Alaska Sea Grant College Program
University of Alaska
3 Bunnell, 303 Tanana Drive
Fairbanks, Alaska 99701

SMOKED FISH MANUAL

Compiled from papers presented at
the Smoked Fish Conference
Seattle Center
April 27-29, 1981

Edited by
Brian Paust
University of Alaska
Marine Advisory Program

John Peters
Washington Sea Grant
Marine Advisory Program

Alaska Sea Grant Report 82-9
December 1982

ACKNOWLEDGMENTS

The Smoked Fish Conference was organized by Brian Paust and Don Kramer of the University of Alaska Marine Advisory Program, John Peters of the University of Washington Marine Advisory Program, and Dick Reynolds of the Alaska Division of Economic Enterprise. We would also like to thank the sponsors: the University of Alaska Sea Grant College Prgram, the University of Washington Sea Grant College Program, and the Alaska Division of Economic Enterprise; and Brenda Melteff of the Alaska Sea Grant College Program for her assistance in setting up this conference.

This publication was produced by the Alaska Sea Grant College Program sponsored by NOAA Office of Sea Grant, Department of Commerce under grant number NA81AA-D-0009, project number A/75-01, and by the University of Alaska with funds appropriated by the state.

TABLE OF CONTENTS

PAGE

LIST OF TABLES v

LIST OF FIGURES vi

INTRODUCTION vii

PLANT DESIGN AND EQUIPMENT ENGINEERING CONSIDERATIONS

Plant Site Selection
Marvin Carlson 3

Physical Design of Fish Processing Ovens
Dr. Min-nan Huang 7

Thermal Processing and Smoking of Fish
Erwin Waters 23

HEALTH REGULATIONS AND QUALITY CONTROL CONSIDERATIONS

Federal Health Regulations
Raymond Mlecko 37

Microbiological Safety of Smoked Fishery Products with Special Reference to Botulism
Dr. Mel Ecklund 43

Quality Control Procedures
Ken Hilderbrand 55
Hazard Analysis and Critical Control Point Applications to the Seafood Industry
J.S. Lee 57
Preparation of Salt Brines for the Fishing Industry
Ken Hilderbrand 80
Quick Determination of Salt Content of Seafoods
OSU Seafoods Laboratory 84
Estimating Salt and Moisture Content Needed in Smoked Fish to Meet Good Manufacturing Practices
OSU Seafoods Laboratory 89
Estimating Moisture Content of Smoked Fish by Non-Destructive Means
OSU Seafoods Laboratory 93

TABLE OF CONTENTS
(continued)

PAGE

FISH SMOKING PROCESS

Smoking Fish: Special Considerations
George Pigott 97

Description of the Smoking Process: Hot Smoking
Vern Swanes 125

The Torry Kiln: Its Design and Application with Particular Reference to the Cold Smoking of Salmon, Herring, and Cod
Alex McK. Bannerman 135

Description of the Smoking Process: Cold Smoking
Ken Hilderbrand 147
Mild Curing, Drying Salting, and Smoking Salmon
Norman D. Jarvis 148

Smoking Fish at Home Safely
Ken Hilderbrand 163

Canning Smoked Fish Products
Al Bailey 169

The Design of Dryers for the Dehydration of Seafood Products
Malcolm Hunter 173

APPENDIX 185

LIST OF REGISTRANTS 191

LIST OF TABLES

PAGE

HUANG

Table 1. Percentage of defective fish 14

EKLUND

Table 1. Food involved in botulism outbreaks in 1899-1977 45

Table 2. Occurrence of C. botulinum in marine and freshwater sediments collected on the Pacific Coast of the United States 49

HILDERBRAND
LEE

Table 1. Food ingredient hazard categories in order of decreasing risk 62

Table 2. Seafood hazard categories in order of decreasing risk 63

Table 3. Food product hazard class assignment 64

Table 4. Growth and heat inactivation characteristics of food poisoning bacteria important in seafood processing 67

Table 5. Bacteria pathogens and the most sensitive seafoods 70

Table 6. Control measures against seafood pathogens 71

HILDERBRAND

Table 1. Sodium chloride brine tables for brine at 60°F 82

PIGOTT

Table 1. Dried salted or smoked fish (production by country) 98

Table 2. Production of principal cured fishery products in the United States 99

Table 3. Definition of water activity 101

Table 4. Importance of water activity in foods 102

Table 5. Humidity vs. minimum water content 104

Table 6. Effect of oil content on salt pick-up 105

Table 7. Moisture content of haddock samples.................. 108

Table 8. Bacterial change in haddock 112

Table 9. Microbial load, NaCl, and water phase salt (WPS) of smoked salmon.................................... 113

Table 10. Selected characteristics of gram-positive cocci isolated from smoked salmon 115

Table 11. pH values of fresh, brined, and smoked haddock 117

Table 12. Storage life of smoked fish 119

Table 13. Wholesale and retail prices of various salted fish products (FOB Seattle, WA)..................... 121

Table 14. Some smoked fishery items current on the market..... 122

BANNERMAN

Table 1. Preparation of fish for smoking 137

Table 2. Fish smoking in a Torry kiln 143

LIST OF FIGURES

	PAGE
HUANG	
Figure 1. Effects of air flow on smoke absorption	8
Figure 2. Effect of relative humidity on smoke absorption into mackerel fillets at 160°F	9
Figure 3. Effect of temperature on smoke absorption by mackeral fillets at 60 percent RH	10
Figure 4. Internal temperature of fish during smoking at constant temperature and humidity	12
Figure 5. Smokehouse dry and wet bulb temperatures and product internal temperatures in a staged heating schedule	13
Figure 6. A batch type processing oven for fish products	15
Figure 7. The mechanisms of heat transfer involved in fish processing smokehouses	16
Figure 8. Schematic of a batch processing oven with mechanical refrigeration	21
HILDERBRAND	
LEE	
Figure 1. Fish smoking process	58
Figure 2. Cooked and picked crab processing	59
Figure 3. Cooked and peeled shrimp processing	60
HILDERBRAND	
Figure 1. Freezing point of salt brine mixtures	81
Figure 2. Equipment for measuring salt concentration in brine	83
OSU SEAFOOD LABORATORY	
Figure 1. 3.5% water phase salt smoked fish	90
Figure 2. 5.0% water phase salt smoked fish	91
BANNERMAN	
Figure 1. Basic steps in the processing procedure	136
Figure 2. Diagrammatic flow of brine	140
Figure 3. The Torry kiln	141
HILDERBRAND	
Figure 1. Typical internal fish temperature during smoking cycle	165
Figure 2. Basic components of a smokehouse	166
HUNTER	
Figure 1. Sectional view of the Torry kiln and smoke producer	175
Figure 2. Sectional view of ventilated drier	176
Figure 3. Sectional view of dehumidifier drier	177
Figure 4. Psychometric chart for dry-bulb temperatures 20°F to 130°F	179
Figure 5. Comparison of drying times between standard drying equipment and accelerated drier developed by AFOS Ltd. and Torry Kiln	182

INTRODUCTION

The Seattle Smoked Fish Conference was conducted in April 1981 in response to the need for a review of practical and technical information pertaining to commercial smoking of fish. The Smoked Fish Manual is a report of this conference. The smoked processes and species dealt with in this report are those associated with the northeastern Pacific Ocean, but this information is equally useful to those operating in other temperate regions of the world.

The smoked fish manual contains five major sections of information of interest to the new or established fish smoker: plant design, kiln (smoker) design, health regulations, quality control procedures, and smoking procedures. In addition, a bibliography is included for further reference on fish curing and smoking.

Contributors to this handbook welcome inquiries from users. For this reason their mailing addresses and telephone numbers have been included in each heading. Feel free to call on them for assistance.

PLANT DESIGN AND EQUIPMENT

ENGINEERING CONSIDERATIONS

PLANT SITE SELECTION

Marvin E. Carlson
Small Business Development Center
Washington State University
Pullman, WA 99164-4740
(206)753-5616

Plant site selection can appear to be a very easy thing to discuss. However, with current laws and regulations, the selection and development of a site can now involve a great deal more difficulty than in previous years. To be perfectly frank, I was becoming completely exasperated with the new regulations in the food processing industry, so I joined the state government in an attempt to understand regulations from the inside. During my four years as assistant director of the Washington State Department of Agriculture, I found that there were even bigger frustrations in administering regulations.

I would like to review some of the basic principles of plant site selection. The basis of the food processing and most of the food production enterprises in the United States is that selling across state boundaries is governed by the federal Food, Drug and Cosmetic Act, Section 403A. I'll review some details of the regulations concerning smoked fish. Then I'll give you a qualifier. Under Section 128A.2, current Good Manufacturing Practice (GMP) is covered, as are criteria determining facilities, methods, practices and controls used for the manufacturing, processing, packaging, and holding of fish and seafood products. Additional criteria for plants and grounds are to be found in Sub-Chapter 128A.3, which states, among other things, that unloading platforms shall be made of readily obtainable material with drainage facilities adequate to accommodate all seepage and wash water.

The GMP also deals with internal plant processes and states that rooms or facilities and their interior walls which separate various processes should extend from floor to ceiling and contain necessary openings for conveyors and doorways. These separate areas would include the following:

- Receiving and shipping
- Raw fish storage
- Pre-smoking operations, thawing, dressing, brining, etc.
- Drying and Smoking
- Cooling, packing, and storage

The overall intent of these regulations is to allow the products to be processed "to prevent contamination by exposure to areas, utensils or equipment involved in earlier processing steps, refuse or other accessible areas." Therein we begin to get an overview of the basic regulations to be met when designing a plant for the production of a food product and the regulations that we live under must be considered in developing the plant. However, keep in mind that the federal Food, Drug & Cosmetic Act and its subparts relating to smoked fish have been challenged. As a consequence, in the state of Washington the smoked fish GMPs are presently used as a general guideline. There has not yet been a challenge to this regulation within the state of Washington.

The act was challenged in the case of U.S. vs. Nova Scotia Food Products Corporation in 1977. I will share with you some of the facts concerning that case. The basic argument was whether or not following the proposed GMP would destroy the commercial value of the product. One significant finding was that the administrative process should disclose whether a proposed regulation is considered commercially feasible. Another finding was that the agency which drafted the regulations relied on undisclosed data. The regulation setting criteria such as time, temperature, and salinity requirements in fish smoking was found invalid because the FDA had relied on undisclosed data and it had disregarded the question of commercial feasibility. The failure to disclose the scientific research upon which the agency relied prevented relevant comments on that data and, therefore, the FDA was not able to consider all the relevant factors. To suppress meaningful comment by not revealing basic data was found to be akin to rejecting comment altogether. So with these findings, the court overturned the federal regulations in the case of Nova Scotia Food Products Corporation.

This case has established a legal precedent. Another challenge may be forthcoming as well. Nevertheless, the food manufacturing practices as outlined in the federal regulations are important and, ultimately, they will be upheld in modified form. So, in selecting a site one has to consider these future legal requirements. If you are looking at an existing facility for a smoking business, it may help to determine how closely the plant can adhere to the Good Manufacturing Process guidelines for design, structure, layout, partitioned walls, separation of facilities, etc. These situations are so unique that it is hard to address them in a general sense. So I will direct my comments to the general considerations in selecting a new site for a new facility.

In site planning one should consider the following desirable characteristics:

- The site should have gentle but even slope from front to rear

- The site should be free of springs and have good soil bearing capacity

- The site should be readily accessible to municipal services, but not necessarily within the city fire limits due to tax costs, etc.

- The site should be readily accessible to major highways and distribution points. In Alaska the transportation of the finished product is important and faces unique problems; and in many cases, would involve water transport

- Very important--the site should be large enough to allow for 100 percent expansion of facilities. The greatest shortcoming I have observed in development of processing facilities is "shortsightedness." One should always contemplate a production process that would satisfy a visible market. But it must be remembered that if the enterprise is very successful, it will probably have to be expanded. In many cases, expansion is not adequately addressed in the initial site selection process. There is nothing more exasperating than spending $2 million or even $20,000 developing a facility and then finding you need to double it and have no more room

- The site must be located out of areas scheduled for redevelopment. It is difficult to envision all the developmental characteristics of an area. The smaller communities perhaps will not have this problem, nevertheless there are developments that should be considered including planning and zoning ordinances. If you are establishing a plant of any size, it will be very wise to work with the governmental agencies to be sure that the zoning and land use plans accommodate and protect that operation in the future

- The site should also be as far away from sewage plants as possible. This may seem strange from a sewage discharge standpoint, but our biggest environmental problem is with odors from your plant. The greater amount of odor in the area, the greater the attention that you are going to receive.

- The plant should be located near a labor pool

- The site should be close to where the raw product is received.

Additional mention must be made about waste disposal. A site location may be determined entirely by this problem. You will have a significant waste discharge from a fish processing operation and handling this material is an important problem. Three major factors are involved. Ask yourself:

- Where the waste material is going to be discharged

- The best way to dispose of material available to you

- The laws covering seafood waste disposal in your area.

If waste is to be disposed of in soil, soil suitability will depend upon several things including capacity, infiltration rate, and the permeability rate. Many state universities have maps and analyses showing various soil characteristics such as these.

In some instances the building site can be located outside the city limits but connected by extension to city-owned sewers, city treatment plants, and water mains. The cost to extend a sewer or water line can be amortized over a period of years Thought must be given to land topography if you are planning an extension into distant municipal systems. You may have to build pumping stations which may defeat some of the capital advantages you had in mind. Water is a very important item in food processing, both in the production process and in plant cleaning. The water must be potable, in adequate supply, and of high quality. From a safety standpoint, it is generally practical to assume that the domestic water supply is safe for use in all food processing plants. Water from privately owned sources will require monitoring and, in most cases, chlorination before use in a plant.

We touched a little bit upon environmental impact and certainly this is an area where we have a great deal of concern. It will probably be your greatest problem in site selection and development. It is now necessary to consider the total environmental impact of the food processing plant. It is necessary to be concerned with the chemical, materials, energy, and their effects on the ecological balance. Local, state and federal agencies should be contacted for detailed regulations relating to disposal of waste materials. The Federal Water Pollution Control Act amendments of 1972 require the application of the best available technology economically achievable for category or class. If you are discharging any water from the plant, you must demonstrate that you are employing the best available technology to treat water and restore it to pristine quality or quality comparable to that existing before use.

The greatest problem that a small operator will have in opening up interstate and international market opportunities will be getting through the myriad of environmental impact assessments and meeting the federal processing guidelines. The physical development of the plant is straightforward and will become obvious to you as you get along with the concept of your facility. Its process will dictate the type of facility in which it takes place. The University of Alaska has a very impressive program of extension service and I would recommend the University be a good resource to you. I would suggest that perhaps the University form a consulting approach to support development within Alaska.

PHYSICAL DESIGN OF FISH PROCESSING OVENS

Dr. Min-nan Huang
ALKAR/DEC International
Box 296
Lodi, WI 53555
(608)592-3211

INTRODUCTION

Modern smokehouses equipped with pneumatic or electronic programmable controllers which have the capability of achieving a uniform and repeatable temperature, relative humidity, and movement of air flow in the oven have long been used in the meat industry successfully. The same engineering know-how has been applied to designing smokehouses for processing various types of fish products.

The quality of smoked fish is measured in terms of appearance, saltiness, smoke flavor, texture, juiciness, uniformity, etc. These factors are affected by salt penetration during the brining process, and the extent of smoke penetration and dehydration in the smokehouse. Proper control of smokehouse operation is essential to obtain a good quality product.

EFFECT OF SMOKEHOUSE TEMPERATURE, HUMIDITY, AND AIR FLOW ON SMOKE PENETRATION

In 1975 Chan, Toledo and Deng of the University of Georgia in Athens, investigated the effect of smokehouse temperature, relative humidity, and air flow on smoke penetration in Spanish mackerel. The processing oven used in this study was a laboratory-type gas fired smokehouse from ALKAR, division of DEC International of Lodi, Wisconsin.

