fish were developed as a result of a demand during the Second World War for a fish product that resembled fresh fish in taste and texture, but that could be shipped in a small space, stored without refrigeration for long periods, and be easily reconstituted. The products that were made were tolerably acceptable, but there was a noticeable loss of palatability, the storage life in the tropics was limited, and consumers objected to the culinary limitations of reconstituted minced fish. Unless there is again an emergency need for compact stowage at ambient temperature, expensive dehydrated products of this kind are unlikely to be of commercial interest.

8. STORAGE OF DRIED FISH

A high proportion of dried fish products, whether they are produced in temperate or tropical zones, are destined for shipment to and storage in a tropical climate. The method of packing and the conditions of storage are therefore extremely important, because losses of unprotected dried products during storage and distribution have been reported to be as high as 50–70 percent in many parts of the world.

The main causes of spoilage in storage are moulds, bacteria, insect infestation, rancidity, discoloration, and texture changes. These deteriorative changes are generally most severe in climates with high humidity, and one of the main aims in good storage is to prevent the dried product from taking up water again.

A few moulds can grow at a relative humidity of 65 percent, and most moulds grow rapidly at a relative humidity of 75 percent. Thus in climates where the relative humidity is frequently higher than 65 percent some protection against the uptake of water is essential for long term storage. Conversely, packaging designed principally to prevent entry of water vapour is generally not necessary for storage of products in air with a relative humidity below 65 percent. Generally speaking, dried salted fish are rather more resistant to bacterial spoilage than dried fish in dry climates, because most of the putrifactive bacteria will not grow successfully in the presence of salt, but some saltloving bacteria can flourish in salt fish and produce the condition known commonly as pink. The infection frequently occurs while the fish are still wet after the salting stage, and if any pink discoloration is discovered at this stage, the pink patches should be removed by scrubbing and washing the infected surfaces under running water. At this stage the fish are usually little damaged. If the contamination is not eradicated, more serious changes will occur. The pink bacteria, and also some associated colourless types, begin to grow and vigorously attack the flesh; characteristic putrid odours develop and the flesh becomes a soft muddy coloured mass that will eventually fall to pieces. These particular bacteria will not grow in less than 10 percent salt. It should be noted that although the flesh becomes putrified, it does not become poisonous; although pink fish has been incriminated in the past as a source of food poisoning, the evidence is that this was due to the presence of a well known food poisoning organism that can tolerate high concentrations of salt. All the evidence seems to show that the curing salt is the most likely source of the pink microorganism. As a general rule it may be stated that rock salts are usually free from pink bacteria while solar salts often contain very large numbers. Many manufactured salts are also relatively free from pink bacteria but occasionally even they can contain large numbers. Since solar salts are often used in tropical fisheries, it is advisable to use salt that has been allowed to age for a considerable period; there is then less likelihood of harmful organisms surviving until the salt is used on the fish.

Moulds occur on dried fish, salted or unsalted, whenever there is enough water to support their growth. Even in heavily salted products, a mould known in the fish trade as dun can occur when the surface of the fish becomes damp. The surface becomes covered with numerous small tufts or spots of a black, brown or fawn material that makes the fish look as if it had been peppered. The 'pepper spots' do not damage the flesh of the fish in the same way as the pink bacteria, and although the discoloration is unsightly it is usually fairly harmless. Dun flourishes in stores on low ground, or near damp soil or structures, and will grow in a salt concentration of 5 percent or higher. Some of these moulds are again almost certainly present in solar salts. Control of moulds depends a great deal on the provision of dry well ventilated stores and the avoidance of damp, dirty areas anywhere in the vicinity of the product. Even in the best of stores moulds will sometimes occur; since they occur largely on the surface of the fish, brushing and scraping will remove much of the infection, and where attack is severe there is some experimental evidence to show that dipping of the fish in a 0.1 percent solution of sorbic acid will give some added protection.

Dried fatty fish products become discoloured, and acquire rancid odours and flavours in storage, and it is usually impracticable to wrap them well enough to exclude oxygen completely. It is almost inevitable that wherever fatty fish have to be dried, some odd flavours will be encountered after a period in store. Trials of antioxidants and other preventive treatments have not proved successful in combating this form of spoilage.

