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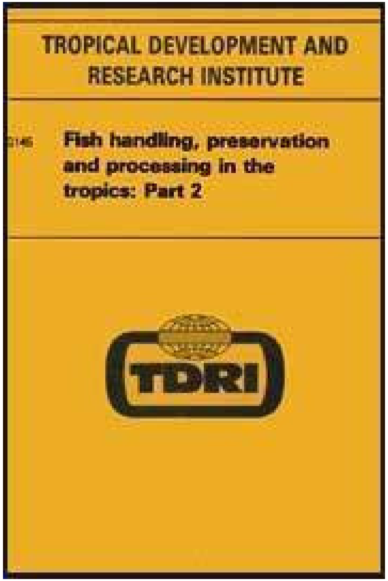


Fish Handling, Preservation and Processing in the Tropics: Part 2 (NRI)

of quality assessment

- **Organoleptic (sensory) measurement of spoilage**
- **Microbiology of spoilage**
- **Microbiology of fish spoilage**
- **Public health microbiology**
- **International standards for fisheries products**
- **Large-scale fish landing facilities**
- **Small-scale landing facilities: design and operation**
- **Retail sale facilities**
- **Fisheries extension services: their role in rural development**
- **Training in the field**

Appendix

Drying of fish: basic principles

Drying is the removal of water from fish. Normally the term 'drying' implies the removal of water by evaporation but water can be removed by other methods: for example, the action of salt and the application of pressure will remove water from fish. Since water is essential for the activity of all living organisms its removal will slow down, or stop, microbiological or autolytic activity and can thus be used as a method of preservation.

Where drying has evolved as a traditional method of preserving fish, the action of the sun and wind is used to effect evaporative drying. In recent times, the controlled artificial dehydration of fish has been developed in some

industrialised countries so that fish drying can be carried out regardless of weather conditions.

In any process of drying, the removal of water requires an input of thermal energy. If the outward movement of water occurs in the following sequence: migration within the material to the surface - removal from the surface - mixing with the atmosphere surrounding the material - removal from the vicinity of the surface,

it must be accompanied by the inward transfer of heat in the following sequence: emission from the heat source - transfer to the surface of the material - conduction within the material - provision of latent heat of evaporation and the partial enthalpy of dilution of the system which is regarded as a solution.

The thermal energy required to drive off the water can

be obtained from a variety of sources, e.g., the sun or the controlled burning of oil, gas or wood. The thermal energy can also be supplied directly to the fish tissue by microwave electromagnetic radiation or ultrasonic heating.

At normal temperatures, fish muscle can be considered to be a gel; it remains a gel until a considerable quantity of water has been removed. During drying, considerable shrinkage takes place, as well as other irreversible changes, and dried fish will not reconstitute to their original condition.

During air drying, water is removed from the surface of the fish and water moves from the deeper layers to the surface. Drying takes place in two distinct phases. In the first phase, whilst the surface of the fish is wet, the rate of drying depends on the condition (velocity,

relative humidity etc.) of the air around the fish. If the surrounding air conditions remain constant, the rate of drying will remain constant; this phase is called the 'constant rate period'. Once all the surface moisture has been carried away, the second phase of drying begins and this depends on the rate at which moisture can be brought to the surface of the fish. As the concentration of moisture in the fish falls, the rate of movement of moisture to the surface is reduced and the drying rate becomes slower; this phase is called the 'falling rate period'.

Constant rate drying

During this period the rate of drying depends on the speed at which moisture can be carried away from the surface of the fish. Several factors influence the rate of drying:

(i) Relative humidity (RH) of the air: if the air is fully saturated with water vapour (relative humidity 100 per cent), it cannot carry any more water and no drying of the fish will occur. If the RH is less than 100 per cent, the air has the ability to absorb water and drying will proceed; the lower the RH, the greater the ability to absorb water and the faster the rate of drying.