Chan, Toledo and Deng reported, as shown in Figure 1, that at a temperature of 100°F, and a relative humidity of 22 percent, the smoke deposition is faster and a higher saturation concentration of smoke is observed when the oven was operated at 10 air changes compared with smoking with no air movement. Obviously, the impingement of smoke with fish product's surface enhanced the smoke absorption process.

Relative humidity (RH) has a significant effect on smoke deposition. As shown in Figure 2, at an oven temperature of 160°F, maximum smoke deposition was achieved at 60 percent RH. Decreasing the relative humidity to 40 percent and 22 percent decreased the saturation concentration. When relative humidity was set at 80 percent, the smoke absorption was slower. The slow rate of smoke absorption was attributed to condensation of water vapor on the cold fish fillet's surface, as evidenced from the appearance of water droplets during the experiment.

Figure 3 shows the effect of smoking temperature on the rate of smoke deposition. Saturation concentration of smoke in the fish when the oven is maintained at relative humidity of 60 percent increased with increasing smokehouse temperatures until it reached 160°F. Further increases in temperature beyond 160°F reduced the smoke deposition.

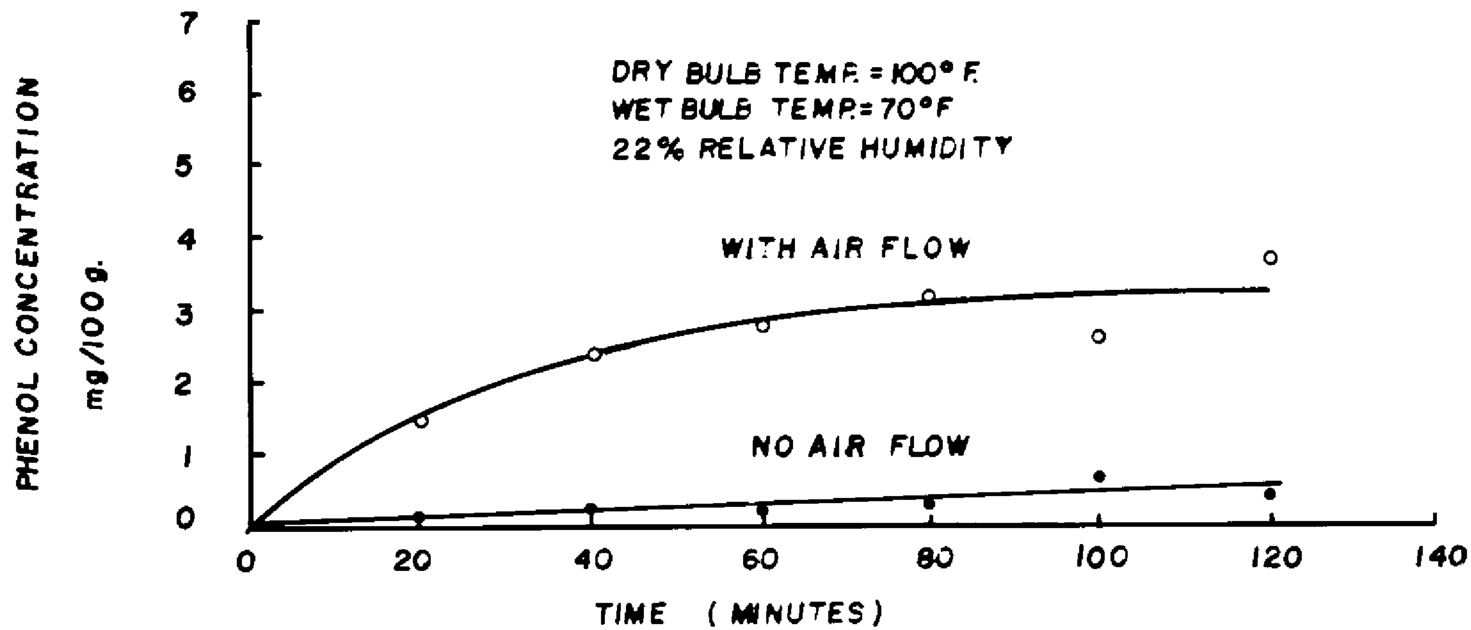


Figure 1. Effects of air flow on smoke absorption.

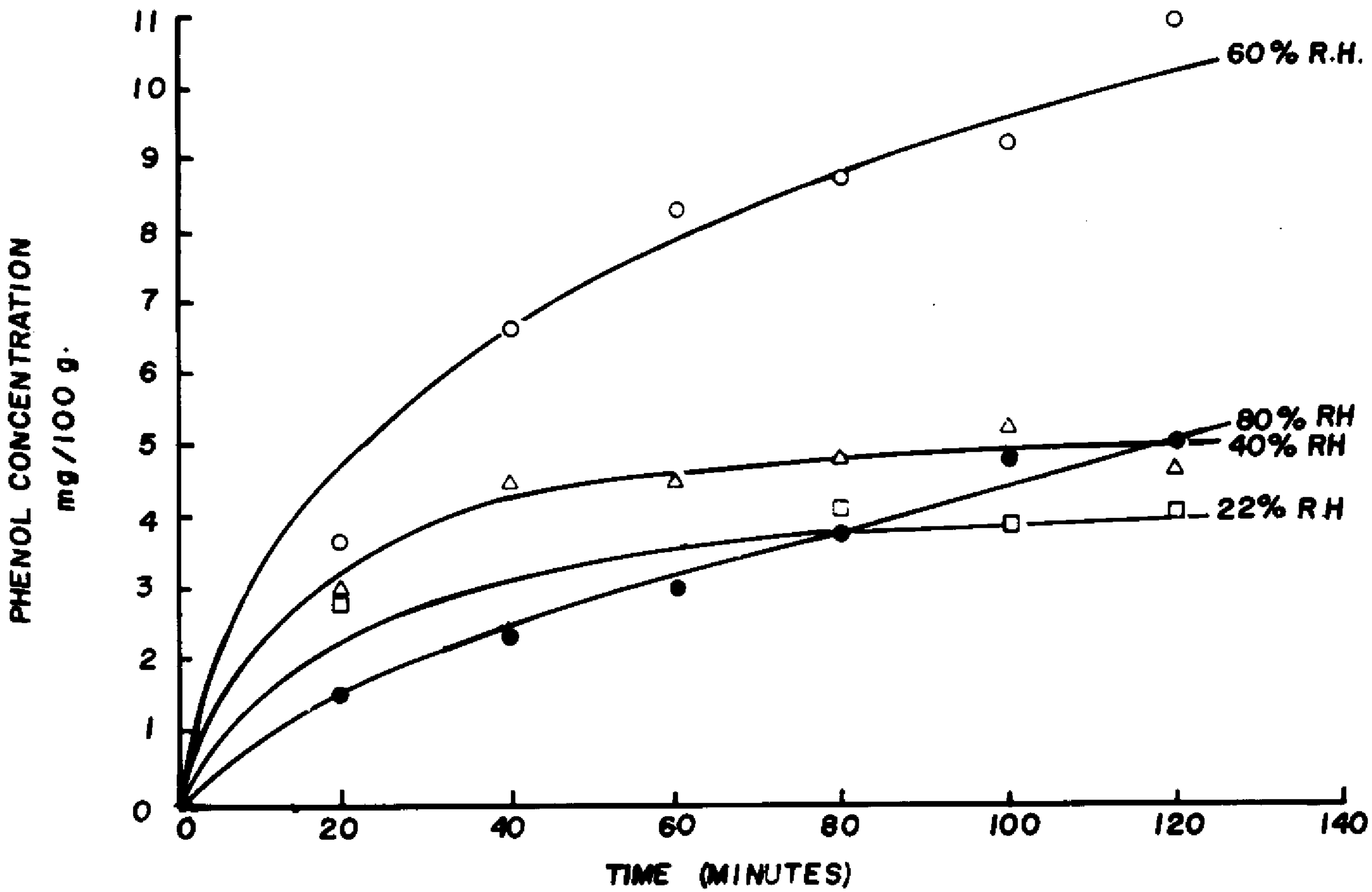


Figure 2. Effect of relative humidity on smoke absorption into mackerel fillets at 160°F.

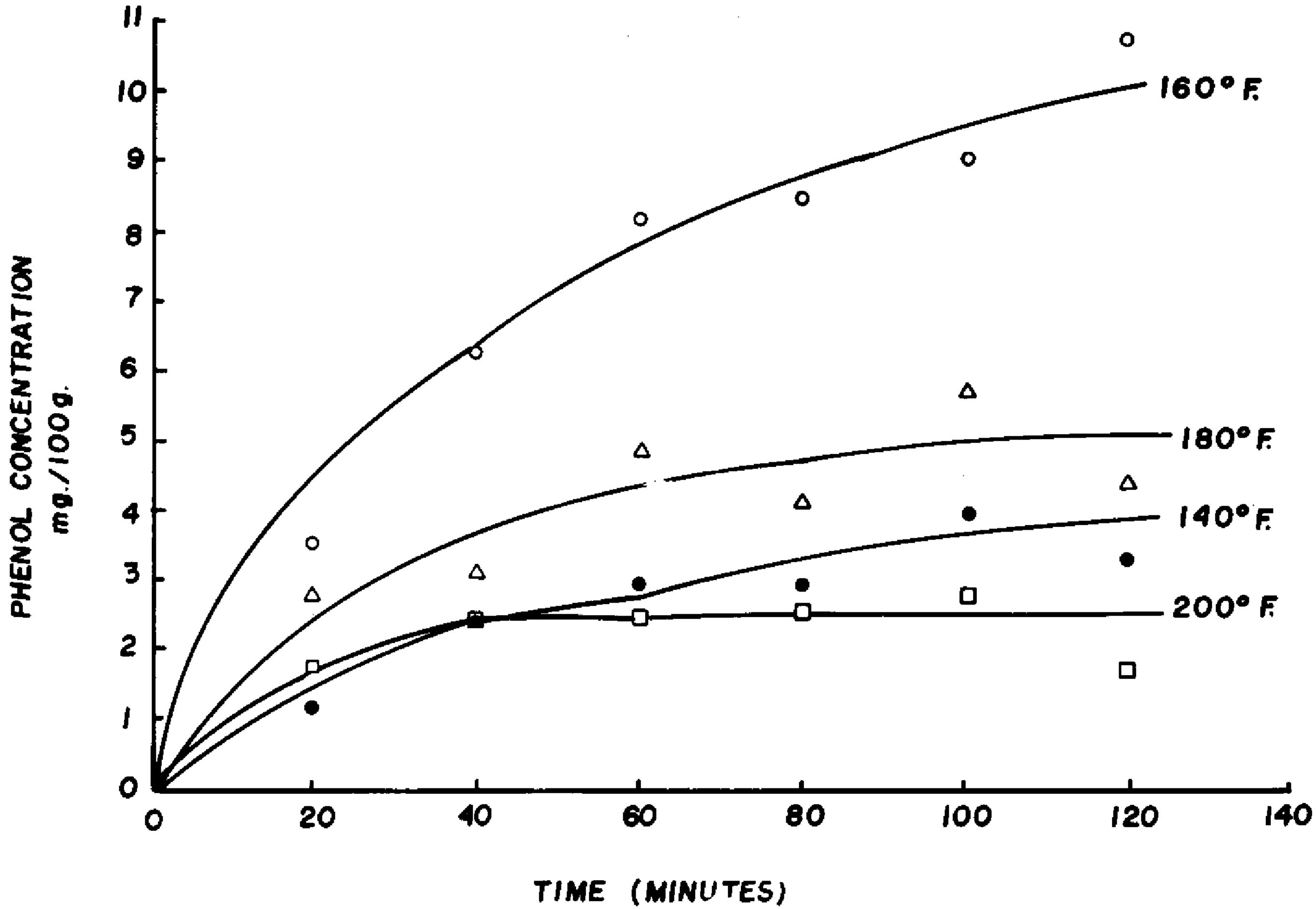


Figure 3. Effect of temperature on smoke absorption by mackerel fillets at 60 percent R.H.

Although the specific data shown in Chan's study is limited to the Spanish mackerel, the effect of air flow, temperature, and relative humidity on smoke deposition is generally true for other fish products. Therefore, it is desirable to understand the physical design of a smokehouse, so optimum processing conditions for various types of fish products can be developed.

In 1980, Kosak and Toledo of the University of Georgia studied product quality and energy use in high temperature smoking of fish products. The fish products used in this study were mackerel, mullet, and croaker.

Kosak and Toledo reported that when fish products were smoked at high temperatures, the product became deformed and split. If the rate of increase of dry and wet bulb temperatures is stated in 10°F increments every 10 minutes, the severe curling and splitting of the fish product is eliminated. Results of their study were shown in Figures 4 and 5 and Table 1.

In fish product processing, maintaining a uniform smokehouse temperature, and controlling relative humidity and movement of air flow are essential for good smoke deposition, product texture modification, appearance, etc. Depending on whether the product is cold- or hot-smoked, various amounts of heating always takes place in the process.

BATCH TYPE PROCESSING OVEN

At the present time, fish products are processed predominately in the batch type smokehouse. A batch type processing oven for fish products is designed to provide drying, smoking, and heating. As shown in Figure 6, the heated air imparts heat energy to the product, removes water vapor around the product, then leaves the processing cabinet. A certain volume of this warm, moist air is then discharged to the atmosphere and an equivalent amount of fresh air is admitted into the recirculating air stream. This exchange of moist air with the fresh air is how the relative humidity in a conventional processing oven is maintained. The air stream will then go through the heat source, admit smoke if it is required, adjust the humidity if it is necessary, and re-enter the processing cabinet.

If the oven is designed for 10 air changes, it means the recirculating air stream will go through a re-conditioning sequence 10 times every minute.

The mechanisms of heat transfer involved in fish processing smokehouses are predominantly conduction and convection. As shown in Figure 7, the air supply inside the processing oven is at temperature of "Ts," and humidity of "Ws," carring heat energy "Qs." Part of the heat energy is transferred via convection to the product, then through the conduction heat transfer process to the product's interior to raise its temperature. Part of heat energy "Qm" is transferred to the product surface by convection to increase the kinetic energy and mobility of the water molecules on the surface. These subsequently escape from the meat product surface in the form of water vapor. Because of the absorption of heat energy by the product and the release of water vapor from the product, the return air will be at a temperature "Tr," lower than "Ts," and a humidity condition "Wr," greater than "Ws."