There is very little reliable evidence on record of the storage life of dried fish products in tropical climates, particularly for products of unknown composition made in the tropics, but the following examples give some idea of what may be expected in practice. Dried unsalted freshwater sardine from Lake Tanganyika keeps for up to 3 months, and the same fish salted and dried to a water content of 13-25 percent keeps for about 6 months in polyethylene bags, although there may be some browning and some rancid flavour. Bombay duck produced in India keeps for 2-3 months in air at 65 percent relative humidity, and salted sundried Sardinella containing 17 percent water and 5 percent salt is reported to keep for up to 6 months in the Philippines. Dried lean fish is claimed to have been kept free of moulds for more than one year in air at 65 percent relative humidity in India, but in other tests Rastrelliger species containing 15 percent salt and 40 percent water became mouldy after 2 months and inedible after 3 months in high humidity storage, even when wrapped in a variety of packaging materials, for example greaseproof paper, cellulose film or polyethylene film. Trials with sorbic acid dips, antioxidants such as BHT, and other additives have been tried on dried fatty fish with mixed results that have proved inconclusive; no treatment has been shown to be consistently effective, and none is known to have become established commercially.

Information on the storage of stockfish, klipfish and other dried products, produced in temperate climates and shipped to the tropics is more plentiful, and more specific. When the air surrounding the stored product has a relative humidity above 75 percent, packaging of some kind is essential, otherwise the products will take up moisture again from the air. Medium density polyethylene film has been found to be suitable for the protection of pieces of dried salt fish against uptake of water, provided the fish has a water content of less than 28 percent on a salt free, wet basis. This would mean a water content on a wet basis of less than 20 percent for a product containing say 30 percent salt.

Single plastics films are easily punctured by bones and sharp corners of dried fish, and because of this difficulty it is sometimes necessary to resort to more elaborate forms of packaging materials. For example a multiwall wrap of absorbent tissue and polyethylene film with a rectangular corrugated fibreboard outer case has been used successfully in one application. A rectangular pack of this kind is claimed to be no more expensive than some of the better kinds of wooden crate sometimes used for dried fish exports from Scandinavia, and the shape helps to make better use of shipboard stowage space than is possible with irregularly shaped bales wrapped in hessian or jute sacking.

Insect infestation is not normally a problem with heavily salted fish; provided the fish are kept dry, and the packaging is robust enough to withstand physical damage in store, klipfish and similar dried fish products with a high salt content can be kept for long periods in tropical storage without any marked deterioration. Conventional packaging for dried salt fish, namely hessian bales, wooden cases or fibreboard cartons, are rarely sufficient protection against the entry of water vapour; properly sealed cartons, made from waxed or plastics coated board, although more expensive, can be made sufficiently moistureproof, and rigid enough, to withstand rough handling. The maximum storage time for unwrapped dried salted fish in humid climates is about 2 months.

