SMOKING FISH AT HOME SAFELY

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INTRODUCTION

This presentation was based on the Oregon State University Sea Grant Program publication SG 66. That text is reprinted here. Although the pamphlet was intended for hobbyists, this presentation made some modifications pertinent to commercial smoking.

Present Food and Drug Administration (FDA) good manufacturing practices do not require a 180°F cook for 30 minutes, but it is still good practice to do so for fish containing at least 3.5 percent water phase salt (but less than 5 percent). As discussed in other sessions on quality control, commercial smokers should conduct salt and moisture analysis to whatever extent necessary to insure a safe product. Small natural convection smokehouses can be used effectively, but only if the operators have the appropriate knowledge of the physical process. Continuous monitoring of internal fish temperatures is essential for the proper operation of a small natural convection smokehouse.

A typical smoking cycle as illustrated in SG 66 will partly dry the fish prior to cooking. This will help avoid the "baked" flavor most people find undesirable. Monitoring internal fish temperature will help determine when the fish is dry enough to cook. Internal temperature rise due to reduced water evaporation is the signal to begin the cook cycle.

NOTE:

SINCE THE PUBLICATION OF THIS BULLETIN, SG 66, RESEARCH HAS SHOWN THAT NEITHER 3.5 PERCENT WATER PHASE SALT CONTENT IN FISH, NOR HEATING 30 MINUTES AT 180°F INTERNAL TEMPERATURE WILL INSURE TOTAL DESTRUCTION OF BOTULISM ORGANISMS. THE READER IS CAUTIONED TO REFRIGERATE ALL SMOKED FISH AND OTHER SEAFOOD PRODUCTS NOT CONSUMED IMMEDIATELY.
Smoking fish at home — safely

by Kenneth S. Hilderbrand, Jr., Extension Seafood Technologist, Oregon State University

Three common ingredients in all fish-smoking recipes are salt, smoke, and heat. This bulletin points out that only salt and heat are important for safety, and it explains the basic techniques for preparing delicious—and safe—smoked fish. It also recommends refrigerated storage for all smoked fish.

Smoked fish are good—but . . . !

Fish smoked without proper salting and cooking can cause food poisoning—it can even be lethal. Most food-poisoning bacteria can and will grow under the conditions normally found in the preparation and storage of smoked fish. Botulism is, of course, the most harmful of these bacteria.

There are two requirements for the smoking of fish so that it will store safely without refrigeration:

- You must heat fish to 180° F (82° C) internal temperature and maintain this temperature for 30 minutes.
- When smoked, your fish must have at least 3% WPS.

(The phrase “3% WPS”—for “water phase salt”—means that the salt content is 3% of the moisture left after smoking.)

Strict attention to both of these requirements is essential, for two reasons:

- It is difficult to predict in advance exactly how much salt a given piece of fish will absorb.
- It is difficult to determine after smoking whether the internal temperature did indeed remain at 180° F (82° C) for the full 30 minutes.

(Measuring the WPS after smoking requires equipment unavailable to the average home smoker.)

Clean all fish thoroughly to remove blood, slime, and harmful bacteria. Keep fish as cool as possible at all times, but do not freeze. When you cut fish for smoking, remember that uniformly-sized pieces will help achieve more uniform salt absorption without risk of oversalting. Do not let fish sit for extended periods after cleaning and before smoking.

Salting

Salt is what preserves smoked fish. Products with high-moisture content require more salt than “dry” products. The minimum salt required for proper preservation is 3% WPS.

Without chemical analysis, it is hard to be certain that 3% WPS has been achieved in your final product. That is why proper cooking and storage are essential for absolute safety. However, some rules of thumb are useful.

Salt the fish before smoking in a strong salt solution (brine); salting in a brine that is 1 part table salt to 7 parts water—by volume, not by weight—for 1 hour will do in most cases. (This proportion is approximately 60% SAL, as measured on the salometer scale; see Preparation of Salt Brines for the Fishing Industry under “For further information.”)

