



FOOD DRYING

**Proceedings of a Workshop
Held at Edmonton, Alberta, 6-9 July 1981**

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Food Drying

**Proceedings of a workshop held at Edmonton
Alberta, 6-9 July 1981**

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Abstract/Résumé/Resumen

The authors of this volume include researchers and scientists from many countries that encompass diverse climatic, geographic, and socioeconomic conditions. Their disciplines were also numerous: home economics, food science, nutrition, physics, and engineering.

The workshop covered the most important areas in the design and operation of a drying system. These are: drying requirements, consumer acceptance, heat and mass transfer, and heat sources. Within drying requirements, the need for drying the product is discussed as well as drying times and rates, sample preparation, quality changes during drying, rehydration problems, and problems with storage of the dried product. The section on consumer acceptance includes the effects of drying on the nutritive value of food, the introduction of a dried food to the consumer market, and how consumers provide valuable information to scientists to help in improving a process or product. The theory and design of a drying chamber and process control are explained under heat and mass transfer and an operational, full-scale drying system is examined. Finally, under heat sources, a number of examples are given in the use of the sun, petroleum products, agriculture wastes, and wood as heat sources for a drying process. A final concluding commentary is made on the overall recommendations derived from the workshop and proposals for future work are given.

Les auteurs de ce volume sont des chercheurs et des techniciens venus de pays très différents les uns des autres du point de vue climat, géographie et conditions socio-économiques. Les disciplines représentées étaient aussi très diverses: économie domestique, alimentation, nutrition, physique, génie mécanique.

Le colloque a examiné les questions les plus importantes en ce qui concerne la conception et l'utilisation d'une installation de séchage: besoins en matière de séchage, l'accueil du consommateur, transmission de la chaleur et évacuation de l'humidité, sources de chaleur. Le chapitre sur les besoins en matière de séchage traite de la nécessité et de la durée de cette opération, de la préparation des échantillons, de l'action du séchage sur la qualité du produit, des problèmes de réhydratation et des problèmes de stockage du produit sec. Le chapitre sur l'accueil du consommateur traite des effets du séchage sur la valeur nutritive du produit, de la commercialisation d'un produit sec et de l'aide que peuvent apporter les consommateurs à l'amélioration d'un procédé ou d'un produit. Le chapitre sur la transmission de la chaleur et l'évacuation de l'humidité traite de la théorie et de la conception d'un séchoir, des modes de réglage et décrit une installation en service. Enfin, le chapitre sur les sources de chaleur donne des exemples l'utilisation du soleil, des produits pétroliers, des déchets agricoles et du bois. Un exposé des conclusions dégagées par le colloque et de ses recommandations est présenté à la fin de l'ouvrage.

Los autores de este volumen comprenden investigadores y científicos de varios países que, en conjunto, abarcan diversas condiciones climáticas, geográficas y socio-económicas. Sus disciplinas respectivas también son numerosas: economía del hogar, ciencias de alimentación, nutrición, física e ingeniería.

El cursillo abarcó los aspectos más importantes en el diseño y operación de un sistema de deshidratación. Estos son: requisitos de la deshidratación, aceptación por el consumidor, transferencia de calor y masa y fuentes de calor. Entre los requisitos se examina la necesidad de deshidratar el producto así como los tiempos e índices del proceso, preparación de muestras, cambios en calidad durante la deshidratación, problemas que presenta la rehidratación y problemas resultantes del almacenamiento del producto deshidratado. La sección de aceptación por el consumidor comprende los efectos de la deshidratación sobre el valor nutritivo del alimento, la introducción de un alimento deshidratado en el mercado del consumidor, y como éstos a su vez proveen información valiosa a los científicos ayudándoles a mejorar un proceso o producto. Se explican la teoría y diseño de la cámara de deshidratación y el proceso de control bajo transferencia de calor y masa, examinándose un sistema operativo de deshidratación a escala comercial. Finalmente, y bajo el concepto de fuentes de calor, se citan varios ejemplos relacionados con el uso del sol, de productos petrolíferos, y desechos agrícolas, así como el de la madera como fuentes de calor para procesos de deshidratación. Se efectúa un comentario final sobre recomendaciones generales derivadas del cursillo al tiempo que se efectúan propuestas para el trabajo futuro.

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Foreword

For as long as we have historical record, the heat of the sun has been used to dry cereal grains, vegetables, fruit, fish, and meat. Solar radiation is widely used as a direct source of energy by which to dry and dehydrate foods of many kinds in many countries. As fossil fuel costs continue to rise, direct and indirect solar drying will gain increasing importance as a method of food preservation throughout the world.