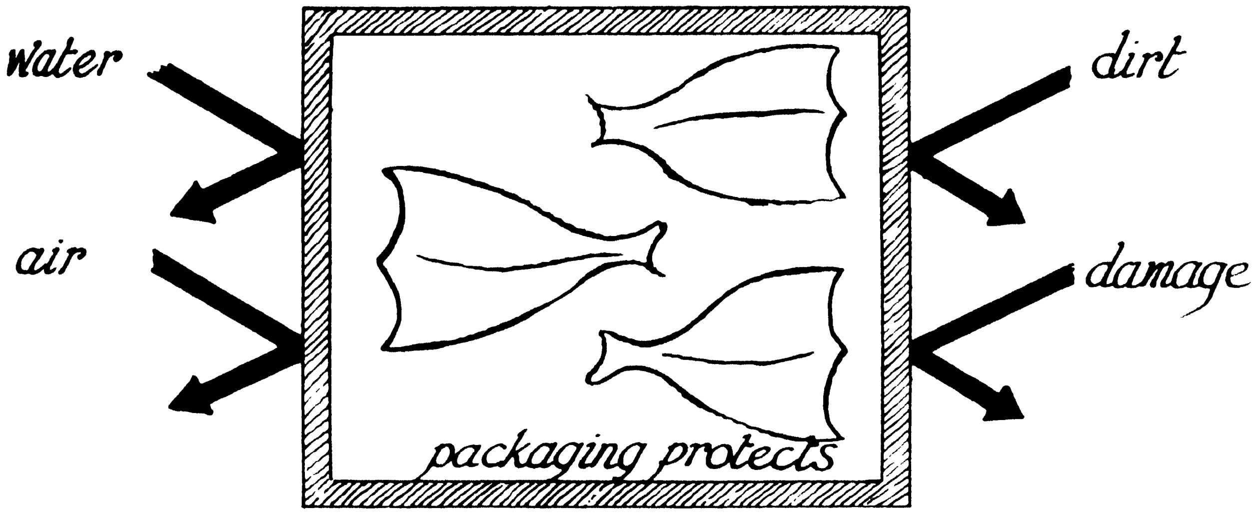


Fig. 10 Some of the reasons for packaging dried fish

Stockfish that is to be kept in humid tropical storage should have a water content of less than 15 percent, otherwise moulds will grow. Insect damage is prevalent in stored stockfish; the larvae of the Dermestes and other beetles are the most common cause of trouble in tropical storage. Treatment with pyrethrin dips is sometimes effective. A series of experiments at Lake Rudolph, Kenya, showed that a dipping technique could give a storage period of about 6 weeks free of beetle infestation, if the treatment was applied immediately after sundrying was completed. The most successful emulsion was one containing 0.018 percent pyrethrins and 0.036 percent piperonyl butoxide, suitably diluted to the supplier's instructions before use. There was no deterioration in eating quality as a result of the treatment, nor any harmful effect due to the presence of the chemical protectants. The dip was claimed to be inexpensive, and simple to use. The same treatment has also been used to protect fresh fish during the sundrying period against attack by blowfly larvae, but since the pyrethrins are degraded by sunlight during the drying process, a further dipping is required to prevent infestation during storage.

More recent work in Zambia on smoke dried freshwater fish has shown that a similar emulsion, containing 0.018 percent pyrethrins and 0.036 percent piperonyl butoxide, prevented infestation by Dermestes for 8–12 weeks; part of the preventive effect was claimed to be due to the repellant effect of the emulsion. Other dipping and dusting treatments were found to be less effective. A salt content of 30 percent in the final product will probably give protection against infestation without the need for a dip, but for products containing 8–10 percent, an additional dip in pyrethrins gives further protection, since the salt alone, although it may reduce damage by beetle larvae, will not stop infestation by adults. The pyrethrins treatment was again shown to be an economic proposition for small producers and traders in remote areas, and there was no detectable taste or any other unacceptable after effect.

10. SHORT LIST OF FISH DRYING TERMS

Accelerated freeze drying, afd	Improved freeze drying process employing better escape of water vapour and better heat transfer; see freeze drying.
Artificial drying	Drying process in which the operator has some control over the air conditions used, that is temperature, speed and humidity of the air being used for drying.
Bacalao (Spain)	Dried salted cod; may also include dried salted products made from other species in other countries.
Balik (Turkey); Balyk (U.S.S.R)	Dried salted dark flesh of sturgeon, lightly salted and dried.
Banda (West Africa)	Smoke dried fish.
Bernfisk (Norway, Sweden)	Special type of dried cod or dried ling, used for making lutefisk.
Bodard (Japan)	Split cod or pollock, washed and sundried without addition of salt.
Bokkem (South Africa)	Dried salted maasbanker, *Trachurus trachurus*.
Bombay duck (India)	*Harpodon nehereus*, split, boned and dried unsalted.
Bonga (West Africa)	Smoke dried *Ethmalosa fimbriata*; other smoke dried West African species are also sometimes called bonga.
Botargo (North Africa)	See bottarga.
Bottarga (Italy)	Roe from mullet, tuna or other fish, lightly salted, pressed and dried.
Bumalo	See Bombay duck.
Bummalow	See Bombay duck.
Casehardening	Hardening of the surface layer of fish during drying, before the water in the deeper layers of the flesh has had an opportunity to diffuse to the surface.
Constant rate drying period	First stage of the drying process, in which, under steady air conditions, water is able to diffuse to the surface at a rate sufficient to maintain a constant drying rate.