High-oil-content fish is usually the best for smoking. It absorbs smoke faster and has better texture. On the West Coast, some of these species are shad, sturgeon, smelt, herring, steelhead, salmon, mackerel, sablefish, and tuna. You can smoke any fish, however, without fear of food poisoning if you observe some basic principles. You will find these principles in the fundamental steps of all fish-smoking recipes: preparation, salting, smoking and cooking, and storage.

Preparation

Different species of fish require different preparation techniques. Salmon are usually prepared by removing the backbone and splitting. Bottom fish are filleted. Herring are headed and gutted. Columbia River smelt are smoked whole.

In general, however, certain principles apply in all cases. First, use good quality fish. Smoking will not improve fish quality; it may, in fact, cover up certain conditions that could create food-safety problems later.
About 30 minutes should do for a gutted herring. However, large or oily fish will require more time. Two hours for large chunks of a 30-pound salmon is a good starting place for experimenting.

Decrease the time for nonfat fish and for skinned fish. A final product that has a definite, but not unpleasant, salt flavor probably has achieved a 38% WPS.

Dry salting techniques are acceptable, and the same general rules apply. However, brining should give more uniform salting than dry salting.

Many recipes call for lower salt brine concentrations than the 1 part table salt to 7 parts water formula given above—but for extended periods, 18 to 24 hours. These recipes may be sufficient, but they tend to offer more opportunity for bacterial growth and possible spoilage later. In addition, these procedures prolong the entire process and increase the mess you must clean up later.

Rinse and air dry all fish before smoking. This not only gives smoke a chance to deposit evenly but also helps to prevent surface spoilage during smoking. Smoke will not deposit easily on a wet surface.

If proper drying conditions are not available (cool, dry air), try placing the fish in the smokehouse with low heat, no smoke, and doors open. With a wood heat source, use a low, clean flame.

**Smoking and cooking**

Cook the fish at 180°F (82°C) internal temperature for at least 30 minutes at some time during the smoking "cycle." This is probably the most important part of any fish-smoking recipe—and one that is often forgotten in home smoking.

Because you cannot determine the final salt content (without chemical analysis), proper cooking is the only way you can insure a product safe from botulism without adequate refrigeration.

A typical fish-smoking cycle (see figure 1) should bring the fish to 180°F (82°C) internal temperature within 6 to 8 hours (internal—not oven—temperature).

If your smokehouse cannot provide 200°F to 225°F (93°C to 107°C) oven temperatures, you will have to cook the final product in your kitchen oven. Waiting longer than 6 to 8 hours for that vital 30 minutes at 180°F (82°C) presents a danger of spoilage caused by bacteria growing under ideal conditions (120°F to 130°F, 48°C to 54°C).

*Remember*: Smoke itself is not an effective preservative under most smokehouse conditions.

A standard meat thermometer will work for checking the internal temperature of the largest piece in the smokehouse. This should insure that all the fish has reached 180°F (82°C). (Some smokehouses may have cool spots.) A long-stemmed dial thermometer inserted into the fish through a hole in the smokehouse wall may be desirable; it allows temperature monitoring without opening the door.

It is best to wait 3 to 5 hours before elevating the fish to the 180°F (82°C) internal temperature. This is easier to do after most of the moisture is gone, and there will be less tendency for a baked fish flavor. In addition, there will be less "curd" formation caused by juices boiling out of the fish.

Further smoking and drying can be done after the 30 minutes at 180°F (82°C). Keep the fish temperature above 140°F (60°C) to prevent growth of harmful bacteria. However, some oily fish (such as sablefish) may never "dry out" the way salmon or tuna does.

Figure 2 illustrates the basic components of a good smokehouse.