(ii) Air velocity: the greater the speed of the air over the fish, the greater the drying rate. The air around fish can be considered as three layers: a stationary layer close to the fish, a slowly moving layer outside this and an outer turbulent layer. The stationary layer of air next to the fish is saturated with moisture that passes into the slowly moving layer. The higher the air speed in the outer layer, the thinner the slow moving layer, which allows more rapid movement of water away from the fish.

(iii) Air temperature: the evaporation of water produces a cooling effect. At the beginning of drying, the temperature of the fish is reduced below ambient; after a short while it reaches a steady value. At this steady value, the heat energy required for evaporation is balanced by the heat supplied by the surrounding air. The degree of cooling is related to the wet bulb depression of a hygrometer and reflects the ability of the air to hold water. Warm air can provide more heat energy and, provided that the air speed and relative humidity will allow a high rate of water movement, the rate of drying will be increased.

(iv) Surface area of the fish: the larger the surface area, the faster the rate of drying. If a fish is split, the surface area increases relative to the weight/thickness; the rate of drying will, therefore, be faster.

Falling rate drying

Once the free surface moisture has been removed, the rate of drying depends on the movement of moisture to the surface of the fish. Several factors influence the rate of drying:

(i) The nature of the fish: a high fat content in the fish retards the rate of drying.

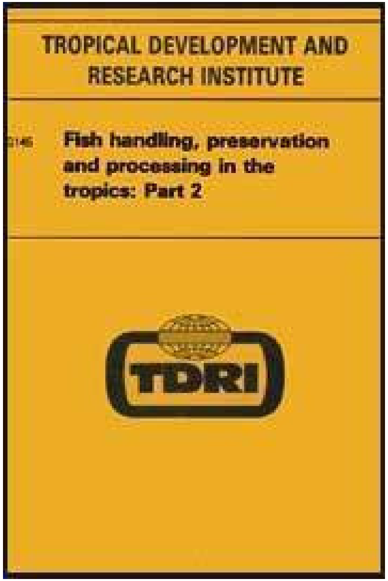
(ii) The thickness of the fish: the thicker the fish, the further the water in the middle layers has to travel to reach the surface.

(iii) Temperature of the fish: diffusion of water from the deeper layers to the surface is greater at higher temperatures.

(iv) The water content: as the water content falls, the

rate of movement to the surface layers is reduced.

Provided that the air passing over the fish is not fully saturated with water, the rate of drying is independent of the condition of the air. Under certain conditions, where the constant rate drying has been very rapid, the surface of the fish can become 'case hardened' and the movement of moisture from the deeper layers to the surface is prevented. This can result in a fish that is dry on the surface and looks, to all intents and purposes, fully dry but the centre will be wet and spoiled. This can be a particular problem with some designs of mechanical and solar driers.



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Drying of fish: methods

Natural drying

The energy of the sun and/or the wind is used in many countries to dry fish. To obtain the best possible rate of drying under natural conditions, several factors should be considered:

(i) Air movement at ground level is usually very slow; if fish are raised above the ground, by even one metre, the air movement is greater.

(ii) Drying fish at ground level does not allow air to pass under the fish; drying fish above the ground on raised, slatted or mesh racks allows drying from the upper and lower surfaces.

(iii) Fish placed on racks above the ground are less

likely to be contaminated by dust or sand; fish placed on mats on the ground are likely to be contaminated by dust kicked up by people walking past. Raised racks provide some protection from animals.

(iv) Fish dried on racks can be more easily protected from rain by covering them with plastic sheets. Fish on the ground can be covered for protection against rain but not against water on the ground.

(v) Sloping racks allow any surplus water on the surface of the fish to drain away. Water trapped in the gill or body cavities can cause localised spoilage and/or increase the drying time.

The use of drying racks obviously has many advantages. However, they should be located to take the maximum advantage of climatic conditions:

(i) low lying swampy areas with a high relative humidity should be avoided and

(ii) racks should be sited away from forests or high buildings which will reduce the air movement or cast a shadow over the racks.