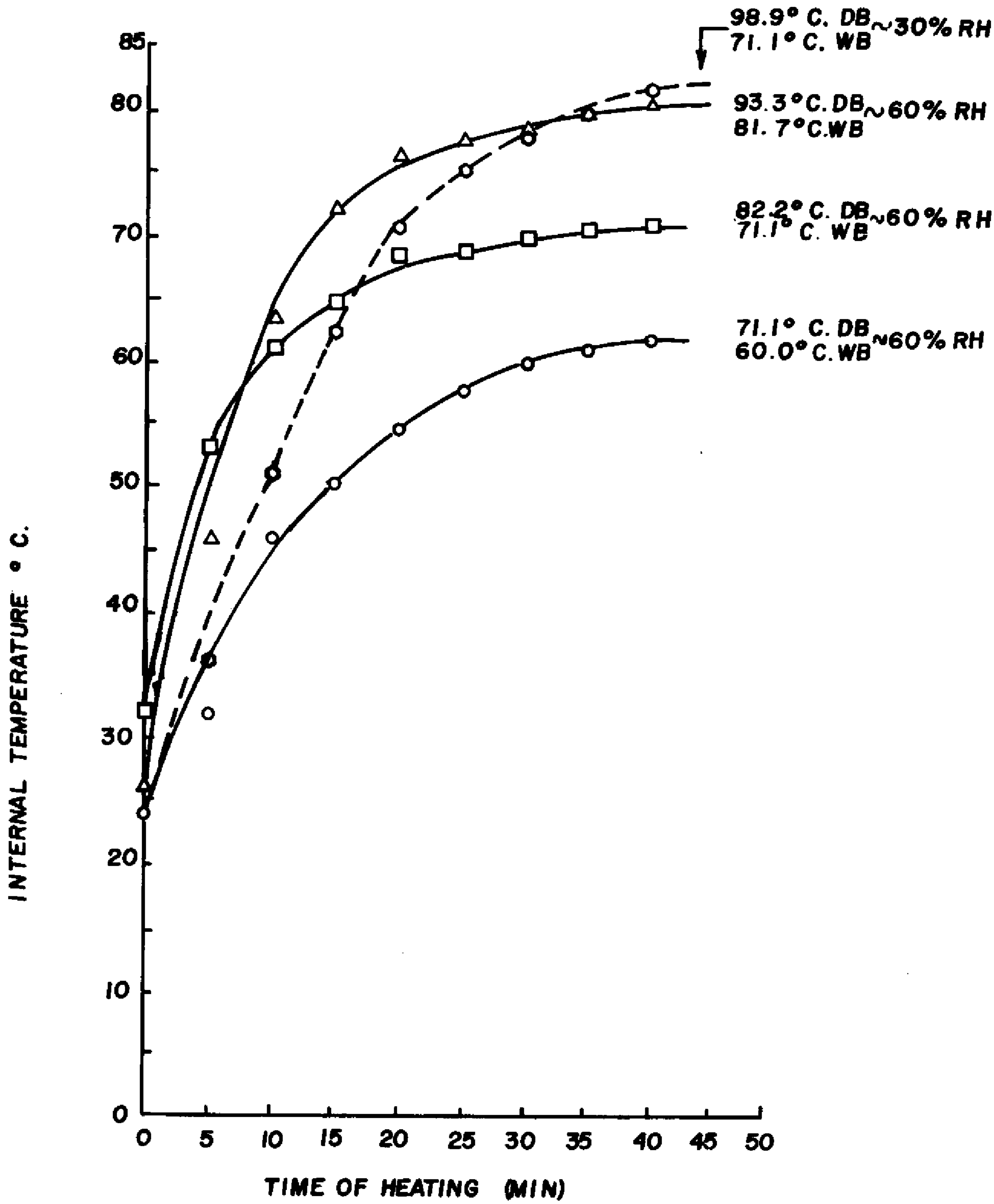


Figure 4. Internal temperature of fish during smoking at constant temperature and humidity.

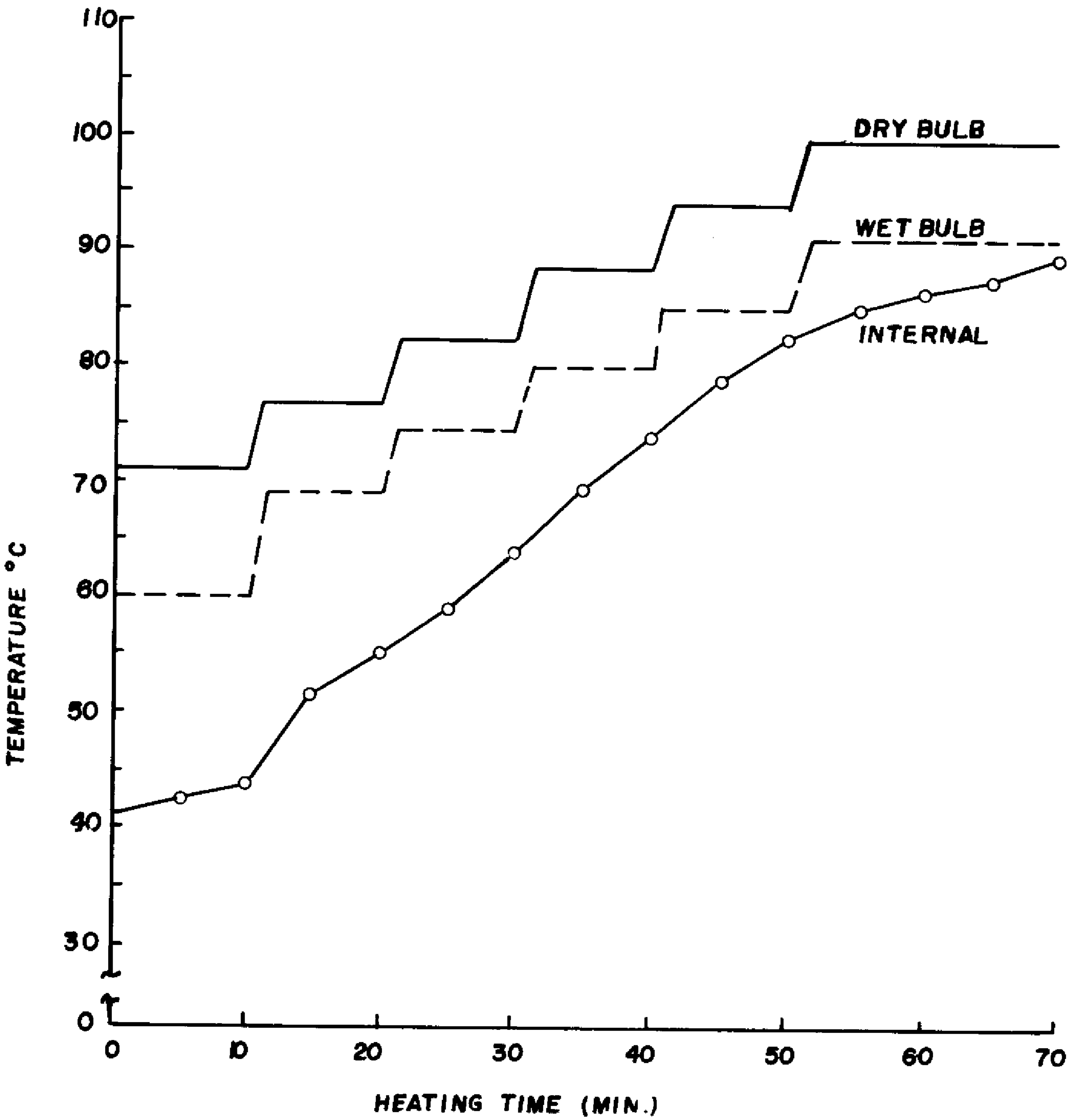


Figure 5. Smokehouse dry and wet bulb temperatures and product internal temperatures in a staged heating schedule.

TABLE 1. Percentage of defective fish

		ABNORMALITIES				
		BUTTERFLY MULLET/MACKEREL FILLETS/WHOLE CROAKER				
		HOOK LOSE	SLT. CURL	SEV. CURL	SLT. SPLIT	SEV. SPLIT
1.	160°F, 60 min.	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
2.	160°F, 30 min.	0/0/0	40/40/50	30/0/50	70/30/10	30/0/80
	200°F, 35 min.					
3.	200°F, 55 min.	0/0/0	0/50/20	100/10/80	30/60/0	70/10/100
4.	Staged	0/0/0	90/10/90	0/0/0	20/0/30	0/0/0

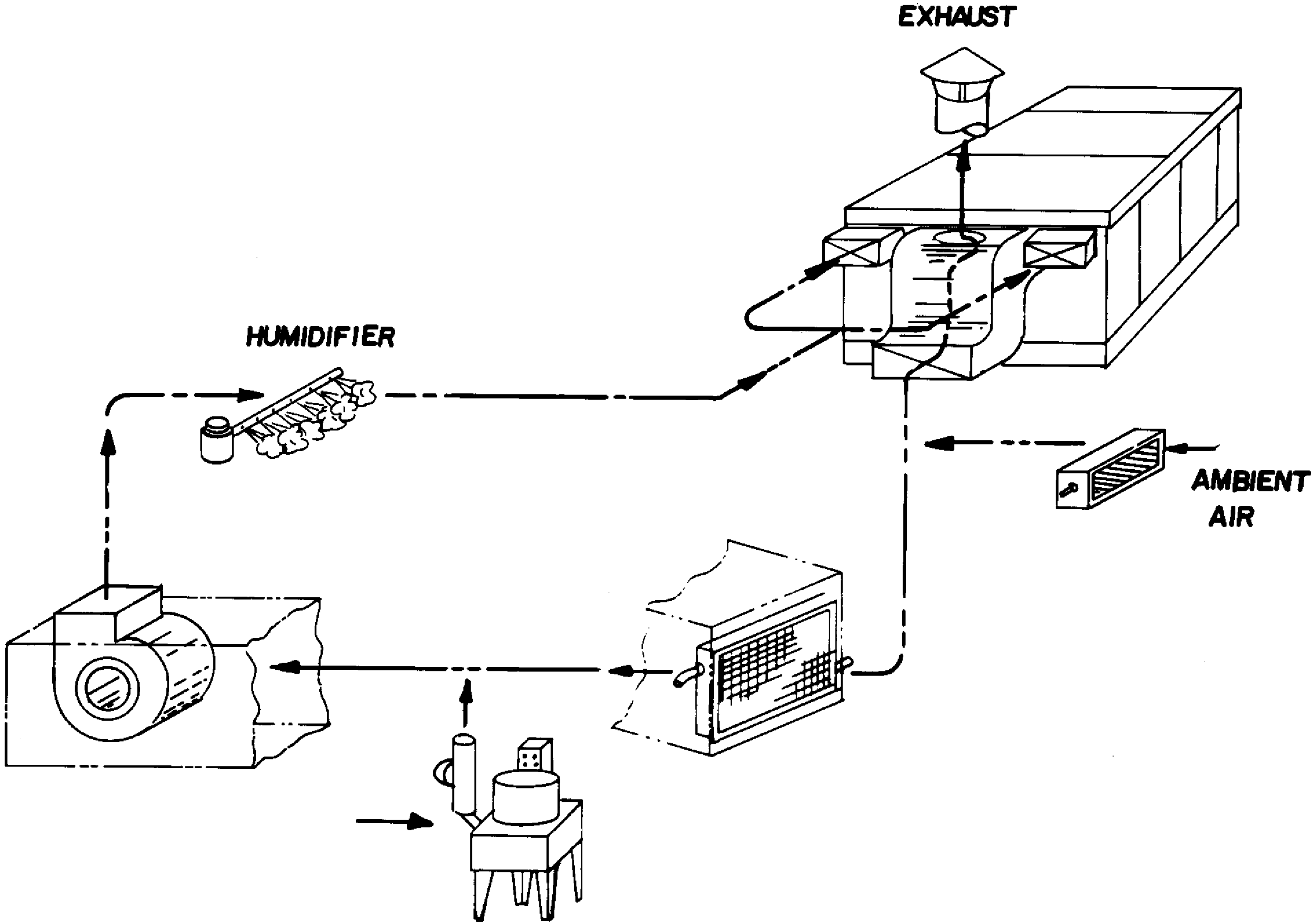


Figure 6. A batch type processing oven for fish products.

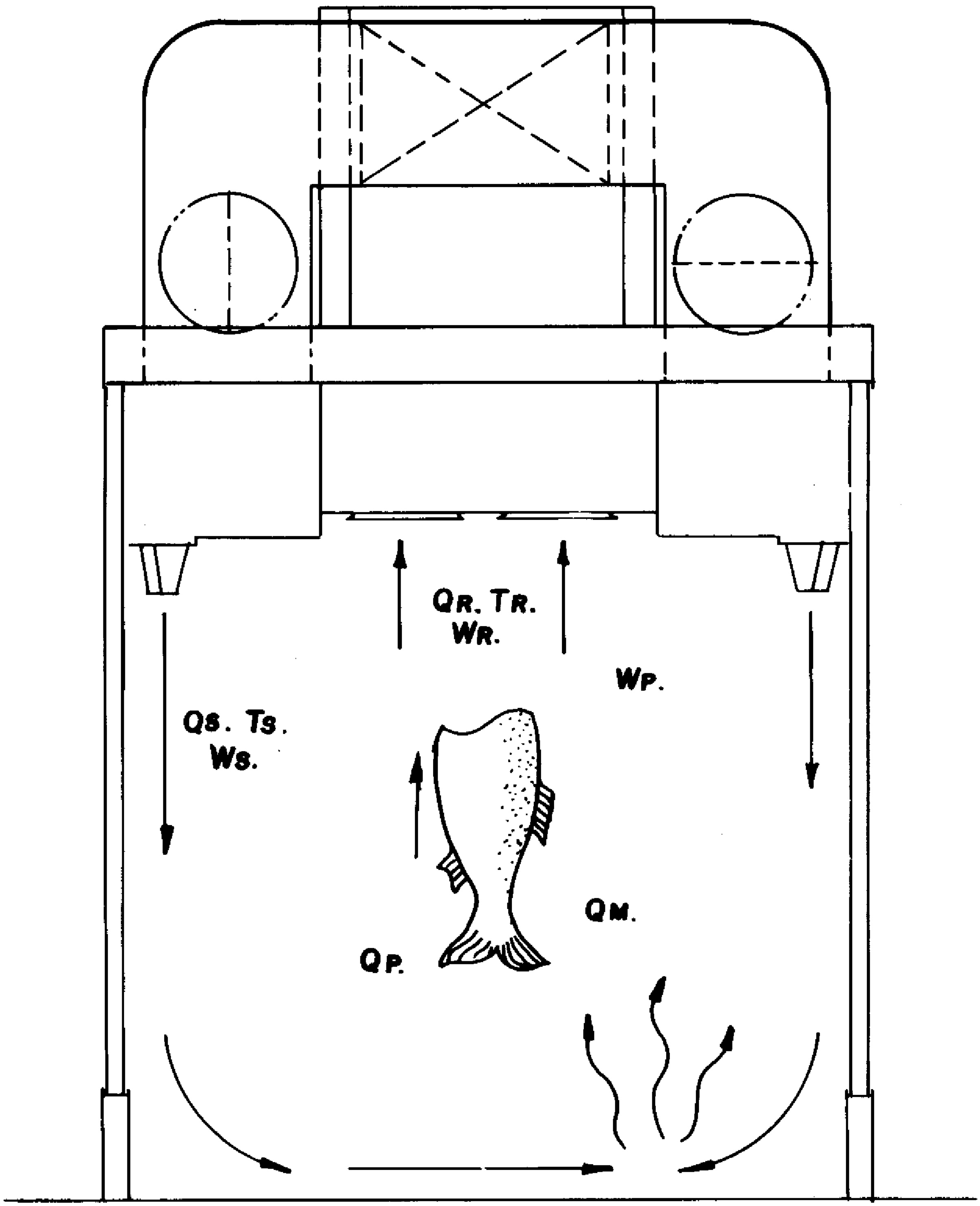


Figure 7. The mechanisms of heat transfer involved in fish processing smokehouses.

Conduction is a process by which heat energy flows from a region of higher temperature to one of lower temperature within the same medium or between different mediums in direct physical contact. The molecules in the region of higher temperature absorb and convert the heat energy into kinetic energy. Through the equalization of this kinetic energy, heat energy is transferred to the lower temperature region. The simplest mathematical expression of a conduction heat transfer process is:

$$Qc = \frac{Ak}{L}\left(T_h - T_c\right) \tag{1}$$

If the rate of heat transfer to the product varies with the processing time, the rate of conduction heat transfer becomes:

$$Qc = 2T_o LC\rho \sum_{n=1}^{\infty} \left(1-e^{-\delta n^2 Fo}\right) \times \frac{Sin^2\delta n^2}{\delta n^2 + \delta n Sin\delta n \; Cos\delta n} \tag{2}$$

Convection is an energy transport process using the combined action of heat conduction, energy storage, and the mixing motion of a warm and cold fluid. First the heat will flow by conduction from a surface of higher temperature to adjacent particles of fluid in the boundary layer. The energy thus transferred will increase the mobility of these fluid particles, and move to a region of lower temperature.