A common question asked about fish smoking relates to the small metal smokers readily available in most hardware or sporting goods stores. This equipment may be adequate, but it has difficulty achieving temperatures high enough to obtain proper cooking. So if you do use one of these small devices, you will need to use your kitchen oven to achieve the 30 minutes at 180°F (82°C) internal temperature.
Figure 2.—**Basic components of a smokehouse.** This drawing is not intended, nor should it be used, as a blueprint for building a smokehouse. It shows the features to look for in a smokehouse and their general arrangement. The key features are: (1) an independent source of heat for the pot of wood chips or logs; (2) a controllable vent, or flue, at the top; (3) a controllable draft at the bottom; (4) some thermostatic control over the oven temperature connected to (5) another heat source to raise temperature in the smokehouse to 200° to 225° F (93° to 107° C).
Storage

Refrigerate your smoked fish (below 40°F, 4°C) if you do not plan to consume it in 1 or 2 days. This is essential; the salt content is unknown, and there may be doubt about the time and temperature achieved in the smoking cycle.

You can retard mold growth on your smoked fish if you package it in a porous material such as cloth or paper toweling. This prevents "sweating," a process where moisture moves from the fish to the inside of the bag, causing a wet spot where mold can grow. This is especially severe if you place warm, plastic-wrapped fish in a refrigerator.

For extended storage (longer than 1 or 2 weeks), tightly wrap and freeze smoked fish. Little quality is lost in frozen smoked fish because of its low moisture content. (For instructions on correct packaging for freezing, see Home Freezing of Seafood under "For further information").

For further information

Most bookstores and sporting goods stores carry a variety of books on "smoke cooking." Most have delicious recipes and clear instructions. These, plus the use of common sense in following the principles outlined in this publication, will insure safe, pleasing home-smoked fish.

Here are some suggestions for further reading:


Hilderbrand, Kenneth S., Jr., Home Freezing of Seafood, Oregon State University Extension Service, Sea Grant Marine Advisory Program Publication SG 7 (Corvallis, revised 1976).

CANNING SMOKED FISH PRODUCTS

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If you are planning to can smoked salmon or any other seafood, you will first need the following:

AN ASSURED SUPPLY OF QUALITY FISH. These fish must be received free from bruising, internal bleeding, and decomposition. If fresh-caught, it should be less than 48 hours out of the water, well-iced or refrigerated. Frozen fish should be top-quality rather than rejects from some other market.

CANNING EQUIPMENT. This should include a closing machine, vacuum pump (if the closing machine is a vacuum type machine), some form of exhaust or steam box to heat the canned product prior to closure (if the closing machine is not vacuum or steam flow). For a vacuum closing machine, you may need a clincher to code the ends and clinch the ends on the cans prior to the seamer. You will need baskets or trays to hold the packed cans for retorting, retorts and boiler that will pass state and local certification, certified accurate thermometers for the retorts, recording equipment to show that the retort cooks meet time and temperature requirements, and an automatic steam controller for the retort.

TECHNICAL STAFF. You will need someone in your employ who can maintain and repair all of the equipment, mechanical and electrical, and plumbing.

MANAGEMENT STAFF. You will need someone in management that has been certified by the FDA after attending the Better Process Control School put on each year by University of Alaska, University of Washington, Oregon State College, or University of California at Davis.

This school teaches the essentials of microbiology and plant sanitation. Also taught are the essentials of chlorination, can handling, retort processing, and container closure and evaluation. Knowledge of these aspects of canning is necessary for commercial operation of any cannery.

AUTHORIZED THERMAL PROCESS FOR RETORTING. The usual processing authority in this area is National Food Processors Association, 1600 S. Jackson Street, Seattle, WA 98144. Phone (206)323-3540. Membership or a fee is required for this work.

The process you receive will be specific for a can size, initial temperature of the product, retort temperature, and time. The process may be a general one that will cover any fish product and style of pack or it may be based on your product. This requires having your processing authority run heat penetration tests on your product. Once
this has been done and you have an authorized cook in your records, you will need to continue to pack the style of pack, fill in weight, degree of moisture in the smoked product, and cooling procedure on which the cook was based. Changing any of these factors will require you to obtain additional heat penetration work.