Salted fish will take up moisture from the surrounding air if the relative humidity rises above 75 per cent. It may, therefore, be necessary to remove the fish from the racks at night, or during rain, when the humidity tends to rise. If the fish are piled and covered in plastic overnight, the absorption of water is minimised until the fish can be put out for further drying the next day. If the fish are press-piled at night by placing weights on top of a stack of fish, movement of water to the surface of the fish is encouraged and the subsequent drying rate will be increased.

Other methods

Mechanical driers

Several types of mechanically powered driers have been developed and used commercially in different parts of the world. Fish are dried in a fan driven air-stream; the air is usually heated and, in some cases, the air can be recirculated to control the relative humidity.

Freeze drying

Evaporation of moisture from fish placed in a vacuum quickly cools the fish due to the transfer of heat energy. The fish freeze after about 15 per cent of the water has evaporated. If the fish are allowed to freeze during drying, they do not shrink and will dry with an open porous structure. They will rapidly reconstitute to look

very similar to fresh fish although the water will not be as tightly bound as in fresh fish. If heat is applied to the fish in a vacuum drier and they are not allowed to freeze, shrinkage similar to that found in normal air dried fish occurs.

For rapid freeze drying, some heat must be supplied to the fish if evaporation is to proceed at a rapid rate. Moisture must also be removed from the vacuum chamber, otherwise it will become saturated and no further drying will be possible.

Freeze drying requires a high energy input and is only feasible for very high value products. Freeze dried products have the advantage that they can be stored under ambient conditions as long as the packaging is impervious to water.

Solar driers

Considerable interest has been shown in the development of solar powered driers in recent years. In these, the energy of the sun is collected and concentrated to produce elevated temperatures and an increased rate of drying. Raising the air temperature increases the amount of water the air can hold, thus the relative humidity will be reduced and the air will be able to absorb additional water vapour. In the humid tropics, the relative humidity is often too high for rapid natural drying and it is hoped that solar powered units which are simple, inexpensive and efficient can be developed for drying fish.

There are two basic methods of collecting and concentrating the sun's energy:

1. Parabolic reflectors: sunlight falling on a mirror is focused to a point, where the temperature becomes much higher. Reflectors have not been applied to fish drying, since the normal requirement is to slightly increase the temperature of large volumes of air.

2. Absorption units: a black surface absorbs heat energy from the sun far more effectively than a light coloured surface. If an insulated box, painted black on the inside and covered with clear glass or plastic, is placed in the sun, the temperature of the enclosed air is increased considerably. If the box has openings at the top and bottom, the air, as it is warmed, will rise and create a flow. Fish placed in the box will, therefore, be exposed to a flow of air that is warmer and of a lower relative humidity than the ambient air.

The black heat collection units can be connected to a

drying chamber to supply a flow of warm air and it is not then necessary to expose the fish to the direct rays of the sun which can cause problems with case hardening and cooking of the fish if the temperature is not adequately controlled.

Several experimental designs of solar fish driers have been developed but, at the present time, none are in widespread commercial use.

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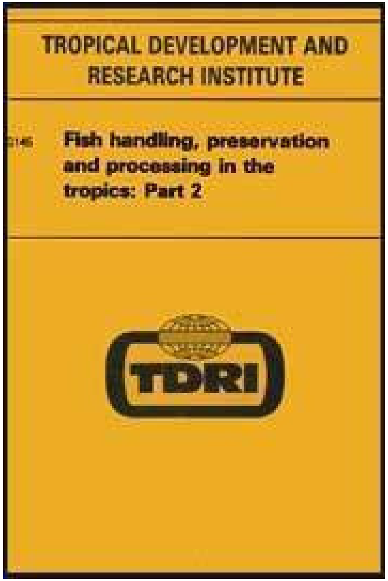
Fish Handling, Preservation and Processing in the Tropics: Part 2 (NRI)

(introduction...)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Smoking of fish

Methods and equipment

Smoking is a method of preserving fish which combines three effects:

1. Preservative value of the smoke: the smoke produced from burning wood contains a large number of compounds, some of which will kill bacteria, e.g., phenols.