When the mixing motion takes place as a result of the density difference caused by a temperature gradient, it is called free or natural convection. The rate of net transfer is expressed as:

$$Q = \bar{h}cA(Ts-T_\infty) \tag{3}$$

$$\bar{h}_c = 0.13 \; \frac{Kf}{L} \left(\frac{\rho^2 qB(Ts-T_\infty)L^3}{\mu^2}\right)^{1/3} \left(\frac{C_p\mu}{K}\right)^{1/3} \tag{4}$$

If the mixing motion is induced by an external mechanism such as a pump or a blower, it is called formed convection. A typical expression of convective heat transfer over the exterior surface of a cylindrical object is:

$$\bar{h}_c = 0.33 \; \frac{Kf}{D} \left(\frac{\rho VD}{\mu}\right)^{0.6} \left(\frac{C_p\mu}{K}\right)^{0.3} \tag{5}$$

In the case of fish products, the geometric product configuration could vary from a whole fish to split halves or fillets and equations (1) through (5) are not directly applicable. However, these mathematic expressions do show how, in the order of magnitude, the rate of heat transfer to the fish product can be affected by a temperature gradient, the thermal conductivity of fish muscle, the exposed surface area of fish, density, viscosity, specific heat, velocity of air movement, and physical geometry of product.

Basically, the energy requirement to process one load of product in a conventional smokehouse is composed of the following: (1) BTUs required to raise the product's internal temperature to the required finished temperature; (2) BTUs required to remove the proper amount of moisture from the product; (3) BTUs required to heat up the smokehouse hardware; (4) BTUs required to heat the incoming ambient air to the processing temperature; and (5) BTUs required to make up the heat loss from the smokehouse surface.

Information on the mechanism for drying fish products may be found in reference literature. For a design engineer, it is necessary to know or be able to estimate the maximum drying capacity required of the equipment. During actual operation, the smokehouse control system will automatically control humidity conditions according to the wet bulb setting as shown in Figure 4, as the air stream in the oven is recirculated. A portion of hot, moist air is discharged to the atmosphere to make room for admitting an equivalent amount of drier fresh air. Assuming the rate of moisture evaporation from the product is Mp, mass flow rate of recirculating air is Ma, the specific humidity of fresh air and discharged air was Wa and We respectively, then the discharge ratio of processed air, r, to the atmosphere is:

$$r = \frac{\dot{M}p/\dot{M}a}{We-Wa} \qquad (6)$$

In a processing oven, smoke particles, tar, creosote, organic vapor, and so on are always present during the procedure. The interior surface of the oven is cleaned with chemicals. These substances are all detrimental to the direct humidity-sensing device. Once the surface is contaminated, the response from humidity sensors becomes erratic and unreliable. Therefore, in smokehouse operation, dry and wet bulb sensors are used to monitor and control the relative humidity in the oven.

As mentioned previously, moisture evaporation from the product surface always happens during the heating process. To control this moisture evaporation properly, the relative humidity inside the oven must be regulated.

In many industrial applications, such as processing meat, fish, and poultry products, the relative humidity of the moving air stream is measured indirectly through the use of wet bulb temperature. The validity of this approximation is as follows: on a steady state condition, when an unsaturated air stream passes the wick of a wet bulb thermometer, the sensible heat transfer to the water from the air stream will equal the latent heat of evaporation for water. The mathematical expression of wet bulb temperature under this condition is the same as the expression of air temperature under the adiabatic saturation process when the Lewis number h/KwCm equals unity. This assumption is valid in the case of water vapor. Therefore, the wet bulb temperature is equal, fortuitously, to the temperature of adiabatic saturation. The specific humidity, which is defined as the mass of water vapor per unit weight of dry air, can then be expressed in terms of wet bulb temperature as:

$$w = \frac{0.24(t_{wb}-t_{d \cdot b})+W^{*}h^{*}_{fg}}{h_{fg}^{*} + 0.45\ (t_{d \cdot b}-t_{w \cdot b})} \qquad (7)$$

where $t_{d.b}$ and $t_{w.b}$ are dry and wet bulb temperatures, respectively. The quantities with asterisks are to be evaluated at the wet bulb temperature.

The relative humidity is expressed as:

$$\emptyset = \left.\frac{Pv}{PS}\right|_{T=C} = \frac{WP}{Ps(0.622+W)} \qquad (8)$$

The approximation as derived in equation (8) is valid, since the ratio of the coefficient of heat transfer, h, and the coefficient of mass transfer, Km, is equivalent to 0.26 BTU/lb°F, which is approximately equal the humid heat capacity, Cm. Therefore, the Lewis number is unity and the assumption is valid. If other substances are used in lieu of water vapor in the wet bulb sack, equation (8) becomes invalid.

In the drying or thermal processing of food products, control of relative humidity is always very important. The accuracy of relative humidity depends upon the measuring accuracy of dry and wet bulb temperatures. As shown in Table 2, a ± 1°F measuring error will entail as much as 14 percent variation in relative humidity. Therefore, when specifying the process requirement for relative humidity, be realistic with respect to how accurately the relative humidity can be controlled with the temperature sensing and recording instrument.

TABLE 2 - MEASURED ERROR IN HUMIDITY

Dry-Bulb 70°F.	+1° = 71°F.
	-1° = 69°F.

Measured 48 percent RH could actually be anything from: 55 percent RH 41 percent RH

Wet-Bulb 58°F.	+1° = 59°F.
	-1° = 57°F.

To minimize the measuring error in the wet bulb temperature, the air velocity over the wetted wick should be maintained around 800 FPM to 1000 FPM. Also, the wetted wick should be kept free of contamination which may retard water evaporation.

There are some drawbacks to regulating drying capacity by discharging moist air from the oven to the atmosphere and admitting fresh outside air. First, since the discharge ratio is finite, there is always some discharge of processed air to the atmosphere and it may cause air pollution. Second, the specific humidity of fresh air, Wa, changes according to the weather conditions and this invariably affects the actual processing conditions inside the oven. Third, since the specific humidity of fresh air, Wa, and maximum discharge ratio are limited, the controllable range of relative humidity inside the oven is also limited.

In more recent batch processing oven designs, mechanical refrigeration is used to remove the excessive moisture, We - Wa, inside the system. The discharge ratio becomes a bypass ratio which regulates the amount of air necessary to pass through the dehumidification equipment. Wa depends upon the suction temperature of the refrigeration coils. A schematic of such a system is shown in Figure 8. Since the removal of excess moisture in the air stream is always controlled, the duplication of processing conditions is assured irrespective of ambient conditions. By controlling the condensing temperature and the bypass ratio in the dehumidification system, the desirable range of controllable relative humidity can be anticipated. Also, since there is no need to discharge the processed air, the air pollution problem can be eliminated or minimized.

Although mechanical refrigeration may require more initial capital investment, it does have several advantages: (1) the system is more adaptable to automatic process control; (2) it efficiently removes water vapor from the air; (3) its operation and maintenance is simple.

SUMMARY

The proper control of smokehouse temperature, relative humidity, and air flow systems are essential in developing optimum processing conditions for fish products. Knowing the features and limitations of smokehouse operating conditions will definitely help to improve the process operation.

REFERENCES

Chan, W.S., R. Toldeo and J. Deng. 1975. Effect of smokehouse temperature, humidity and air flow on smoke penetration into fish muscle. Journal of Food Science, Volume 40, p. 240.

Kosak, P. and R. Toldeo. 1980. Product quality and energy use in high temperature smoking of fish. Journal of Food Science, Volume 45, p. 1481.

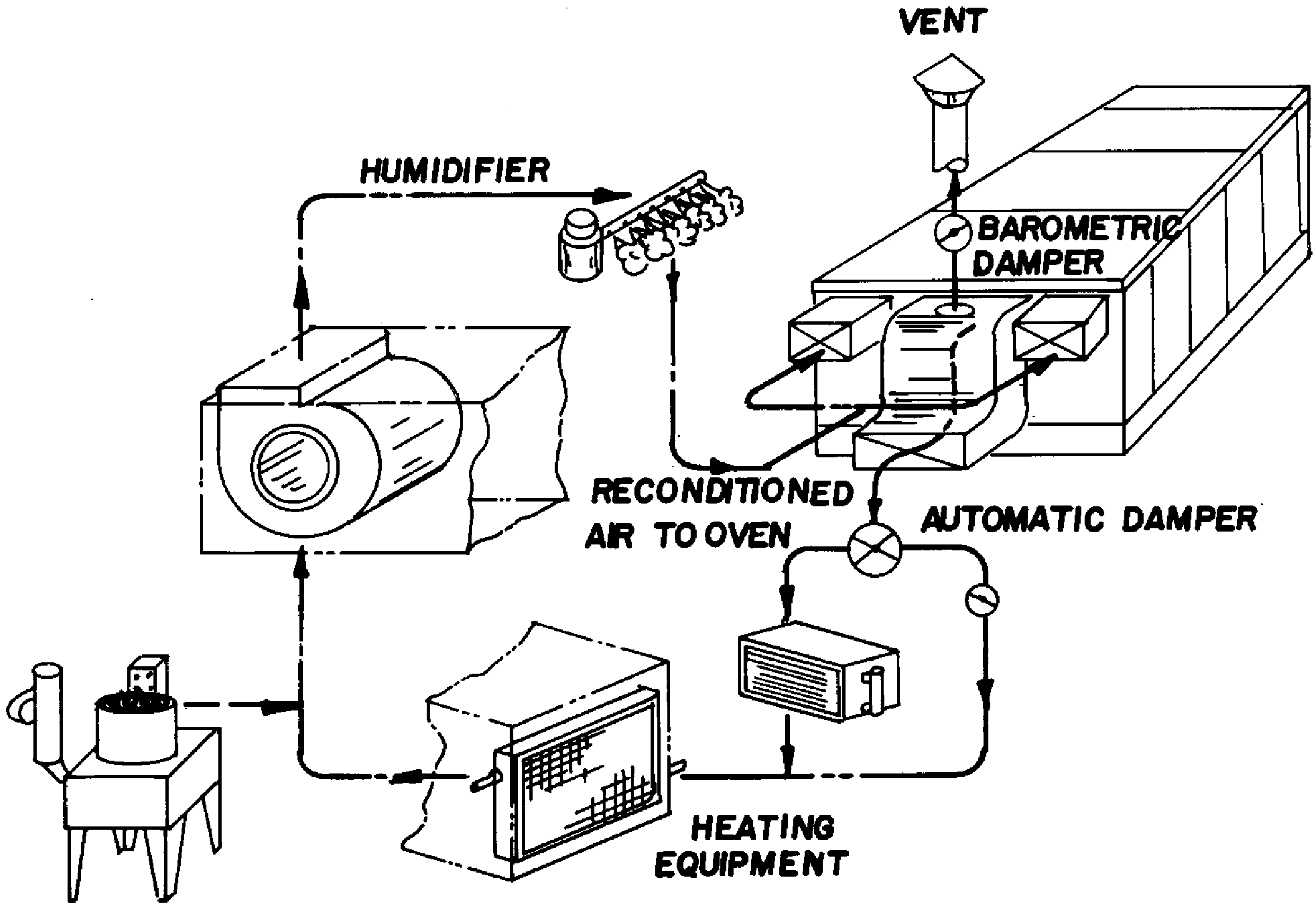


Figure 8. Schematic of a batch processing oven with mechanical refrigeration used.

THERMAL PROCESSING AND SMOKING OF FISH

Erwin Waters
S & F Mauer
649-57 Whittier Street
Bronx, NY 10474
(212)589-3600

INTRODUCTION

All fish that are converted from their fresh state are thermal processed, whether cooked, matured, dried, or roasted, sold chopped or solid. The temperatures of thermal processing can vary from 30°F, depending on the process. The temperature range is limited, excluding those that would cause freezing or burning to the point that the product is unusable.

Thermal processing methods include water immersion (boiling), direct contact heating (frying), water molecule activation by electronic impulse waves (microwave), radiation heating (broiling), and air processing (a combination of conduction and convention). We will narrow the subject and deal primarily with air as the transfer medium in a thermal process. Although air is not the most efficient thermal transfer agent, it is the only medium which can be easily used for other processes.

Let us examine quickly what can be accomplished by using air as the processing medium:

- Air temperature can be closely controlled within the required temperature range.
- The water content (relative humidity) of the air can be varied within these temperatures. The relative humidity of the air at specific air temperatures will have a specific effect on the product.
- When required, additives such as wood smoke, liquid smoke, or other gases, can be diffused into the air and thus contact and affect the product.

One additional factor must be applied for air to accomplish its function. The air must be circulated through the product zone and back to the air treatment area. Let us briefly examine the three factors that will affect the processing, beginning with air circulation since poor circulation means poor processing.

AIR CIRCULATION

The air inside the processing chamber must have a certain velocity and volume to achieve quick, even processing. The velocity determines how far and at what speed the air will travel prior to losing its direction and power. The volume of air will determine the amount of heat and moisture available to perform the required functions. Cold, warm, and hot air with different moisture contents will react differently at specific velocities.

I am not going to give a technical explanation of the aerodynamics in processing ovens, but I wish to point out the following facts:

- The velocity of the air exiting from the supply duct will affect the distribution of the processing medium (in this case, air) in the chamber. The friction between the air and the product surface, and the heat transfer (BTU) released by the air to the product), will change with velocity.

- If the velocity is too high in a vertical air circulation system, too much air will fall to the floor, causing over-processing of the low product zone; too little velocity will have the opposite effect. In addition, the air must also flow in a horizontal plane through the product zone. Driving the air for too great a distance will result in uneven processing.

- To accomplish all factors correctly, a balance of air velocity, vertical and horizontal distances, and BTU transfer must be maintained.

- The volume of air delivered at the specific velocity must be balanced with the cube of the processing area, required heat transfer load, and the average density of the air.

- The density, or weight, of the air varies with temperature and humidity. The hotter the air is, the lighter it is, and more power is required to drive it on its correct course. The expression "air changes", as applied to processing chambers, means how often a cube of air in a cube of area is replaced. Replacement can be at high velocity with low volume, or high volume with low velocity, or any combination of both. The correct velocity expressed in feet per minute, and the correct cube as expressed in cubic feet are what we should know. With these figures, the cubic feet per minute can be calculated. Dividing this number into the cubic feet of oven space results in air replacement per minute. Again the velocity is as important as the volume.

HEATING AND COOLING

A way to efficiently heat the chamber air must be designed into the system. Direct gas fire heating is the most inefficient, wasteful, and dangerous system. A system using a remote heating station is equally bad. Ducts transfer the heat from the energy source to the processing chamber, wasting energy and increasing costs. Good planning puts the heating element directly into the chamber, eliminating heat loss during transfer and using all latent heat in the element for processing. The shorter the air flow distance, from element to processing area, the more efficient the system will be.

Air used in processing must be clean and its heat and moisture content controllable. This can only be assured if the air begins free of impurities and the by-products of the burning fuel are not allowed into the processing area. The free air space can be minimized and the load factors per cubic area increased within the chamber by using proper air velocity and heat exchanger area.

HUMIDIFICATION

Humidity is one of the most misunderstood factors in the processing cycle. Humidity is the water content of air. Relative humidity is expressed as a percentage and measures the water content of air at a particular temperature compared with the maximum amount of water air could hold at that temperature.

The higher the temperature is, the more water the air can hold. To have meaning, relative humidity must be expressed as a percentage at a given temperature.