KNOWLEDGE OF REGULATIONS. You will need to be very familiar with the federal, state, and possibly local regulations that apply to your operation.

CANS. You will need to have a supply of cans from a manufacturer, distributor, or a local cannery.

The can specification used for fresh salmon is suitable for smoked salmon, trout, or sturgeon. This can will have a full inside enamel coating on either #25 electrolytic tinplate or tin-free steel. Usually, a full outside coat of gold lacquer will cover the can to reduce rusting.

If you are canning some other seafood product prone to black sulfide discoloration, such as crab, clams, tuna, or cod—you will need a can with two coats of enamel on both the body and ends and a side seam stripe on the inside over the seam.

If the product is prone to sulfide formation, you will also need to be absolutely sure that the product is free of incipient decomposition. Stale product releases sulphur-bearing volatile products that react with oxygen and metal from the can during and after processing. To reduce the oxygen available in cans to form sulfide (actually forms of rust), fill the cans with brine, broth, or oil prior to closure. This is far more effective than increasing can vacuums.

CANNERS. You will need someone in your employ that has experience in food canning. They will need experience in:

a. Product handling
b. Plant sanitation
c. Plant maintenance
d. Obtaining and maintaining supplies
e. Obtaining and working with employees
f. Can handling, filling, seaming, seam evaluation, keeping records, and record evaluation
g. Retorting in steam and boiler operation
h. Warehousing, product storage, shipment, and labeling
i. What to do in emergencies
MARKETS. Most importantly: You must determine in advance that you will have a market for your product at a price that will result in a profit to you. All of this will require a large initial funding.

GENERAL PROCEDURES

Now, in the canning operation, fill the cans with your products. Obtain uniform fill in weights that conform to your label declaration. Frequently check-weigh cans and record weights. Be sure the tare weight for the empty cans is the tare weight of the actual cans used.

Code the cans to show your company, location, product, canning date, and shift, period, or retort load. Know the specific requirements that may apply to your product.

Some means of producing internal can vacuum in the range of 5 to 15 inches is necessary. Vacuum in the can, drawing the ends inward, tends to assure the consumer that the can has not leaked and the product is safe to eat. It is most important that all of the cans leaving the cannery have a vacuum as shown by inwardly concave ends. Be aware that can vacuum does not assure product safety.

In a vacuum closing machine, the vacuum is formed mechanically. Ends are coded and clinched on and the air is pulled from the can in a vacuum chamber. The double seam is completed in the vacuum chamber.

In small-scale canning operations, the closing machines used are American Can Company #1 High Speed (125 cpm), 00-6 Vacuum Closing Machine (60 to 90 cpm), #1 Pacific Vacuum (5 cpm), and Rooney Vacuum Closing Machine (5 cpm) (Rooney Machine Co., 2801 St. Paul, Bellingham, WA 98225, phone (206)733-5470). Information on the American Can machines can be obtained from American Can, Box C 88789, Seattle, WA 98188, phone (206)246-9000. In addition, used machines are available from cannery equipment dealers and almost forgotten in cannery storage warehouses. Remember to get any change or spare parts that may be found, as these are costly when ordered new. Vacuum pumps are available from these same sources.

Another means of obtaining can vacuum is by steam flow closure, where steam is injected into the head space of the can just as the cover is being applied. The steam in the head space of the can condenses to leave a partial vacuum. The amount of vacuum will depend upon the size and uniformity of the head space and the design of the steam flow machine.

Typical machines would be American Can Company, Canco 400 steam flow (200 cpm), 00-6 steam flow (60 to 90 cpm), and Continental Can Company CR steam flow (250 cpm). Occasionally some small machine has been modified for steam flow closure but these modifications often are not effective.