The International Development Research Centre (IDRC) is supporting several research projects in which solar radiation alone or together with combusted agricultural wastes is used to dry crops and other food materials, in several of which the influence of variable drying conditions upon nutrient retention is being studied.

Because the food dehydration and crop drying projects financed by IDRC are located in countries with widely different environmental conditions and the spectrum of research activities calls for a variety of scientific disciplines, it appeared desirable to bring together research workers representative of the geographic and scientific diversity involved.

A workshop was, therefore, organized from 6 to 9 July 1981, at the University of Alberta and in collaboration with the Alberta Department of Agriculture (ADA), which included 2 days of formal sessions; a 1-day tour organized by the ADA of a grain dryer manufacturing plant, a local farm, and a primary elevator; and 1 day of informal visits to various university departments and commercial organizations by individual participants. Those attending the workshop came from Bangladesh, Chile, Egypt, Guatemala, India, Indonesia, Kenya, Korea, Malaysia, Mali, Niger, Costa Rica, Peru, the Philippines, Sierra Leone, Singapore, Thailand, and Zambia, encompassing immensely diverse climatic, geographic, and socioeconomic conditions and with experience that embraced home economics, food science, nutrition, physics, and engineering. The main topics covered included drying requirements, consumer acceptance, heat and mass transfer, and heat sources. This publication comprises the papers presented and discussed, together with a commentary by the technical coordinator of the meeting.

It is the belief of my colleagues in the Agriculture, Food and Nutrition Sciences (AFNS) Division that, thanks to the contributions by those who took part, this publication may prove of lasting value to others in developing countries who share similar interests and concerns.

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Drying of Fish in India

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Abstract. Among the several methods of long-term preservation of fish, drying is perhaps the simplest method that does not require sophisticated equipment or highly skilled workers. Traditional drying in the sun, although practiced widely, poses some problems such as slow drying and contamination with sand, insects, and pathogenic bacteria. It is, therefore, necessary to consider mechanical drying of fish. The influence of temperature of drying, relative humidity in the dryer, and the air velocity as well as salting before drying are discussed in this paper. General defects observed in the course of storage of fish and some methods for minimizing them are also given.

Fish spoil quickly because of bacteria, enzymes, and chemical reactions, but bacterial and enzyme actions can be minimized or arrested by controlling the storage temperature of the fish. Chilling, freezing, and canning are some of the processes; however, these are techniques that require sophisticated equipment for the processing, storage, and distribution of the processed products.

Water is essential for bacterial growth as well as for the activity of enzymes. The removal of water from fish reduces the chances for the action of spoilage bacteria. Drying, either without or after salting and with or without smoking, is a widely accepted traditional practice of preserving fish. Salting, smoking, and drying are processes that can be employed with the minimum of equipment and operated by semi- or unskilled workers. Normally, drying is done in combination with either salting or smoking or both. Salting slows down or even prevents the bacterial spoilage of fish. Some chemicals present in smoke also destroy spoilage bacteria. The removal of water by drying can halt the growth of bacteria and moulds. Drying is, therefore, a simple method of preserving fish that does not require complicated equipment, can be handled by unskilled workers, turns out a product with good storage properties, and provides a highly concentrated food.

Because drying involves the removal of water to stop the action of bacteria or enzymes, attention must be given to what amount of water can be removed before the quality and flavour of the product are affected. Most of the spoilage bacteria do not grow in foods that have less than 25% moisture content (MC). Similarly, moulds also cease to grow when the moisture content is 15% or less. However, if the fish is salted before being dried the permissible amount of water can be higher. Depending upon the amount of salt used, 35–40% MC can be considered safe enough to inhibit the action of bacteria or moulds.

In this paper, the discussions on drying will be limited to sun or mechanical drying of fish, fresh or salted. The principal method of drying practiced in India is sun drying, which is mainly used for the by-catch from shrimp trawling. Fish is dried fresh or salted depending upon the species. The most common practice is to spread the fish on sandy beaches, bamboo mats, or raised cement platforms where they are allowed to dry for 2–3 days. Fish like anchovies (*Engraulis indica*) are dried without salt; however, larger fish are generally salted whole or after having been split. Even larger fish like shark are split; deep scores are made in the open flesh to allow the salt to penetrate, and the fish are left heavily salted overnight and then dried. Fish like Bombay duck (*Harpodon nehereus*), which contain 90–92% water, are hung from scaffolds erected in the open and then dried. In most cases after a day's drying the fish are usually heaped together overnight and spread out and dried again the next day. This facilitates the diffusion

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of water from the relatively moist interior to the surface from where it can be more easily evaporated during the subsequent drying operation.