To determine wet bulb temperature, take the air temperature with a wet sock placed over the bulb end of the thermometer. The water evaporates off the sock, cools the thermometer, and results in a temperature reading lower than actual air temperature. The drier the air, the faster the evaporation, the quicker the thermometer cools, and the lower the reading will be. Comparing the difference between the air temperature (dry bulb) and the evaporation temperature (wet bulb) on a prepared scale, gives relative humidity.

Air must blow at and around the wet bulb at a specific rate (approximately 2 m/sec) to give a correct reading. If the velocity is too low, there is not enough evaporation and the wet bulb temperature will be too high. If the air velocity is too great, the evaporation will be too fast and the temperature reading too low. Either way, the moisture reading is incorrect.

This brings us back to the importance of air velocity. Your product is saturated with water. It will act much like the wet bulb thermometer at a specific temperature and air velocity. The location of the wet bulb thermometer during the reading is crucial. If the reading is taken by the supply ducts, then you will measure the humidity of the air before it picks up or gives off moisture to the product. If you take a reading at the exhaust duct, you will measure the humidity of the air after processing has taken place. Every point in the chambers will have a different reading because of evaporation or condensation. Depending on circumstances however, readings will eventually equalize.

Because fish products contain a high percentage of water, the effect of the product on the air is as important as the effect of the air on the product. The product gives off or absorbs moisture at a rate dependent on its own temperature, water activity, and pressure differential. As the product absorbs or gives off heat, dries, or changes in pH, that rate changes, even if processing air values stay the same.

Thus, the relative humidity, or wet bulb, reading becomes only a guide to the type of air one should use. Sometimes you may want to reach or even exceed the dew point. This is called "steaming." Moisture condenses on the product passing its energy content to the product. You may want to be in a balance where only a bit of evaporation occurs, but the dew point is not reached. If drying, however, you want the greatest amount of evaporation to take place, taking into consideration the water activity of both the inside and shell of the product, to avoid "case hardening" which prevents water from getting out of the product's interior.

Sometimes, dehumidification at a specific point is more important than humidification. It is also impossible that a slowly rising or falling humidity over a certain time interval is more important than maintaining a constant humidity. To get this effect, humidity must be removed or added on a time interval rather than at a constant rate. When temperatures exceed 212°F (100°C), no relative humidity readings are possible. However, air moisture content can still be controlled by adding moisture to the air. It is easiest to add moisture to the air as steam. Using water droplets or fog can cause water droplets to form on the product. Even when using steam, care must be taken. If the steam is too hot (at pressures over 7 psi) the air will be overheated and unwanted excess condensation will occur, causing spotting, burning, and separation. The air must have time to absorb the moisture introduced. Thus, injections of moisture that are small and fast are preferred over one continuous injection.

ADDING SMOKE DURING THE THERMAL PROCESS

Smoke is not added to all the products which are thermally processed. We have become used to calling a thermal processing oven a "smoke house", since in the past wood was used to product heat in a "pit house." To eliminate the possibility of wood burning too hotly, water was sprinkled on the flame, eliminating the hotter flame, but causing smoke.

The historical purpose of smoking was preservation. It was not particularly effective because it preserved only the outside of the product, and not for very long. Smoke combined with heating and drying, however, was quite a good way to preserve products. When drying, smoke acted as an inhibitor and preservative, keeping the product from spoiling during the rather long process.

With modern controlled systems, this preservation function is no longer required. Refrigeration, shorter processing times, and vacuum packaging take care of freshness, and smoke is used more for flavoring and coloring. In well-designed thermal systems, it should be possible to add smoke under any function: during drying, heating, cooling, and cooking, at any relative humidity or air velocity.

QUALITY AND CONCENTRATION OF NATURAL WOOD SMOKE

The quality of smoke is important when it is used to flavor. We can achieve excellent color with softwoods, but the resulting flavor is not desirable. Hardwoods result in both good color and good flavor, but the process takes longer than when using softwoods, all processing factor being equal.

Smoke generation plays an important role in the quality of smoke produced. The best quality smoke comes from the natural glow of wood particles. For wood particles to glow without excessive heat, the sawdust must either be moist or the amount of oxygen available must be restricted. Under these conditions, the smoke produced is cool (140° to 180°F, depending on the type of wood used). A higher smoke temperature, such as those produced when kiln-dried sawdust is charred on a high-temperature hot plate, a burned odor and flavor are apparent. The concentration of smoke per cubic foot of air has a direct effect on the process. The higher the concentration, the quicker the deposition.

ELECTROSTATIC SMOKE APPLICATION

Helping smoke transfer from the air to the product by applying opposite electrical charges to the smoke and the product is not a new idea. It was used in Germany eight years ago to decrease air pollution by depositing a greater amount of the suspended smoke from the air onto the product, reducing the concentration of smoke required and the emission level. After an eight-month test at a plant in Basel, Switzerland, a number of problems arose:

- Only the product can carry a charge. If not, the charge will spread to the whole unit, and smoke deposit will be as great or greater on all metallic parts of the processing unit, both inside and outside. This problem caused extreme sanitation and mechanical difficulties. These problems alleviated when the smoking trees were isolated from other metallic areas and each wagon was separately connected to the electrical system.

- On string-hung items, the system did not operate as it should have.

- Dust particles which were charged and blown in with the air clung to the product and caused spotting.

Eliminating these problems, the basic principle is good and should be considered for the fish industry. If this system is to serve only as a part of air pollution control there are simpler, better, less expensive methods to use.

LIQUID SMOKE

Liquid smoke, whether commercial produced or made on-site with high pressure steam, has one major advantage. At this time, it is considered non-polluting. It also has some disadvantages:

- It has a slightly acidic, bitter flavor which is imparted to the product

- It does not inhibit mold growth as well as natural smoke

- It is costly

Even though some European plants produce liquid smoke on-site that has been approved, I do not suggest this system. There are too many problems with the equipment and its use.

After two years of study, we have concluded that liquid smoke can be used successfully if applied properly. During application, if the air circulation continues at a low velocity, if air temperature is raised by 10° to 15°F from the previous program, and if the liquid is injected in short bursts as a fine fog, then a number of positive results occur.

- The bitter flavor is considerably reduced

- A better, more even color is achieved throughout the load

- The process is faster
- Less liquid smoke is used, lowering processing costs

The future of liquid smoke is therefore very good, provided that application can be perfected.

BASIC FUNCTIONS FOR FISH PROCESSING

The processing unit must be able to quickly and accurately produce a high quality product in large volumes. Fish processing differs considerably from meat or cheese production, requiring different controls and procedures. Engineers who design a fish processing unit must understand this process and what results should be achieved. There are two basic thermal processing procedures, each requiring a different type of unit. These are hot processing and cold processing.

HOT PROCESSING

Products are hot processed at temperatures exceeding 85°F, at low or high humidities, with or without smoke. In almost all instances, fish must first be dried to a certain degree, prior to heating or smoking. The drying must be fast and accurate. If too much humidity builds up during this step, or if processing takes too long and the meat and bone is exposed to heat before drying, the product will fall apart.

To prevent this, the protein must be set or denatured with low temperature drying before applying higher temperatures. If high temperatures are applied before the fish is sufficiently dry, the moisture in the fish will turn to steam. The steam will solubilize the connective tissues and the fish will separate. Temperature, humidity, and air velocity play a very important part in this step. We must remove the internal as well as the surface moisture in the product.

If the surface of the fish is overdried at this point, it will wrinkle later and smoke color formation will be poor. Traditionally, because proper fish processing equipment was unavailable, drying meant using low temperatures and a long processing time, factors which considerably reduced the product's quality. The longer processing takes, the greater the protein deterioration is, especially at lower temperatures before the protein is denatured or set. Time, then, is an important factor in quality production.

Humidity must be controlled at all times. If the humidity is too high during this process, the connective tissue holding the fish's tissue together will be destroyed and the flesh will separate. The longer the product is exposed to high temperature, the greater the possibility that it will fall apart. To shorten the smoking process time, a very high concentration of smoke is required. The only way to achieve this is to have the system fully closed during the process to let the smoke concentrate.

When excess humidity occurs, a dehumidification cycle is automatically initiated to drive down the moisture content of the air in the processing chamber. This dehumidification can be accomplished in a number of ways. The simplest, fastest, and most economical way is to introduce fresh, ambient air into the oven, removing some of the moist air until the humidity drops to the desired set point. Some air pollution will occur during this dehumidification cycle, but if the system is engineered correctly, the amount of pollution occurring can be kept under the prescribed maximums allowable. If the community has very stringent air pollution requirements, a small afterburner, electric precipitator, or water scrubber can be used to further reduce the pollutant in the exhaust air.

The second system available to eliminate pollution while dehumidifying is with closed system which utilizes a regenerator and refrigeration to dehumidity and cool the circulating air when necessary. This system has no exhaust duct. Because all of the circulation is redirected through the regenerator, this system is non-polluting. The only disadvantages of the integral system are that the initial investment is high and the maintenance requirements demanding.

The third system is semi-closed with water spray dehumidification. In this case, a fine spray of water is introduced into a chamber through which the air is recirculated during the dehumidification cycle. The water cools the air, forcing out moisture. The disadvantages of this system are numerous. First, the water must be colder than the air at all times, resulting in high water use even if recirculating pumps are used. Secondly, the smoke is removed by the water spray causing a reduction in smoke concentration and water pollution. Third, maintenance requirements are greatly increased due to its costs and limitations. This is not a system which we recommend.

Control of fish processing functions is very important. Because accurate dry and wet bulb temperatures are required, automatic program stepping should be considered. Unless the unit performs all the required functions automatically, processing costs will be high and quality poor.

One species of sea animal, the eel, requires special attention. To correctly process eels a very high initial heat source is required. To be precise, a high BTU availability is required in a short period of time. Processing units in which eels are to be smoked will need additional heat-generating elements. Eels must have a fast heat rise. The first program for eel processing is hot air processing at a temperature of 185° to 195°F with a high humidification until the eel's core temperature reaches 91°F. If enough heat is available for a fast rise, the eel's belly will open properly without the skin creasing or shriveling. We suggest that the oven be preheated to 250°F prior to loading the eels, to further speed up the process. Once the core temperature reaches 90° to 91°F, a drying cycle at 120° is used, then smoking starts. Again, we see that the equipment must be engineered to the product.

COLD PROCESSING

Cold processing is the thermal processing of products at temperatures under 90°F. Some items that fall into this category are cold smoked salmon (lox and nova), black cod (sablefish), and herring. Achieving quality results in cold smoking is somewhat more difficult than in hot smoking, thus even more exacting controls and equipment are required. Drying is, again, an important part of the process. This time, however, the drying must be slow with the relative humidity closely controlled so that case hardening does not occur. Case hardening is the fast overdrying of the product surface which causes the protein to set and form an exterior crust. This crust will, in turn, prevent moisture from leaving the inside of the product resulting in a long processing time and a wet, soft product interior. In addition, when a crust is formed, smoke penetration and adhesion will be reduced.

Long processing times will also affect the quality due to the deterioration of protein under the processing conditions. In a correctly engineered unit, the total cold processing time of salmon will range from eight to 12 hours depending on the size and type of fish used.

Hot and cold processing can be combined into one unit if all requirements are met in the controls. The system must have closed air circulation to insure close temperature and humidity controls, high smoke concentrations when required, and low energy consumption. Cold smoke units are also available but, again, they must be able to perform all the functions required. These units can only perform cold smoking functions and can be constructed much larger than the combination units. Cold process units should be considered when high volumes of cold smoked product are to be produced.

As an example of the importance of closely controlled processing steps, let us examine one of the procedures used in salmon smoking. The process starts with drying at a dry bulb temperature of 75°F and a wet bulb of 66°F. The second step would be medium smoking at a dry bulb temperature of 75°F and wet bulb of 70°F. The final step is intensive smoking (very high smoke concentration) with a dry bulb temperature of 75°F and a wet bulb of 71°F. This last step is continued until the fish reaches a core temperature of 72°F. The reason for core temperature operation on the last step is so we know precisely when the fish is dried correctly. How can the core temperature of the fish indicate drying? As long as the fish is too wet, it will act like a wet bulb thermometer, and will not rise above the 72°F wet bulb setting in the final processing step. As soon as enough moisture is removed from the fish, evaporation will be slowed down and the internal temperature of the fish will start to rise to the maximum of the dry bulb setting. In this example, we had the core temperature set 1°F above the wet bulb. To make the fish drier, we raise the core temperature; to make it moister, we lower it.

The dry and wet bulb in this case are not changed to achieve different results. Operating at a slightly higher or lower dry bulb temperature will affect the final product and can be used to achieve the type of product desired. The relationship between dry bulb, wet bulb, and core temperature does not change. This example shows that accurate temperature humidity and product core temperature controls are extremely important in cold processing.

SUMMARIZING THE PROCESS

Engineers divide smoking into two types: hot and cold processing. The process is cold if done between 70° and 90°F and hot if done at temperatures greater than 100°F. In each case, smoke is an additive like salt, sugar, or spices. It is applied as a gas rather than a solid or a liquid. The fish accept each process in a separate way.

THE EQUIPMENT

Engineers designing a kiln have to know a great deal about the process and the desired products in order to make a machine that works. They are more interested in the reasons that smoking works. As an owner/operator, you are probably more interested in what types of machines are available, what functions they perform, and whether they will work for the type of fish and product you have in mind. When looking for a piece of equipment, here are some general guidelines:

- Be sure the unit is specifically designed for fish processing and that it can produce the types of product you desire.
- Older smokehouses are usable, but unreliable. Product quality varies, it is harder to control processing factors, and the units are usually more labor intensive.
- Look for a sturdily built piece of machinery with a long life span.
- In light of newly proposed sanitation regulations, I suggest that you consider only stainless steel units.
- Heating and cooling units should be an integral part of the unit. Having these parts located away from the oven wastes energy.
- Be sure your unit can handle loads of the appropriate size.
- Be frank and detailed about your needs when ordering a machine. The manufacturer is not a mind-reader and must know the specifics of your operation in order to suggest the proper equipment.

THE PROCESS

First, water has to be gently removed from the fish you intend to smoke. Common sense tells you that if air is too hot and moving too quickly, the surface of the fish will be damaged and it will not dry properly. If the air is too wet, the fish will not dry enough. Fish, like other animals, are partially composed of protein. When protein is dried too fast, it hardens, or "denatures" and the skin forms a hard case. When this happens, water is not allowed to escape from the core of the fish and the outside forms a crust.

So, the oven must dry the fish slowly enough to prevent case hardening, but fast enough to avoid deterioration due to bacterial and enzymatic activities. The air circulation pathway should be as short as possible so the air flow can be properly controlled. Since air is a gas, it can easily change direction, pick up or give off moisture or heat, and change in other ways harmful to your product. The air is also being reprocessed, so temperature and humidity must also be controlled.

The next step is to add the smoke. If you add it too early, the fish will be too wet and you will ruin the product. If it is added too late, you will not get proper absorption and the product will be poor quality. It is very important that the smoke be introduced at the right time.

Today's smoke generators are commonly separated from the processing unit. Wood is no longer used as a heat source because it is too expensive and makes the moisture content of the air too difficult to control. Most of today's machines use steam run through a radiator fired by electricity, oil, or gas. Selecting the proper heat source is largely a matter of convenience.

So far, you can see that keeping the product at the proper temperature and moisture and carefully controlling the smoke addition are crucial points. These are usually best controlled by an automatic system which constantly monitors and adjusts these factors. Each of you will want to process slightly differently. Some of you may want to cold smoke salmon a bit drier or wetter than others, depending on your market. Smoke is acidic, and will dry the product. If added at a certain temperature it will denature the product, causing a crust to form that will not allow water to escape from fish. The smoke generator then, must work automatically.