Can vacuum can also be obtained by passing filled cans through a steam box or exhaust box prior to closure. This may work very well for a small canner. If the product is heated to 140°F or higher, there will probably be at least 5 inches vacuum after closure and processing.
If you are canning, you must know can closure specifications and federal and state requirements for double seam examination and recording. This is covered in the Better Process School. (The text for this school is a valuable reference work. It can be obtained from the Food Processors Institute, 1133 20th Street, N.W., Washington, D.C. 20036.) Can closure specifications can be obtained from the container manufacturer.

After closure, the cans must be processed according to the authorized cook in a retort equipped with a mercury-in-glass thermometer and chart recorder. It is necessary to use some form of heat-sensitive process indicator on each basket of cans being retorted. Following this, the cans may be air or water cooled, depending on the authorized process.

The quality of the final canned product will depend mostly on the initial quality of the seafood and the smoking process. It will also depend upon the style of pack, whether the product is hard, soft, dry, moist; and packing material, brine, oil, or broth. The canned, smoked product should not be secondary product.

The quality of can closures must be carefully maintained and good records kept. All defects in product and containers must be retained and kept out of markets. Whether or not a consumer purchases your product a second time depends on the care with which the first can was produced.
THE DESIGN OF DRYERS FOR THE DEHYDRATION OF SEAFOOD PRODUCTS

by
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When I joined AFOS, Ltd., some 20 years ago, the majority of our turn over was in the heating, ventilating, and air conditioning business, with a small sideline manufacturing Torry Kilns. The company's experience in the heating and ventilating industry prepared us well for an involvement in the food processing industry. Our position is now reversed, with the larger proportion of the turn over taken up by kilns, dryers, and associated equipment on an international basis. My own background is in engineering and not food technology. I therefore propose to concentrate on this aspect of the subject.

There are five basic methods of preserving sea foods: salting, drying, smoking, freezing, and canning.

Only during the last 40 years has freezing been used to any extent, and controlled mechanical methods developed for drying and smoking.

In developed countries, the main methods of preservation are freezing and canning. Salting, drying, and smoking are largely used to provide taste, flavor, and quality of the products. Mr. Bannerman and others have already covered these aspects of preservation. I will concentrate on drying seafood products.

Drying, or dehydration, is still used in developed nations, but only for relatively low volume traditional products such as bacalao in Mediterranean countries and lutefisk in Scandinavia. However in developing nations, which largely have hot climates, dried sea foods are still of great importance as a protein source. Until the advent of mechanical driers, seafood products were dried outdoors. In colder climates this was acceptable because low ambient temperatures prevented most spoilage. In hot climates this was not so. In some cases, the final products were contaminated during the long outside drying process and had a higher protein content in the infesting bugs than in the remaining product. Mechanical driers solved the problem of drying fish in hot climates and also made it possible to control the process accurately in colder climates, reducing production time appreciably.

Although there are many differing types of dried seafood products, design requirements for mechanizing the process are similar. Two basic requirements are:

1. A robust, hygenic drier insulated for fuel economy
2. We propose loading large quantities of product into the drier, so even dehydration rates must be maintained throughout the drier.

Both these requirements are well-satisfied by the basic design of the Torry Kiln as described in the previous lecture by Mr. Bannerman. If we refer to the sectional drawing of the Torry Kiln (Figure 1) and simply remove the smoke producer, a ventilated drying remains (Figure 2). This can pull in a percentage of ambient air and exhaust a similar amount through atmosphere. The equipment is robust - manufactured with a metal main frame and sheeting either of galvanizing material or all stainless steel. It is insulated between the inner and outer sheeting and is easily kept clean using detergents and pressure spray equipment. More important however, is the airflow design which ensures that the lamina flow across the product as required for even and consistent drying in all parts of the dryer.