Drying of Unsalted Fish

The type of fish that are usually dried unsalted includes anchovies, small silver bellies, and Bombay duck, for example, which are all used for human consumption, as well as several other varieties of small fish that are converted into fish meal. The facilities available at landing sites determine whether these fish are dried either by being spread on sand on the beach or on mats or, less often, on cement platforms erected for this purpose with the exception of Bombay duck, which, as discussed earlier, is often dried by hanging on scaffolds.

Bombay duck is a typical fish of the Gujarat coast in India where a huge quantity of fish (about 80000 t) is landed within a period of 4 months. Only a small proportion is consumed in fresh form, the rest is sun dried and used for local consumption and export. The drying practice presently used is to wash the fish in creek water and to hang them by pairs joined jaw-to-jaw on horizontal ropes. Ten to twelve of these ropes are then tied horizontally, one above the other, leaving a space of about 30 cm between them. Normally, 80–100 fish are hung per metre. A systematic study covering various aspects of drying Bombay duck on scaffolds has shown that optimum water loss occurs when 50–60 fish are hung on a 1-m length of rope. This permits adequate circulation of air over individual fish and yields a final product that is satisfactory both in physical and in organoleptic characteristics. With this method water loss of 87% of fresh fish has been achieved. Decreasing the number of fish per metre of rope did not improve the drying time, whereas increasing the number of fish resulted in a slower drying rate and excessive spoilage.

Normally, in cases where the fish is dried without salting, the process is continued until about 10% MC. Although Bombay duck and anchovies dried in this manner are exported, other fish are used locally, some being converted into fish meal.

Salted Sun-Dried Fish

A number of species of fish, large and small, fatty and lean, are salted and sun dried in India.

Mackerel, jew fish, sole, lactarius, cat fish, and shark, among others, are most commonly preserved by this method. The fish are normally split open from the dorsal side, mixed with common salt (marine salt) in the ratio of 5:1, kept overnight, and dried the following day. The fish are then dried for 2 or 3 days in the sun until about 35% MC. Salted and dried fish are generally marketed within the country.

Generally, the fish that are used for drying are not very fresh. Often, only fish that cannot be sold in the fresh fish market are dried. Ice is either not used at all or used only sparingly. Proper handling is also not observed, and drying is done, with very limited exceptions, in the open, which increases the risk of contamination. Flies often lay eggs that, although not detected immediately, become a problem during storage. Occasionally, contaminated fish present a significant public health concern.

Drying of Fish in Mechanical Dryers

Because of the problems connected with sun drying, consideration is now being given to the mechanical dehydration of fish. In mechanical dehydration, the drying process is carried out under controlled conditions. The temperature of drying, air velocity, as well as the relative humidity (RH) in the drying atmosphere should be strictly controlled to ensure that the final product is of satisfactory quality.

Drying Temperature

In mechanical dryers, hot air is employed as the carrier of heat to the fish as well as water vapour from the fish. At the initial stages, when the fish flesh is saturated with water, the temperature of drying should not exceed 40–50°C depending upon the fish used. At temperatures above 40–50°C most of the fish flesh gets cooked, which makes the final dry product brittle.

Air Velocity

In mechanical hot-air dryers, it has been observed that the higher the velocity of air passing over the fish the greater will be the rate of evaporation of water. However, if the air velocity is increased beyond a certain limit, a small whirlpool of air will occur between the fish and this will result in nonuniform drying. Experiments have shown that an air velocity of 1.5–2 m/sec is ideal for drying most of the fish.

Relative Humidity

The rate of evaporation of water depends on the partial pressure of water vapour in the air surrounding the fish and the partial pressure of water vapour on the surface of the fish. Therefore, at a constant air velocity, the drier the air the faster is the rate of evaporation of water.

Water in fish is not present as pure water. It contains dissolved salts and protein, etc. When water leaves the fish at the surface these residues are left and if the air is very dry a crust will form on the surface. This phenomenon is called case-hardening. Case-hardening also occurs when the temperature of the air is raised and, therefore, diffusion of water from deeper layers to the surface becomes difficult. This will result in an increase in the temperature of fish flesh, which will affect the quality. Also, if the relative humidity of the air at the inlet point of the dryer is too high, the drying process will be prolonged, and the fish will spoil before the drying process is over. Relative humidity between 50 and 60% is recommended for drying in hot-air dryers.

Constant- and Falling-Rate Periods

There are two distinct stages when fish are air-dried: the constant-rate period and the falling-rate period. In the first stage, the rate of evaporation of water per unit area per unit time remains a constant and this is similar to evaporation from a saturated surface. Once the surface water is evaporated, further evaporation can take place only as fast as it diffuses to the surface from within. The rate of diffusion slows down as the drying process progresses and consequently the rate of evaporation also falls. This is the falling-rate period.