Wood is no longer used to fire the oven, but is used to generate smoke. Each type of wood will give a different quality or taste, and some will make the product taste awful. Softwoods in particular, will cause problems. Many times legal requirements specify hardwoods. The type of wood you choose depends on the product you desire and market preference. I find that hickory wood is good for fish smoking. Some people prefer apple wood, or other kinds. The important thing is to get a unit that will use any kind of sawdust, giving you flexibility in choosing woods.

Through precise control of temperature and air moisture content, the modern oven can smoke a batch in a shorter time than was otherwise possible. This reduction of time is important because the less time a product is in the oven, the better it will be, within certain limits of course.

Controlling core temperature of the product is another critical step. The smoking temperature should be built around this program, not just the amount of time the fish spends in the unit. The modern processing unit must accept inputs at various initial temperatures, to process the fish through various steps, and to arrive at some critical core temperature. To do this, the unit should be able to automatically change from one processing step to another. For example, you may put the fish in with a temperature probe that allows you to change to the smoking cycle when the core temperature reaches 50°F. The unit should also be able to continue various steps for creating different products, as well as allowing control over individual steps in the process.

This brings us to air pollution. Air quality assurance can be remarkably easy with a good processing unit. Each community has its own pollution requirements. The basic processing cycle includes drying, smoking, and finishing the fish. If you dry a fish a little more in the beginning and raise the humidity a bit in the smoking step, you will eliminate the need for smoke venting to reduce the humidity within the smoker. During finishing, the moisture in the air can go up a little, because you want to raise the temperature inside the fish. At the end of the cycle, smoke can be slowly vented up the chimney without creating air pollution problems. You should have the ability to program these functions into your unit.

CONCLUSION

Modern fish processing is no longer dependent on outside environments. Science has made it possible for equipment to regulate the steps required to achieve desired results and products.

- Product quality can be uniform and high with equipment engineered to perform all of the processing steps accurately, using time and core temperatures for processing length control.
- The most expensive mistake a processor can make is to install equipment that is not specifically designed for the fishing industry, or lower priced equipment that will not perform all required functions.
- The processor must know the product and the steps required to make it. The equipment engineer must first know the product and the processes in order to design equipment which will perform required functions. It is only with this combined knowledge that a successful fish processing industry can exist.

HEALTH REGULATIONS AND QUALITY CONTROL

FEDERAL HEALTH REGULATIONS

Raymond Mlecko
U.S. Food and Drug Administration
5003 Federal Office Building
Seattle, WA 98174
(206)442-5310

(Eds. note: Copies of federal regulations are available from the above address.)

The purpose of my discussion is threefold: to briefly explain the acts and the regulations enforced by the Food and Drug Administration (FDA) as they apply to smoked fish; to pass out copies of the regulations covering smoked fish; and to invite you to call our office if you have any problems with or questions about the laws we enforce.

All food products, including smoked fish and its variations, shipped in interstate commerce or made from ingredients received in interstate commerce, are subject to the provisions of the Federal Food, Drug, and Cosmetic Act (FDCA); the Fair Packaging and Labeling Act (FLPA), and their regulations. At first, the definition of interstate commerce seems simple: commerce between two states. But what about commerce between a state and a territory, or a state and a foreign country? Under the FDCA, these are also examples of interstate commerce. In fact, commerce between any state and any place outside its borders falls under this act.

In general the FDCA requires that food be prepared, packaged, and held under sanitary conditions. The food must be safe and wholesome. Its labeling must be accurate and informative. The Fair Packaging and Labeling Act requires certain information to be carried on all labels of food intended for retail. This is to distinguish between food which goes on for further processing or institutional trade, and food that is retailed.

Under the Federal Food, Drug, and Cosmetic Act, good manufacturing practice regulations have been established. The first of these regulations, Current Good Manufacturing Practice in Manufacturing, Processing, Packing, or Holding Human Food, is contained in Part 110 of Title 21 of the Code of Federal Regulations. If you are in the food processing business, you should have a copy of Part 110. These regulations cover all foods and are so broad and basic that they are often referred to as the "umbrella GMPs." They cover a wide variety of areas, including personnel cleanliness, disease prevention, employee training, and supervision; sanitation, disposal, and maintenance procedures; use of equipment suitable for the intended function; and control of your process to support the sanitation goals of your organization.

In 1977, the FDA added specific regulations for hot process smoked fish and smoke-flavored fish to the general good manufacturing practices. These regulations were developed after a number of Great Lakes cases where people were poisoned by smoked fish contaminated with Clostridium botulinum. The specific regulations are contained in Part 122 of Title 21 of the Code of Federal Regulations. Among the types of limitations found there are:

- Time, temperature, and salinity parameters for hot process smoked fish and smoke-flavored fish

- Product must be cooled to 50°F or less within three hours after processing

- Product must be cooled to 38°F within 12 hours after processing

- During storage and distribution, the product must be held at 38°F or less.

The East Coast smoked fish industry actively opposed the regulations. They felt these smoked fish regulations were unrealistic. They felt that the regulations would result in an inferior product and soon ruin their product and their trade. Consequently, a number of these fish processors disregarded the GMPs and soon were involved in a legal dispute with the FDA. The case United States vs. Nova Scotia Food Products Corporation occurred about 1977 and involved both district and appellate court proceedings. The appellate court held that the FDA regulations on smoked fish were invalid. The court based its decision on procedural grounds, saying that the FDA had used unpublished data to justify the need for the regulations, and that the FDA had not considered the commercial feasibility of these regulations.

As it now stands, we do not have any good manufacturing practice regulations for the smoked fish industry. However, we offer these regulations as guides. There is a possibility that in the coming years these regulations will again be promulgated and the smoked fish industry will have to follow them.

As I previously indicated, FDA is concerned with microbial contamination of smoked fish. Consequently, we suggest a high processing temperature and a proper salt concentration along with refrigerated storage and distribution. The presence of sodium nitrite and sodium nitrate may also deter toxin formation. Our food additive regulations provide for the use of sodium nitrite and sodium nitrate in smoked fish products.

We do not currently have any literature on the safety of cryo-packing or vacuum-packing smoked fish. However, we are concerned with any kind of packing technique which excludes oxygen. Clostridium botulinum Type E has been shown to grow and produce toxin without oxygen in some media at temperature greater than 38°F. We do not have any data on time necessary to produce these toxins in specific fish products. We also realize that it is very difficult for us, as a regulatory agency, to control the temperature of the smoked fish product during distribution. The processor may have good intentions but who knows at what temperature the retailer is going to keep the fish. However, we have occasionally asked manufacturers to conduct tests on their products at various abuse temperatures before the product becomes organoleptically unacceptable.

Because the main problems occur in distribution, the FDA has insisted that manufacturers place adequate, clearly visible storage information on the labels. Until more definite information is obtained or until we identify a situation where temperature abuse is likely to endanger health, we are not prepared to prohibit cryo-packing or vacuum packing of refrigerated products. However, everyone should be aware that there is a potential for great danger if these products are not kept at the proper temperature.

So far, we have talked about noncanned items. Let us look at what you have to do if you want to can your smoked fish product. Again, the FDA has promulgated specific regulations for thermally processed, low acid foods canned in hermetically sealed containers because of the dangers of Clostridium botulinum. These regulations are contained in Parts 108 and 113, Title 21 of the Code of Federal Regulations. Among other things, these regulations require that a manufacturer of smoked fish products in hermetically sealed containers must register his plant and must file processing information with the Food and Drug Administration. This processing information has to cover each can size of product processed. If you need any registration or filing forms, you can contact our office.

Now I would like to briefly discuss the labeling requirements for smoked fish products. Federal low requires four statements on the label:

- The name of the product
- A list of the ingredients in a descending order of predominance
- A statement of the net quantity of contents
- The name and the place of business of the manufacturer, packer, or distributor.

Whether your product goes wholesale or retail, you still need this information. If the product goes retail, the label has to show the product name and the net weight statement on the front panel in a particular location, and the net weight statement must be in a specified type size. The statement of ingredients and the name and place of business of the manufacturer, packer, or distributor can either be on the main panel or on a panel to the right of the main panel. These labeling requirements are contained in Part 101, Title 21 of the Code of Federal Regulations.

QUESTION: Must all fish smokers register with the FDA?

MLECKO: If it is a smoking operation only, there are no registration requirements. If the product is canned and if it is a low acid food in a hermetically sealed container, then you must register and you must file your process. Again, if your product is simply smoked and not packed in hermetically sealed containers, you do not register.

QUESTION: If vacuum packaging is used, will Clostridium botulinum grow if the product is frozen?

MLECKO: You will not have the growth of the organism which produces the toxin.

QUESTION: How should the label read if you have two firms, one of which catches the fish and the other firm smokes the fish?

MLECKO: You would have to show the firm that is buying the raw material, processing and packaging it. This firm would be considered the manufacturer as far as we are concerned.

QUESTION: Must salt and spices be listed as ingredients on the label?

MLECKO: You have to include salt. Spices can be declared as spices. Spices and flavoring can be declared as such.

QUESTION: Can the particular type of smoke or the particular wood used to make smoke be included as an ingredient on the label?

MLECKO: The particular type need not be shown. You may want to show it for marketing reasons, such as "alder smoke."

QUESTION: What are the legal requirements for products distributed within a state?

MLECKO: You would follow the state regulations. You don't follow the federal regulations. The Washington and Alaska state regulations are similar to the federal regulations.

QUESTION: Must the species of fish, particularly salmon, be mentioned on the label?

MLECKO: That is a good question. We have a standard of identity for canned salmon. In other words, if you can nonsmoked salmon, the label has to show the species, i.e., coho, chum, whatever. Technically speaking, on your ingredients statement for smoked fish, you may show chum salmon or king salmon or whatever the species, but this is not required. The word salmon will suffice.

QUESTION: Can it be assumed that the federal regulations are more comprehensive than the corresponding state regulations?

MLECKO: What states are we talking about. I am no expert in state laws but I understand that some states have very strict requirements. Alaska, Washington, and Oregon have regulations that are fairly similar to the federal requirements. We work very closely with the state people and, generally speaking, compliance with federal regulations will satisfy state requirements.

QUESION: Must bulk quantity shipments also bear the labels needed for retail packages?

MLECKO: That container still has to bear the four statements that I have given you.

QUESTION: Can adhesive labels be used for this purpose?

MLECKO: Yes, it could be a stick-on label.

QUESTION: Is the FDA checking the salt content of smoked fish?

MLECKO: The regulations are not forceable at this time. We are not checking. But it would be to your advantage because, of course, as a manufacturer, you don't want to harm anybody.

QUESTION: If a poisoning does occur, will the FDA prosecute the responsible parties?

MLECKO: Well, there aren't any enforceable smoked fish GMP regulations. However, the case may involve a violation of the Federal Food, Drug, and Cosmetic Act. But if a person is injured, I would worry more about your product liability. You are probably going to be sued. As far as we are concerned, we would like you to follow the smoked fish GMPs. But if you don't have the proper salt concentration, you are not in violation of the law because there is no law.

QUESTION: Some states base their smoked fish laws on the federal GMPs. Are these laws valid?

MLECKO: What you are referring to is a model food and drug act. Some of the states may have them and they may be enforcing them. But I suspect that if somebody would go to court, the smoked fish GMPs would be held unenforceable, because according to the court, they are based upon unpublished data.

QUESTION: Does the FDA require registration of fish smoking operations?

MLECKO: If we are talking about licensing, we don't license any of these.

QUESTION: Does the FDA inspect smoked fish businesses?

MLECKO: Yes. If you are smoking and shipping fish in interstate commerce, you will be inspected by the Food and Drug Administration. We will inspect you relative to the Federal Food, Drug, and Cosmetic Act. We will inspect your operation relative to the general good manufacturing practice regulations. We will look at your labels. We will not enforce the good manufacturing practice regulations specifically for hot process smoked fish or smoke-flavored fish products.

QUESTION: Does the federal government have GMPs for cold smoked fish products?

MLECKO: No, we do not. The establishment of one of these good manufacturing practice regulations requires a lot of data. It takes a lot of time. The agency does not have the resources to develop these for every specific industry or product. We established a GMP for the hot process because the product had presented a safety problem to the consumer.

QUESTION: Is a processing operation located on a vessel responsible for the same regulations as a land-based business?

MLECKO: Yes, basically the same regulations will apply to a vessel. However, this causes certain logistic problems for us. For example, how do we get to the vessel?

QUESTION: If a smoking operation closely follows the federal GMPs and is sued because of some fault, can the GMPs improve our position?

MLECKO: Well, theoretically if you follow the GMPs, you should be better off than if you didn't follow them.

MICROBIOLOGICAL SAFETY OF SMOKED FISHERY PRODUCTS WITH SPECIAL REFERENCE TO BOTULISM

Dr. Mel Eklund
Utilization Research Division
Northwest and Alaska Fisheries Center
National Marine Fisheries Service, NOAA
2725 Montlake Boulevard East
Seattle, Washington 98112
(206)442-7728

(Ed's. note: This is a general review of safety of smoked fish products. Specific papers can be obtained from the author.)

INTRODUCTION

Microorganisms are naturally widespread and are very important in the production, processing, and distribution of foods. In fishery products, yeasts, molds, and bacteria are the most important microorganisms contributing to spoilage. Bacterial species are generally responsible for the deterioration and eventual spoilage of raw fishery products, whereas yeasts, and particularly molds, often play an important role in the spoilage of prepared or semi-preserved fishery products where the competitive bacterial flora has either been selectively eliminated by heat treatment or inhibited by salt and other preservatives. Certain species of bacteria also are very important in causing food poisoning. Of the different types of bacterial food poisoning, botulism is the most serious and of most concern to food processors and consumers throughout the world.

In recent years, the smoked fish industry has experienced an excellent record for producing millions of pounds of products that have been safe. In the early 1960s, however, this same industry suffered serious economic losses following human botulism outbreaks caused by a shipment of smoked chubs that were temperature-abused during distribution. These outbreaks caused 16 botulism cases, nine deaths, and resulted in product recall, adverse publicity, and a loss of consumer confidence in smoked fishery products. Even though the chubs were processed and distributed in the midwestern section of the United States, the outbreaks had a severe national impact on the entire smoked fish industry.

To the average consumer, botulism is a somewhat mysterious disease and panic often accompanies any outbreak. In order to help prevent any future outbreak, it is necessary to develop a sensible attitude toward botulism and to become better acquainted with the facts involved. The purpose of this paper is to discuss:

- botulism food poisoning, the bacteria, and its toxin
- characteristics of the bacteria that are important to the food industry
- conditions required for outbreaks

- general procedures to be considered in the production of safe and acceptable smoked fish products.

BOTULISM FOOD POISONING

Several hundred years ago, before man discovered bacteria, "sausage poisoning" occurred frequently in Germany. Early scientists called the disease "botulism" a name derived from the word "botulus," meaning sausage. The disease remained a mystery until 1895 when a Belgian scientist studied a food poisoning case caused by pickled ham that resulted in a disease identical to sausage poisoning. During his studies, he isolated a bacteria from the ham which produced total paralysis and death in laboratory animals. This bacteria which causes botulism is now known as Clostridium botulinum.

Since 1895, additional C. botulinum (C. or Cl. are used as abbreviations of Clostridium) organisms producing different toxins have been discovered and many different foods have been involved in botulism outbreaks. Based upon the production of different toxins, there are now seven recognized types of C. botulinum designated by the letters A through G. Types A, B, E, and F have caused the majority of the human botulism outbreaks, whereas types C and D are usually involved in animal and bird botulism. Type G has been isolated from the soil in Argentina but has not been involved in any botulism outbreaks.