Other common areas of design are:

1. A system for controlling internal air conditions to produce optimum drying rates for the particular products.

2. Control systems designed to work at minimum energy costs.

Due to vastly differing process requirements, which depend on the type of product required, these two common areas of design will produce very different final solutions. In the sectional view of the ventilated drier (Figure 2) the airflow takes up moisture from the fish in the main bottom compartment. This increases the relative humidity of the air. Obviously, if the air were continuously circulated, it would eventually become saturated with moisture and no further drying would take place. This moisture build-up has to be released therefore, as the drying process proceeds. This can be done in one of two basic ways:

1. The ventilated dryer. As shown in Figure 2 this allows colder, drier air to be introduced and moist air to be removed in a controlled way. By varying the amount of air allowed into the drier and providing a re-heat battery, constantly controlled conditions can be achieved.

2. Dehumidifier drier. If we have a totally enclosed system but include a dehumidification coil in the air circulation, we can remove the moisture from the air. Then re-heating it will give the required control conditions. This can be seen in the sectional diagram of a dehumidification drier, Figure 3.

Which of these two basic methods is best suited for a particular application depends not only on the required process temperature, humidity, and air speed, but also on prevailing ambient air condition. It will always be possible to design a suitable drier using the dehumidification principle, but this is not the case when using a ventilated drier. Obviously, when the ambient temperature is 90°F, that air cannot be used if the process requirements are an air condition of 80°F and 45 percent relative humidity onto the fish. The cost of energy also comes into consideration under certain conditions. The simpler, cheaper, ventilated drier design is otherwise
Figure 1. Sectional view of the Torry kiln and smoke producer.
Figure 2. Sectional view of ventilated drier.
Figure 3. Sectional view of dehumidifier drier.
technically viable, but its energy consumption may be greater than that of the dehumidified one.

These points can best be illustrated using a psychometric chart (Figure 4) and the following examples. Consider a drier for a process calling for the condition of the air onto the fish to be 80°F and 45 percent relative humidity (RH). This condition is shown on the chart by point A. As the air passes over the fish, it absorbs moisture. The air does not lose any energy in its passage over the fish, and we can therefore represent the condition of the air leaving the fish by point B. A-B is a line of constant energy or enthalpy. We now have to bring the air back to the required condition at A, to maintain this process requirements. Adding heat to the air is represented by horizontal lines on the chart. The length is proportional to the amount of heat put into the air stream. It is obvious that we cannot return to A in that way alone.

If we wish to use a ventilated drier, it is necessary, therefore, to remove a proportion of the moist air and replace it with less humid air. This mixture will have to be at a lower temperature than the design conditions, and we will then have to re-heat it. Re-heating is represented by a horizontal line, and the mixed air will end up on the line D-A. Re-heating will then allow the point A to be achieved again. Point C is an example of ambient conditions that will enable to satisfy the requirements and, in theoretical terms, ambient temperatures within the shaded zone will allow the use of a ventilated drier.

If we now return to the sectional drawing of the ventilated drier, Figure 2, we can see in practical terms what happens. The condition of the air as it passes through the inlet diffuser wall is represented by point A on the psychometric chart. The air passes over the fish, picking up moisture, and past the outlet diffuser wall (represented by point B on the chart). Depending on the position of the recirculation damper, a proportion of this air is discharged to the atmosphere. The remaining percentage is then mixed with ambient air passing through the air inlet damper. The condition of the incoming air is represented by point C on the chart. The position of the recirculation damper and the air inlet damper are automatically controlled to ensure that the percentage of fresh air and recirculated air are such that the mixture ends up at point E on the chart. This mixed air then passes through the heater battery and fan, and is re-heated along line D-A on the chart to point A, where the cycle repeats itself. The rate of evaporation from the fish changes during the process, so the proportion of re-circulated and fresh air is changed automatically to ensure that the conditions are constant.