2. Drying: the fire which produces the smoke also generates heat and this will dry the fish.

3. Cooking: if the fish are smoked at a high temperature, the flesh will be cooked and this will destroy the enzymes and kill bacteria.

The long storage life of some smoked fish products is due more to drying and cooking than to the preservative value of the chemical compounds deposited on the fish

from the smoke.

The burning of wood or sawdust to produce smoke is extremely complex since the smoke is the result of incomplete combustion and this will vary with the source of the fuel and the ventilation of the fire. A slow burning fire will produce much more smoke than a small intense fire. Wood smoke is a mixture of gases, vapours and droplets. Droplets form the visible part of the smoke although the invisible vapours contribute to the characteristic smell. It has been shown that it is mainly the vapours that are taken up by fish during smoking. The substances in the vapours dissolve in the liquid on the surface of the fish and the rate of uptake depends on the moisture on the surface of the fish and the rate of flow of the smoke.

Smoked fish can be divided into two general categories:

(i) Cold smoked: during the smoking process, the temperature at no time rises to a level where the flesh is cooked (i.e., the protein is denatured). In practice, this means a maximum temperature of approximately 30 - 40°C and is only really possible in temperate climates.

(ii) Hot smoked. during the smoking process, the flesh is cooked. Traditional smoking in tropical countries falls within this category.

Almost all traditional smoked products are heavily smoked and dried; often the fish are salted before smoking. Since the advent of rapid communications (railways) and the use of chilling or freezing to hold perishable commodities, a change towards lighter cured products has occurred in the industrialised countries. In such products, the amount of salt, smoke and drying will not give a long storage life at ambient temperatures and

they must be treated as fresh fish to retard spoilage. In developing countries, the fish are heavily smoked and dried so that they can be distributed and stored without specialised facilities.

Methods and equipment

Fish smokers are often very simple and, in the simplest form, fish are suspended above a slowly burning fire. This may be adequate for the subsistence fisherman who wishes to preserve a few fish for his own consumption but it is not suitable for smoking larger quantities of fish caught by a professional fisherman. A variety of kilns have been developed and these fall into two categories: natural convection smokers and mechanical smokers.

Natural convection smokers

With these smokers, the heat from the fire causes a warm column of smoky air to rise; the fish are hung or laid on openwork trays above the fire.

In one of the simplest types, a fire is burnt in a pit over which a table carrying the fish is built. Since the sides of the table are open, a considerable proportion of the smoke and heat can escape without passing over the fish. A number of designs of smoker have been developed in different parts of the world which utilise locally available materials. Although these may be very cheap to construct, they tend to suffer from some, or all, of the following disadvantages:

(i) They have a high fuel consumption compared to output.

(ii) They have a low capacity.

(iii) They require constant attention.
(iv) They are affected by wind and/or rain.

(v) They are difficult to control and the product is not uniform.

(vi) The materials used in construction are often inflammable.

Several designs of improved natural convection smokers have been developed to overcome some of these problems: they range from the small units based on an old 200-litre oil drum to the multiple units based on the 'Altona' design developed by the Food and Agriculture Organization (FAO). Publications by FAO describe the construction and operation of these kilns. The 'Ivory Coast kiln' is a modification of the 'Altona' design and is simple and inexpensive to construct.

Mechanical smokers

In these smokers, electric fans or blowers are used to circulate the smoke instead of natural convection. In most designs, the flow of smoke is horizontal. Trolleys can be used to hold the fish and these reduce the time and labour necessary to load or empty the kiln. The smoke density, air velocity, temperature and humidity of the air may all be controlled. Although mechanical smokers are expensive, they can produce a uniform product and are particularly suitable for large-scale commercial production. Mechanical kilns are not in widespread use.