Food-borne, infant, and wound botulism are the three clinical forms currently recognized. Food-borne botulism is caused by ingesting C. botulinum toxin during its growth in feeds and foods. Infant and wound botulism are associated with the organism's growth and toxin production in the intestines (infants up to 14 months of age) or in damaged tissue. Of these forms, food-borne botulism is of the most concern to processors of preserved fishery products such as smoked fish.

Between 1899 and 1977, there were a total of 766 botulism outbreaks involving 1,962 cases. C. botulinum type A caused 26 percent of the outbreaks; type B, 8 percent; type E, 4 percent; and one outbreak occurred from type F. The causes of over 50 percent of the outbreaks remain unknown because the incriminating food sample was not available or the toxin could not be detected in the victims' serum. The mortality rate from botulism was 60 percent until 1945. Because of oxygen respiratory care and antiserum treatment, the mortality rate has been lowered to 25 percent since 1945.

Most of the botulism outbreaks have occurred from improperly prepared home-canned foods. In contrast, commercially processed canned foods have had a remarkably good record during the past 54 years. Approximately one trillion food cans have been processed by commercial companies in the United States with only a few food poisoning outbreaks.

Table 1 summarizes the food involved in botulism outbreaks. Vegetables, generally home canned, have caused the greatest percentage of the outbreaks. This is followed by fruits and fishery products. Botulism is usually associated with foods that have been inadequately preserved and abused by storage at non-refrigerated temperature. Fresh or raw fishery products have never been implicated in any of the botulism outbreaks.

Table 1. Foods involved in botulism outbreaks in 1899-1977

FOOD	PERCENTAGE OF TOTAL OUTBREAKS
Vegetables	17.8
Fruits	4.1
Fish	3.6
Condiments	2.2
Beef and Pork	1.3
Milk Products	0.6
Poultry	0.1
Other	0.5
Unknown	69.8

GENERAL CHARACTERISTICS OF BACTERIA CAUSING BOTULISM

SPORES

C. botulinum differs from many other bacteria in that it naturally exists either in the spore or vegetative state. The spores are widespread in nature. During optimum growth conditions, they will germinate and develop into the vegetative state in which they grow rapidly and produce their lethal toxin. During later stages of their growth cycle, the vegetative cells again form spores. The spores are resistant to heat, drying, salting, freezing, and other physical and chemical treatments and can remain dormant for many years in the soil and in areas such as food processing plants. When these spores contaminate foods, they are very difficult to destroy.

ANAEROBIC CONDITIONS

Bacteria have various tolerances to air. Some bacteria called "aerobes" can only grow in the presence of oxygen. At the other end of the scale, we have "anaerobes" which cannot grow in and can even be killed by the presence of oxygen. C. botulinum is an anaerobe that grows in the absence of air. This description, however, often leads to a misunderstanding. Some people interpret this to mean that any vacuum-packed or canned foods can become dangerous, whereas unpackaged foods or food packaged in oxygen-permeable films are safe. The truth is that C. botulinum can grow and produce toxin in both unpackaged and vacuum-packaged foods such as smoked fishery products. To understand this, we must remember that the bacterial cell is very small and about 10 million C. botulinum organisms occupy the space equivalent to the head of a common pin (1 to 2 mm). Anaerobic conditions for growth are therefore easily met in most foods only a few millimeters (a fraction of an inch) below the product surface. In addition, if aerobic bacteria are present on the product surface, they will use the oxygen and create favorable conditions for C. botulinum growth. Some species of bacteria, however, can also compete with and even inhibit C. botulinum growth.

ACIDITY OF A PRODUCT

Acidity and alkalinity of a food are measured in terms of a pH scale of 1 to 14 with pH 7 representing neutrality. Values above pH 7 are increasingly alkaline, whereas values below pH 7 become increasingly acidic. None of the C. botulinum types will grow at values lower than pH 4.5. In some cases, yeasts and molds may aid C. botulinum because they grow at a lower pH and oxidize the acids in foods, causing the pH to rise. When the pH values rise above pH 4.5, C. botulinum spores can germinate and grow. The maximum pH supporting growth is 8.5. The only fishery products with pH values below 4.5 are marinated, such as pickled herring. Adjusting the pH of smoked fish to values lower than 4.5 or higher than 8.5 would drastically change the characteristics of the product.

SPECIFIC CHARACTERISTICS OF PROTEOLYTIC TYPES A, B, AND F

The types of C. botulinum involved in human botulism can be divided into two different groups: group 1 consists of the proteolytic types A, B, and F. Group 2 is comprised of the nonproteolytic types B, E, and F. Since these two groups of bacteria differ significantly, some of their characteristics will be discussed separately.

Group 1 bacterial types are the hardiest of the C. botulinum species. The spores of some strains withstand water boiling temperatures for 6 to 8 hours. This is the reason that low-acid foods are canned with the aid of pressure cookers using higher temperatures. This group of organisms also requires 10 percent water-phase salt (sodium chloride) to inhibit their growth and toxin production. The minimum temperature at which they will grow is 50°F (10°C).

The organisms belonging to group 1 are also proteolytic, meaning that they will attack complex proteins, and their growth is often accompanied by off-odors. Food spoilage by this group of bacteria, however, varies with the stage of their growth and the food's composition. Spoilage therefore does not always accompany toxin production and is not a reliable indicator of whether or not a food is safe.

Measurement of water activity is another way to determine whether bacteria can grow in a food product. This is a measure of the available moisture in a food and is often indicated by the symbol "a_w". The different amounts of water, salt, sugar, protein, and so on will all affect water activity and determine whether bacterial growth will occur. The minimum a_w for the growth of the proteolytic C. botulinum types A, B, and F is 0.94 to 0.95.

SPECIFIC CHARACTERISTICS OF NONPROTEOLYTIC TYPES B, E, AND F

These organisms are more sensitive to heat than group 1, and are rapidly killed in buffer solutions at 212°F. The composition of a food (protein, fat, dryness, etc.), however, increases the heat resistance of these spores and they will usually survive processes used to prepare smoked fish products. These three types of C. botulinum have the unique characteristic of growing and producing toxin at temperature as low as 38°F (3.3°C). Because of their nonproteolytic characteristics, they do not attack complex proteins and their growth in foods usually cannot be detected by off-odors and off-flavors. This group of organisms is less tolerant of salt and, under optimum conditions, 5 to 6 percent will inhibit growth and toxin production. The minimum water activity for growth of nonproteolytic types B, E, and F is 0.97.

TOXINS OF C. BOTULINUM

The toxins produced by all C. botulinum types are the most potent poison known to mankind. It is estimated that a tablespoon of purified toxin is sufficient to destroy all human life. This is why this form of food poisoning concerns food processors and consumers.

Under ideal cultural conditions, C. botulinum growth releases potent neurotoxin into the food. When the food is eaten, the toxin enters the circulatory system through the small intestines. The toxin causes paralysis by acting on the nervous system. If sufficient toxin is present in the blood, the diaphragm and chest muscles are paralyzed and death may be caused by asphyxiation. Usually symptoms develop between 8 and 72 hours after eating the toxic food. The toxin is a protein and can be deactivated by boiling foods for 10 minutes. If particulate material such as chunks of meat are present, it is advisable to increase the heat treatment to 20 minutes to permit sufficient heat to penetrate the center of the food. Because of the extreme potency of the toxin, any food in question should not be tasted and should be disposed of so that animals cannot gain access to it.

CONDITIONS NECESSARY FOR BOTULISM OUTBREAKS

In order for food-borne botulism to occur, the following conditions must be met:

- A food must be contaminated with C. botulinum spores or vegetative cells from the environment in which it was grown or during subsequent handling.

- The processing treatment must be inadequate to inactivate the C. botulinum spores or the product must be recontaminated after processing.

- For C. botulinum to grow, the food must support its growth and toxin production when the food is stored above 38°F for sufficient periods of time.

- Ultimately the food containing the preformed botulinal toxin must be consumed without cooking or after cooking insufficient to inactivate the botulinal toxin.

Now that we understand some of the characteristics of C. botulinum, let us look at each of the conditions necessary for botulism to occur with specific reference to smoked fish products.

CONDITION NO. 1

Because C. botulinum is ubiquitous in nature, it is impossible to assure its absence in any raw fishery product. Table 2 summarizes the incidence of C. botulinum in some of the marine and freshwater environments. Type E is very widespread in nature and is the most prevalent type in these environments. Types A, B, and F may also be present in these environments, and in certain areas they may be more prevalent than type E.

CONDITION NO. 2

Even though type E is more heat-sensitive than proteolytic types A, B, and F, previous studies have shown that the surface drying of fish during the smoking operation and the composition of the fish (proteins, fats, and so on) protect type E spores from being destroyed by heat treatment. As a result, some type E spores will survive smoked fish processes where the internal

Table 2. Occurrence of *C. botulinum* in marine and freshwater sediments collected on the Pacific coast of the United States

AREA WHERE COLLECTED	NUMBER POSITIVE/ NUMBER TESTED	NUMBER POSITIVE FOR INDICATED *C. BOTULINUM* TYPE
Washington		
Bay	91/98	1A,90E
Ocean	51/101	4B,47E
Fresh water	50/55	50E
Oregon	32/92	10A,1B,18E,3F
California		
To 36° N. latitude	19/128	1B,18E
Shore, 41° N. latitutde	2/28	1A,1E
36°to 32° N. latitude	15/160	6A,8B, 1F

temperature of the product exceeds 180°F (82.2°C). If other more resistant C. botulinum types (Group 1) are present on the product, this heat treatment would be even less effective.

CONDITION NO. 4

During smoked fish processing, the predominant fish spoilage bacteria that cause objectionable off-odors and -flavors in raw fishery products are selectively eliminated by heat, smoke, salt, or preservatives. Because of this alteration of the bacterial population on smoked fish, and the nonproteolytic characteristics of type E, off-odors and -flavors often do not accompany C. botulinum toxin growth and production when products containing viable type E spores are stored above 38°F (3.3°C). Spoilage therefore is not a reliable indicator of the safety of this type of food product. In addition, smoked fishery products are usually eaten without any further heat treatment. The chances of inactivating any preformed toxin in a smoked fish product at this point is also eliminated.

CONDITION NO. 3

Based upon our previous discussion, we must assume that smoked fishery products can contain viable C. botulinum spores. Condition 3 is therefore probably the most important to smoked fish processors. In order to prevent botulism food poisoning, the growth of C. botulinum spores must be inhibited during the smoking treatment. Storing the finished product at temperatures below 38°F for short storage periods and freezing for long-term storage are probably the most important conditions for controlling C. botulinum growth. It must be emphasized, however, that these storage temperatures do not destroy C. botulinum spores or their toxin.

Since most botulism outbreaks have been traced to foods that have been poorly processed and temperature-abused, salts and other preservatives are essential in preventing C. botulinum outgrowth and toxin production. Under ideal conditions for C. botulinum growth, 5 percent water-phase salt is inhibitory for type E and 10 percent water-phase salt for proteolytic types A, B, and F. This and other considerations for controlling botulism will be summarized in the last section of this paper.

1963 BOTULISM OUTBREAK AND GOOD MANUFACTURING GUIDELINES

Now that we understand the conditions contributing to botulism, let us examine a specific outbreak. In the early 1960's, three botulism outbreaks occurred from the ingestion of improperly processed stored smoked fish. The largest of these outbreaks occurred in 1963 from the ingestion of smoked chub processed in Michigan. The fish were heat processed, vacuum packaged, and shipped to the southcentral part of the United States. During transit, the smoked chub were subjected to temperatures exceeding 90°F (32.2°C) for several days. The fish were then distributed through supermarkets.

The botulism outbreaks that followed affected 16 people and caused nine deaths. Of the 16 victims involved, only three detected any unusual flavors from the smoked chub and none of them detected any undesirable odors. The finished products also had low concentrations of salt and did not contain sodium nitrite. A brief analysis of this outbreak indicates:

- The C. botulinum organism was in the finished product.
- The smoked fish did not contain enough salt to inhibit the growth of C. botulinum.
- Temperature-abused products do not always show signs of spoilage.
- Toxic foods can be found acceptable and consumed.

Following the 1963 type E botulism outbreak, Good Manufacturing Guidelines (GMPs) for hot-smoked and smoke-flavored fish were published by the Food and Drug Administration. Besides the temperature requirements for brining, storage of the finished product, and plant sanitation, these guidelines required the following processing parameters:

- Smoked fish must be processed to an internal temperature of 180°F for 30 minutes and contain a minimum of 3.5 percent water-phase salt in the deepest part of the loin muscle.
- Smoked fish must be processed to an internal temperature of 150°F for 30 minutes and contain 5.0 percent water-phase salt in the deepest part of the loin muscle.

These processing parameters often resulted in products that were over-processed or too salty and unacceptable to the many consumers. Because of the impracticality of these two processes, the FDA approved a third process for smoked chub only. This GMP required processing smoked chub to an internal temperature of 160°F for 30 minutes, providing the finished product contained a minimum of 3.5 percent salt and between 100 to 200 ppm of sodium nitrite. Since this latter GMP unfortunately was approved only for chub, the remainder of the smoked fish industry had to comply with the first two processes.

The smoked fish processors continued to encounter difficulties in complying with the GMPs which finally resulted in a legal case in 1977. The court ruled that the hot-smoked fish GMP was invalid because it was promulgated in an arbitrary manner. The result was that the GMP processing requirements for salt, processing time, and temperature were no longer enforceable.

Current research at the Northwest and Alaska Fisheries Center in Seattle is developing alternative processing parameters necessary to inhibit the growth and toxin production of C. botulinum in smoked fishery products. These parameters must also permit processors to produce consumer-acceptable products. Until this research is completed, it is strongly recommended that the salt and time and temperature of processing listed in the Good Manufacturing Practice Guidelines for hot-process smoked fish be followed as closely as possible.

GENERAL PROCEDURES TO BE CONSIDERED IN THE PRODUCTION OF SAFE AND CONSUMER-ACCEPTABLE SMOKED FISHERY PRODUCTS

Each processor will have to experiment with the different species of fish or sections of fish that are to be smoked. Some general guidelines for processing smoked fish are discussed in this section. To produce both safe and acceptable smoked products, it is essential that one start with a good quality product. If the raw material is frozen, it must be completely thawed and thoroughly washed before it is placed in the brining solution. It is important to wash the fish with chlorinated water to remove blood, other debris, and as many bacteria as possible. This not only helps to increase the shelf life, but it also reduces bacterial populations that cause food poisoning. Washing the fish after brining is not as effective because once the product has been brined, a water-soluble protein layer covers the fish surface and it is more difficult to remove any entrapped bacteria.

Probably the most difficult, but the most important step in preparing smoked fish is obtaining the desired concentration of salt or other preservative in all parts of the product. Uniform salt concentrations are not only important for the inhibition of spoilage microorganisms and food poisoning bacteria, but also for consumer acceptability.

The factors that contribute to salt variation in smoked fish are: fish size, species, fat content, condition (frozen or fresh, state of rigor), brine concentration, brine temperature, brining time, brine-to-fish ratio, circulation of brine, section of fish, and so on. Before brining, all of the salt added to the water must be in solution and the fish or fish sections should be sorted according to size and thickness. The different sizes should be brined separately so that various brining times or brine concentrations can be used. A longer refrigerated brining time period (18 to 36 hours) with a more dilute brine (20° to 45° salometer) often results in a more uniform salt concentration than a short brining time in a more concentrated brine (over 45° salometer).

As the brine-to-fish ratio increases, the amount of salt per unit weight of fish increases. A ratio of at least 2 to 1 and preferably 3 to 1 should be used. This results in increased salt absorption by fish and more uniformity of salt absorption from fish to fish. During the brining period, the brines should be frequently agitated either by a mechanical device or manually. All pieces of fish should be kept below the brine surface throughout the brining time.