Cummalmum (India)	Sundried bonito.
Daeng (Philippines)	Gutted split Indian mackerel. *Rastrelliger* sp, brined and sundried.
Dehydration	i) Drying ii) Artificial drying iii) Artificial drying of cooked, minced fish flesh followed by grinding to give granular or powdered product; this specialized meaning is what is usually implied in fish drying technology.
Dinailan (Philippines)	Shrimp paste made from very small crustaceans, sundried for 1 day, ground and pounded for 2 days, then formed into cylinders or cubes.
Dried fish	Fish from which some of the water has been removed, usually by evaporative drying, usually in sufficient quantity to retard or prevent the growth of bacteria and moulds during long term storage at prevailing outside air temperature.
Dried Salted fish	Fish preserved by a combination of salting and drying; usually, some of the water, typically in lean fish, is removed by addition of salt, and then more water is removed from the salted fish by evaporative drying.
Drying	Removal of water; in fish drying, usually means evaporative drying.
Equilibrium relative humidity, erh	The relative humidity at which a product stored in air neither gains nor loses water.
Equilibrium water content	The water content that can be attained or maintained when a product is kept in air of a given relative humidity.
Evaporative drying	Drying by converting liquid water in a product to water vapour and transferring it to the surrounding medium, usually air.
Falling rate drying period	The second stage of the drying process, in which water takes progressively longer to diffuse to the surface of the material being dried, thus slowing the drying rate and increasing drying time under steady air conditions.
Fatty fish	Fish in which the main reserves of fat are in the flesh, for example, herring, sardine, sardinella, anchovy and so on.

Fish meal	Fish or fish offal, cooked, sometimes pressed to remove fat, dried and ground to make a granular or powdered product for feeding animals, particularly pigs and poultry.
Freeze drying	Drying by heating the frozen material under a vacuum, so that the water changes directly from a solid, ice, to water vapour without passing through the liquid phase; the structure of the material being dried is then left in a more porous state so that it can be readily reconstituted by adding water again.
Fushirui (Japan)	Dried strips of fish, first boiled and then subjected to a repeated smouldering and drying process; used as condiments or seasoning.
Gaspé cure (Canada)	Lightly salted pickle cured cod that has been dried to a water content of 34–36 percent; amber coloured, translucent product of the Gaspé area of Canada.
Gisukeni (Japan)	Small fish of a number of species, dried, sometimes also baked or boiled, then soaked in seasoning made from sugar and soybean sauce, then dried again by smouldering.
Green cure	See Green fish.
Green Fish	Salted lean fish that are ready for drying after having been stacked for 2–3 days to press out as much pickle as possible.
Green salted fish	See Green fish.
Guinamos alamang (Philippines)	Shrimp paste similar to dinailan, but salt is added after the first drying period; the mixture is dried for only 1 day after it is made into paste.
Hamayaki dai (Japan)	Small porgy, sometimes gutted, skewered with bamboo pins, then dried after being toasted on a fire; also sometimes dried in heated solid salt.
Hard cure	Lean fish, particularly cod, that have been salted and dried to a water content of 40 percent or below: the term is imprecise, and may sometimes refer to fish products that have been heavily salted or heavily smoked.
Hard dried fish	See hard cure.
Humidity	The quantity of water vapour present in a given quantity of air.

Karasumi (Japan)	Salted mullet roe, soaked in fresh water to desalt it, and then dried.
Karavala (Sri Lanka)	Whole or gutted fish, washed, salted and sundried.
Katsuobushi (Japan)	Hard dried meat of skipjack tuna, made by cutting the fish longitudinally into four, removing bones, boiling, smouldering and drying; the product is shaped and defatted by the controlled enzymic action of moulds; used as a condiment for soups and other dishes.
Kiln	Oven heated by natural or forced convection of hot air for drying fish.
Klipfish (Norway)	Split salted fish of the cod family, naturally or artificially dried.
Klippfish	See klipfish.
Krupuk (Indonesia)	Ground shrimp or other fish, mixed with tapioca flour and seasoning, kneaded with water and steamed in moulds; then cooled, cut into slices and sundried; swells and becomes crisp when fried in deep fat.
Kusaya (Japan)	Horse mackerel, <u>Decapterus</u> sp, soaked in special brine and then heavily dried for long term preservation.
Labrador cure (Canada)	Heavily salted, kench cured cod, lightly dried to 42–50 percent water content, 17–18 percent salt content.
Labrador fish	See Labrador cure.
Labrador soft cure	See Labrador cure.
Lamayo (Philippines)	Salted, partially dried minced shrimp.
Lean fish	Fish in which the main reserves of fat are in the liver and not in the flesh.
Leather beetle	<u>Dermestes</u> species that frequently infest dried fish in the tropics; also called bacon beetle.
Lut fisk (Scandinavia)	Product prepared by soaking stockfish for several days in solution of soda and lime, known as lute, and then for several days in water to remove the chemicals.
Meikotsu (Japan)	The cartilage or soft bone of shark or ray, twice boiled and then sundried.
Migaki Nishin (Japan)	Sundried unsalted herring fillets.