If we now return to the psychometric chart and consider point G, representing ambient conditions which are outside the shaded area, it indicates that it is impossible to use this air in a ventilated drier to get back to position A. The solution is to use a totally enclosed system, namely the dehumidifier dryer (Figure 3). A proportion of the air is passed over a dehumidification coil, re-heating is provided by the heat pump principle and topped up, if necessary, using electric elements. This supply of cooled air is equivalent to a supply of low temperature ambient air. It can now be mixed with the recirculating air in the correct proportions, using the modulating damper, with heat pump re-heat, to arrive at position A once more. This system is the most efficient way of providing the required
Figure 4. Psychometric chart for dry-bulb temperatures 20°F to 130°F.
conditions (80°F, 45 percent RH) with high ambients, and will also provide energy savings due to the heat pump principle with dry bulb ambient temperatures below 70°/75°F.

This example of a required conditions of 80°F, 45 percent RH onto the fish well illustrates the effect of ambient temperature on the choice of basic design. Obviously, if the design conditions were different, (say, 100°F, 45 percent RH) a much greater range of ambient temperatures would allow the ventilated design to be used. It is critical therefore to know the process conditions required as well as the details of the ambient conditions when selecting which type of basic design is to be used.

Thus far we have discussed what parameters will affect the type of drier to be used. In order to actually produce a piece of equipment suitable for a particular application further information is necessary:

- Obviously it is necessary to know what daily capacity the client requires. In order to translate this into physical dimensions, it is also necessary to know how long the drying process will take and the loading density of the fish to be put into the drier.

- Previously we have assumed that the conditions onto the fish would be either 80°F or 100°F at 45 percent relative humidity. The optimum conditions for the particular product the client requires must also be determined.

- Whatever the drying process, moisture is removed from the surface of the fish at differing rates during the processing time. It is essential to know what the highest rate of moisture removal will be.

- As mentioned before, it is important to know the local ambient conditions if we are to consider a ventilated drier. It is advisable to know not only the worst conditions but also the "mean" worst conditions. If we design for the absolute conditions, we are going to install equipment which can be operated under any known conditions for the particular area. These conditions may however, happen only 10 or 12 times a year. The customer would therefore, be paying a high premium for these 10 or 12 days drying per annum. If we take the mean worst conditions, the client will probably be able to operate satisfactorily for 95 percent of the year, with considerable savings in capital investment.

Some of this information is relatively easy to obtain, such as the ambient temperature and humidity conditions and the client's planned capacity and production level. This leaves us with a need to know the recommended temperature conditions onto the fish, loading density, the drying rate throughout the process, and the length of the process.

Much experimental and theoretical work done to obtain this information, largely by government establishments in the North American continent, United Kingdom, and Europe. This work has resulted in recommendations on the optimum process conditions for producing various dried seafood products. Three examples of the work areas are as follows:
Canadian research on salt fish drying determined that the optimum conditions onto the fish were approximately 80°F and 45 to 50 percent relative humidity with a velocity of air across the fish of some 300 feet per minute. Ventilated mechanical driers did not give satisfactory results with an ambient wet bulb temperature greater than 55°F. In an analysis of the prevailing ambient conditions in one particular area of the east coast of Canada, it was clear that July and August were the most difficult months. Approximately 50 percent of the days in these two months would have ambient conditions that would not permit satisfactory use of ventilated driers.

The main limiting factor on the process temperature chosen (80°F) was that at greater temperatures, cooking and other problems were evident. Obviously, if the temperature were higher, the drying rate would increase, cutting process time. It also would be possible to cover most ambient conditions experienced in the northern part of the North American continent without resorting to the dehumidification design.

All the experiments in Canada were carried out with North Atlantic fish caught in cold waters. Information available now indicates that the temperature at which salted fish will cook depends to a certain extent on the area from which they come. It may well be that acceptable results can be obtained with fish from equatorial waters even if the drying temperature is increased to up to 100°F. This allows the less expensive ventilated drier to be used and also improves the process time.