Even in mechanical dehydration, 18–22 hours are required so that the end product will be sufficiently low in moisture to ensure safe storage. Although mechanical dehydration takes less time than sun drying, it is still considered to be too long a process, and, naturally, the cost of producing dried fish using mechanical dryers is high compared to the sun-drying process. Dried fish is an inexpensive commodity for the common people, therefore, an increase in the price of mechanically dried fish over that of sun-dried fish is likely to be unacceptable to consumers even though the increase in price would be justified by the improved quality. Consideration should, therefore, be given to

determine ways to cut down the drying time, without sacrificing quality, in an effort to reduce production costs. One method suggested for accelerating the drying process is to subject the fish to successively higher temperatures during the falling-rate period. This method has since been applied in the case of tropical fishes and has resulted in great success.

At the Central Institute of Fisheries Technology (CIFT) in India, freshly split fish (average weight 90–110 g) are dried under a phased temperature program, initially at 45°C until the period during which drying is constant is complete. Then drying is done at progressively increasing temperatures of up to 60°C, with 50% RH. Fish are dried to a final moisture content below 20% in 12–14 hours.

Salted fish do not exhibit any constant-rate period. In the case of salted fish, the initial high rate of drying suddenly falls; however, this fall in rate can be compensated to a large extent by a slow increase in temperature. In the case of salted fish like mackerel, jew fish, etc., it took 10–12 hours to bring the moisture content below 30%.

A tunnel dryer employing this principle with appropriate controls for temperature, humidity, and air velocity has been designed at CIFT.

Rehydration

In India, dry fish is consumed in different styles; after frying in oil, as chutney, or prepared just like fresh fish after reconstitution in water. Denaturation of the proteins takes place during the process of dehydration, particularly when the fish is dried at high temperatures as in mechanical dryers thereby affecting the rehydration capacity. However, if the drying conditions are carefully controlled, case-hardening as well as too high an increase in the temperature of the flesh can be avoided, and a final product that rehydrates to give a fair texture can be produced.

Packaging and Storage

The main causes of spoilage of dry fish are moulds, bacteria, discoloration, rancidity, attack by insects, and changes in texture. Mould growth is relatively low at 65% RH, but mould grows rapidly at 75% RH or higher, a condition generally obtained in the coastal areas. However, in the monsoon season, the relative humidity is 90% or higher and provides an atmosphere quite

conducive for all types of spoilage to progress. Salted and dried lizard fish (*Saurida* sp.) kept outside had the following changes in moisture content during 4 months' storage: initial moisture content (MC_i), 28%; after storage at 55–60% RH for 3 months, 19% MC; and after a month's storage at 90% RH, 45% MC.

At 90% RH, because of the attack of bacteria and moulds, the fish flesh becomes slimy, soft, and severely discoloured. Although bacterial spoilage is controlled in salted fish, spoilage caused by moulds occurs whether the fish is salted or unsalted. Sorbic acid or sodium propionate treatments are effective barriers against moulds; however, the problem of providing an effective barrier against the moisture loss or uptake remains. In the former case, weight loss and toughening of the texture are the main problems, whereas in the latter case incidental spoilage and attack by mould and bacteria are important.

Another important sign of spoilage in salted fish is the "pink," the colour developed because of the growth of halophylic bacteria of the *Serratia* sp. Curing salt is the main source of these microorganisms. Solar salt (marine salt) is known to contain these microorganisms in relatively large numbers and hence the problem's incidence is more widespread where solar salt is used for curing.

Dried fish in general, and dried fatty fish in particular, become discoloured during storage. They also develop rancid odours and flavours. The additional cost of providing an air-tight package for dried fish would not be economically acceptable to the common people and has, therefore, not been attempted.

Although there have been sporadic reports on the effectiveness of various antioxidants like butylated-hydroxyanisole (BHA), butylated-hydroxytoluene (BHT), etc., on the prevention of rancidity in fish, no information is available on their commercial utilization.

Insect infestation has not been a serious problem in the storage of salted fish, but it is common in unsalted fish. Fumigation is one method used to prevent this.

Commercially dried fish in India, particularly on the east coast, are packed in palmyrah (palm) leaf mats and tied securely with ropes, covered with hessian cloth, and sewed at the joints to provide a safe package. At present there are no consumer packs of dry fish available, although mechanically dried fish are packed in polyethylene bags for the retail market. However, polyethylene is not strong enough to withstand any physical damage from fins and other sharp contours of dry fish. Studies on low- and high-density polyethylenes, polyvinylchloride films, etc., are under way on the most suitable packaging for consumer packs of dry fish.