Mirinboshi (Japan)	Headless split fish of various species, soaked in special seasoning usually containing salt and sugar, and then dried.
Mojama (Spain)	Strips of dried salted tuna.
Musciame (Italy)	Dried salted dolphin flesh.
Namaribushi (Japan)	Small whole skipjack, or chunks of bigger ones, boiled and then slowly roasted to remove some of the water.
Natural drying	Drying in the open air by exposure to sun and wind.
Nga bok ohauk (Burma)	Pieces of fish allowed to putrify before being salted and sundried.
Niboshi (Japan)	Small whole fish, often sardine or similar species, boiled in salt solution and then sundried.
Pressfish	Vacuum dried fillets or pieces of fish pressed into blocks.
Pressfisk	See Pressfish.
Press piling	Stacking of salted split fish between drying stages to cause more water from the deeper lying parts of each fish to diffuse to the surface.
Rackling	Sides of flatfish, especially halibut, cut into long narrow strips but still joined together by the shoulder bone, brine salted and dried in the open air.
Reconstitution	The soaking of dried fish products to cause them to take up water again before use.
Rehydration	See reconstitution.
Relative humidity	The degree of dryness of the air that is the ratio of the weight of water vapour in the air to the weight that would saturate it at that temperature, normally expressed as a percentage.
Rotskjaer (Norway)	A special type of stockfish, where the fish is split in two except for a short section at the tail before being hung in the open air to dry naturally.
Shiobushi (Japan)	Whole or split fish of many species, brined or dry salted and then dried.

Smoke drying	The process of drying in the hot smoky air from a wood fire, in which drying is the more important means of preservation.
Soboro (Japan)	The boiled flesh of lean fish, shredded and then dried.
Soft cure	Dried salted lean fish with a water content above 40 percent, typically 44–48 percent.
Soft dried fish	See soft cure.
Spelding	Headed, gutted, split lean fish, usually whiting, dipped in weak brine, often the sea, and dried in the open air.
Spillanga (Sweden)	Split headless ling, with most of the backbone removed, stretched on splints and then dried in the open air.
Split fish	Whole fish cut almost right through, the two severed pieces usually being held together either along the back or along the belly; lean fish like cod being split for making stockfish are usually split from the belly side to beyond the vent, leaving the backbone exposed; most of the backbone is removed except for a short portion near the tail.
Stockfish	Headless gutted lean fish of the cod family, usually split, hard dried without the addition of salt, in the open air; final water content is usually below 15 percent.
Suboshi (Japan)	Dried unsalted fish or shellfish.
Sunburn	Damage to naturally dried fish caused by over-exposure to the sun; the surface becomes wrinkled, the protein coagulates and the product eventually crumbles.
Sundried fish	Fish dried naturally by exposure to the sun.
Sutki (India, Pakistan)	Sundried fish, salted or unsalted.
Tatami iwashi (Japan)	Larval fish of sardine or anchovy, dried in a square frame.
Tokanhin (Japan)	Product dried after removing water by repeated freezing and thawing.
Tom kho (Viet-Nam)	Shrimp cooked in saturated brine and then sundried.
Trepang (Malaya, Philippines)	Sea cucumber, gutted, boiled and dried.

Tuyo (Philippines)	Whole sardinella, brined and sundried.
Vacuum contact drying	Drying on heated plates in an evacuated chamber.
Vacuum drying	Drying by heating in a vacuum.
Vappur pressure	The pressure exerted by a vapour, either by itself or in a mixture of gases or vapours.
Viaziga (U.S.S.R)	Dried food delicacy made from the spinal cords of dried sturgeon.
Viziga	See Viaziga.
Water activity	A measure of the available water in a food relative to pure water, where water is assigned the value of 1.
Water content	The ratio of the weight of water in a product to the weight of the product, usually expressed as a percentage; water content may be expressed on a number of different bases, for example on a wet weight basis, dry weight basis, salt free wet basis and so on; for definitions of each, and an explanation of how to determine each one, See Section 4.
Water vapour	The vapour that is produced by evaporation of liquid water or by sublimation of ice.
Wet stack	Salted fish before drying; usually refers to salted cod piled up in dry salt.
White fish	See lean fish.
Wind-dried fish	Fish dried naturally in the wind.

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$$\begin{array}{r} 52 + 12 \\ \hline 64 \end{array}$$