Research carried out in the United Kingdom on drying non-salted fish (stockfish) shows that the temperature at which the protein denatures or cooks depends on the remaining moisture content. An accelerated drier has been developed which decreases the drying time appreciably while still producing acceptable stockfish products. The later part of this research was financed by AFOS Limited in conjunction with Torry at Aberdeen. The system varies the temperature throughout the process to optimize the drying rate.

Prior to this equipment's development, non-salted fish was mechanically drawn at a constant temperature as was salted fish. This resulted in long drying periods, as the drying rate of the fish varies with time (shown on Figure 5, line A-B). It is obvious that to achieve the low final moisture contents required for preservation (18 to 22 percent), actual drying time can be considerable. The new system gives almost constant rate drying with considerable improvements in drying time as indicated on Figure 5, line A-C. The benefits of this system are two-fold: it allows a much faster turnout of product; and the drying equipment, usually a high capital investment, can be used more often. Thus, for a given output of dried fish per day, the drier size would be appreciably smaller. Because of the higher temperatures this process uses, the most expensive dehumidification design is not necessary. The equipment is based on the ventilated version.

AFOS has been involved in a project investigating the optimum conditions for drying illex and loligo squid for possible export to the Far East and also to supply the Chinese and Japanese populations in the United States. This was carried out in conjunction with a Massachusetts
Figure 5. Comparison of drying times between standard drying equipment (A-B) and accelerated drier developed by AFOS Ltd. and Torry Kiln (A-C).
consulting company and financed by the United States Department of Commerce and the National Oceanic and Atmosphere Administration.

Samples of both types of squid were dried at AFOS in a ventilated dryer using different temperatures, humidities, and times. A selection of the resulting products was sent to the United States for preliminary taste panel approval. This taste panel indicated which of the samples were acceptable. Further tests were run to determine which combination of conditions was the most energy and time efficient, but still resulted in a high quality product.

Samples were then sent off with a detailed report. The final report including the taste panel results was submitted to the Department of Commerce.

A brief resume of the results are as follows:

1. An overall weight loss of more than 70 percent is necessary during the drying process. Otherwise, surface mold can accumulate during the early stages of storing.

2. A product weight loss of 72 percent appears to give the best results. Storage for 24 hours at normal room temperature and humidity (65°F and 50 percent RH) will further decrease squid weight to give a total weight loss of about 74 percent, equivalent to between 18 and 20 percent final moisture content.

3. Iloligo was dried for approximately eight hours and illex for six hours. This covered only the range of squid size and type available for test.

4. The method of putting squid into the dryer was important. Placing the squid on trays gave an unacceptable product due to the marking of the squid. A special method of hanging was devised that kept the mantle stretched out and the tentacles hanging away from it.

The above three examples have produced data allowing the drying equipment designer to finalize the size and other parameters to suit a particular application. It is only with this information, plus details of customer requirements and ambient conditions, that the decision can be made to use a ventilated or a dehumidified drier. Once this is decided, further calculations enable the designer to settle on size, amount of heating, volumes of air, and other parameters for the drier.

I trust this somewhat brief description has proved an adequate introduction to the problems of drying fish and has focused on the areas which will affect the commercial aspects.

In conclusion, I would like to express my thanks to the organizers of the conference for the opportunity to addressing you. I will be pleased to answer any of your questions if I can.
QUESTION: What is the water content of dried squid?
ANSWER: The water content is 18 to 20 percent. Most non-salted seafood products must have water contents at or below this level to have a good shelf life.

QUESTION: How does the oil content affect the drying time of fish?
ANSWER: High oil contents in fish will drastically increase the drying time. For example, compared with a fish having zero oil content, a similar fish with 5 percent oil content, will take twice as long to remove the same percentage weight of water.

QUESTION: Why can't squid be placed on trays for drying?
ANSWER: You should avoid the use of trays because the squid will have crisscross marks on it, and this will affect the acceptability of the product in the market.