Sodium nitrite enhances the inhibitory effects of salt (sodium chloride) and can be used in smoked chub, sablefish, salmon, and shad up to a final concentration of 200 ppm. It can be added to the brine in premixes or in pure form. It should also be dissolved thoroughly in the brine before the fish are added. As a word of caution: if sodium nitrite is used in pure form, bags or other bulk forms of $NaNO_2$ should be kept in a locked room and only quantities needed in a given brine should be permitted out of the room. Sodium nitrite can be dangerous if it is added to brines at very high concentrations.

In laboratory experiments, a rule of thumb is to add twice as much sodium nitrite to the brine as one desires in the final product. For example, if 200 ppm is desired in the product, add sodium nitrite at a final concentration of 400 ppm in the brine. Again, experimentation by the processor is recommended because of variations in brining conditions. Sodium nitrate is not an effective inhibitor unless it is reduced to sodium nitrite. The nitrite form should therefore be used in combination with salt (sodium chloride). Sodium nitrite will eventually be broken down by bacteria present on smoked fish and the inhibitory effect lost. This bacterial action on sodium nitrite can be reduced by storing the product at 32°F(0°C).

Fish should be processed at a minimum internal temperature of 150°F. This helps eliminate other bacteria such as Salmonella and Staphylococcus which can also cause food poisoning. Heating smoked fish to internal temperatures above 150°F does cause a heat injury to C. botulinum type E spores and it becomes less tolerant of salt. This is the reason for the difference in salt requirements for products heated to internal temperatures of 150°F vs. those heated to 180°F. Smoking, in addition to cooking, not only imparts desirable flavor and color, but also has certain harmful effects on bacteria.

After the heating process has been completed, the product should be removed from the smokehouse and cooled for a short period at room temperature. Then the product should be refrigerated at temperatures less than 38°F. Refrigerate the final product as soon after processing as possible to prevent the growth of microorganisms.

After smoking, it is very important that the finished product be protected from recontamination by bacteria from the raw fish or contaminated areas. The finished product should be stored separately from the raw fish and personnel should also be cautioned about working with the finished product after they have worked in the raw fish area. If the same personnel are used for both operations, they should thoroughly wash their hands and change their contaminated clothing before they work with the finished product.

The smoked products should be handled as little as possible and packaged. Vacuum packaging in general is discouraged because it can delay the spoilage of fish products at abuse storage temperatures--especially those of lower salt content--but have little effect on the growth and toxin production by C. botulinum organisms. The package should be properly labeled to inform the consumer to store smoked fish at less than 38°F. Suitable records should be kept for each lot of fish processed.

Each processor will have to experiment with brining and smoking procedures for the specific fish species that is to be used in the process. Once a desirable procedure has been developed, it should be followed closely.

COLD-SMOKED PRODUCTS

Currently there are no specific GMP regulations for cold-smoked products. With the exception of processing temperatures, the procedures recommended for hot-process products should be followed. Cold-smoked products are usually processed at temperatures below 90°F (32.2°C). These temperatures offer an excellent incubation temperature for spoilage and food poisoning-type bacteria. Adequate salt content of these products is very important for inhibiting these bacteria during the smoking operation and subsequent refrigerated storage.

Fish to be used in cold-smoked products should be frozen below -20°C (-6.7°F) for 48 hours before they are used. Many marine species can occasionally contain an anasakis nematode which can cause ulcer-like conditions in the digestive tract of people and certain other mammals. These worms withstand high concentrations of salt but are easily destroyed by freezing or by heating the product to internal temperatures above 122°F (50°C).

FISH JERKY

Fish jerky should have a water-phase salt of 10 to 12 percent to inhibit C. botulinum. If it is to be marketed at room temperature, a water activity of less than 0.85 is required to inhibit Staphylococcus, a food poisoning organisms which tolerates high salt.

QUALITY CONTROL PROCEDURES

Ken Hilderbrand
Marine Advisory Program
Marine Science Center
Oregon State University
Newport, OR 97365
(503)867-3011

(Ed's. note: Mr. Hilderbrand reviewed current literature in his presentation. The texts of those reports he found most informative are included following this summary.)

SUMMARY

This session deals mainly with the model Hazard Analysis and Critical Control Point (HACCP) system for smoked fish. Publications reprinted here include:

Hazard Analysis and critical control point application to the seafood industry
J.S. Lee (Courtesy Oregon State University Sea Grant College Program)
HACCP for smoked fish are outlined in this report. General comments also included are recommended for reading.

Preparation of salt brines for the fishing industry
K. Hilderbrand

Quick determination of salt content of seafoods
Oregon State University Seafoods Laboratory

Estimating salt and moisture content needed in smoked fish to meet good manufacturing practices
These two fact sheets are based on information found in the Bureau of Commercial Fisheries (BCF) circular 331, Guidelines for the processing of hot-smoked chum.

Estimating the moisture content of smoked fish by non-destructive means

Various other sanitation procedures are outlined in the Bureau of Commercial Fisheries circular 259, Effective sanitation in smoked-fish plants; and Public Health Service publication 1589, Sanitation standards for smoked fish processing.

Salt and moisture content analysis was quick, inexpensive, and simply done as explained in BCF circular 331.

At the close of the session, cross-contamination (raw to smoked fish) was point out as the most often violated rule of good practice. Processors were cautioned to prevent cross-contamination wherever possible.

REFERENCES

1. Lee, J. S. 1977. Hazard analysis and critical control point applications to the seafood industry. Oregon State University Sea Grant College publication ORESU-H-77-001. ($2.00)

2. Davidson, William. _____. Life begins at 40°F: How to use a seafood handler's thermometer. Oregon State University Sea Grant College Program publication No. 32.

3. Lee, J. S. ____. Cleaning and sanitizing agents for seafood processing plants. Oregon State University Sea Grant College Program publication No. 21.

4. Hilderbrand, K. 1979. Preparation of salt brines for fishing industry. Oregon State University Sea Grant College Program publication No. 22.

5. U.S. Department of the Interior, U.S. Department of Health, Education, and Welfare. ____. Sanitation standards for smoked fish processing. Public Health Service publication No. 1587. (Usually available through interlibrary loan or marine advisory office.)

6. U.S. Department of the Interior Fish and Wildlife Service. _____. Guidelines for the processing of hot-smoked chum. Bureau of Commercial Fisheries circular No. 331.

HAZARD ANALYSIS AND CRITICAL CONTROL POINT APPLICATIONS TO THE SEAFOOD INDUSTRY

J. S. Lee
Oregon State University
Sea Grant College Program
Publication No. ORESU-H-77-001
December 1977
(Editor's note: Reprinted by permission of Oregon State University Sea Grant College Program.)

INTRODUCTION

Federal legislation* will in the near future make adequate safety assurance programs mandatory for all food processors. It is none too soon that the seafood industry should be aware of this development and be prepared for it. While seafood is no more sensitive to processing hazards than other fresh foods, the particular methods used by seafood processors require individual attention in designing a safety assurance program that will match the industry's needs.

In order to comply with such proposed regulations, food processors SHALL set forth, IN WRITING, the procedures they use to identify the control points in the processing operations and the hazard associated with each point, and to establish adequate control measures and an adequate monitoring plan for each point. In short, it will require food processors to establish safety assurance programs based on the rational and systematic approaches of the Hazard Analysis and Critical Control Points (HACCP) concept.

This bulletin is intended to explain HACCP and explore its applications in the seafood industry of the Pacific Northwest. The process models given for fish smoking (Fig. 1), cooked and picked crab processing (Fig. 2), and cooked and peeled shrimp processing (Fig. 3) indicate suggested processing steps; other models of processing methods are also possible.

WHAT IS HAZARD ANALYSIS?

The hazard analysis (HA) portion of HACCP requires the processor to estimate the degree of hazard associated with each commodity produced, the intended end use of the product, the processing modifications he might have incorporated, and the possibility and extent of abuses incurred during distribution and by the consumer.

Food and food ingredients are grouped according to the degree of risk inherent in the product. This classification is based on scientific and epidemiological data. The Pillsbury Company, which pioneered the

*The "Consumer Food Act of 1976" passed the Senate in March 1976, but the House failed to act on it before its adjournment. A bill similar to above is expected to be introduced in the current congress.

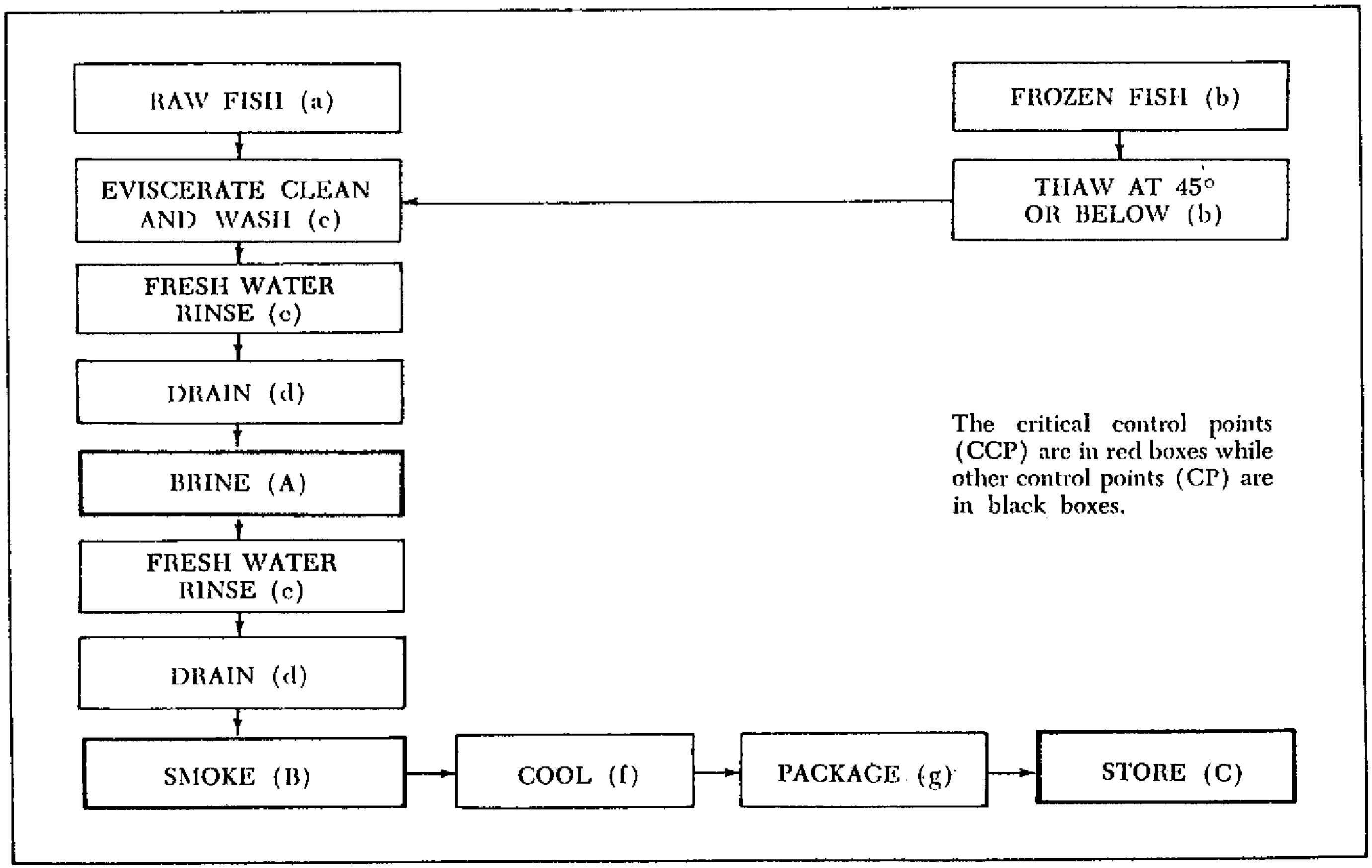


Figure 1. Fish smoking process

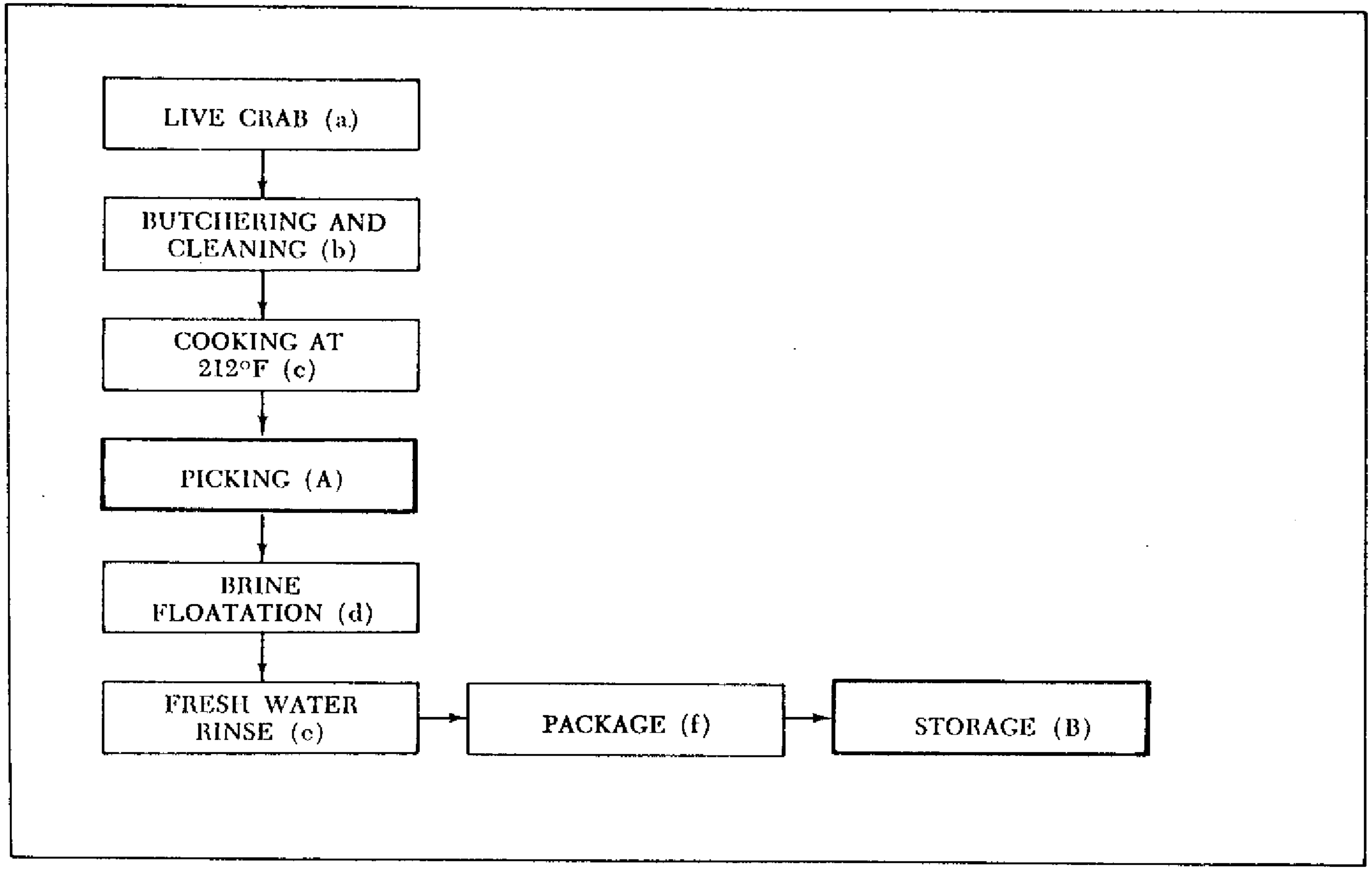


Figure 2. Cooked and picked crab processing

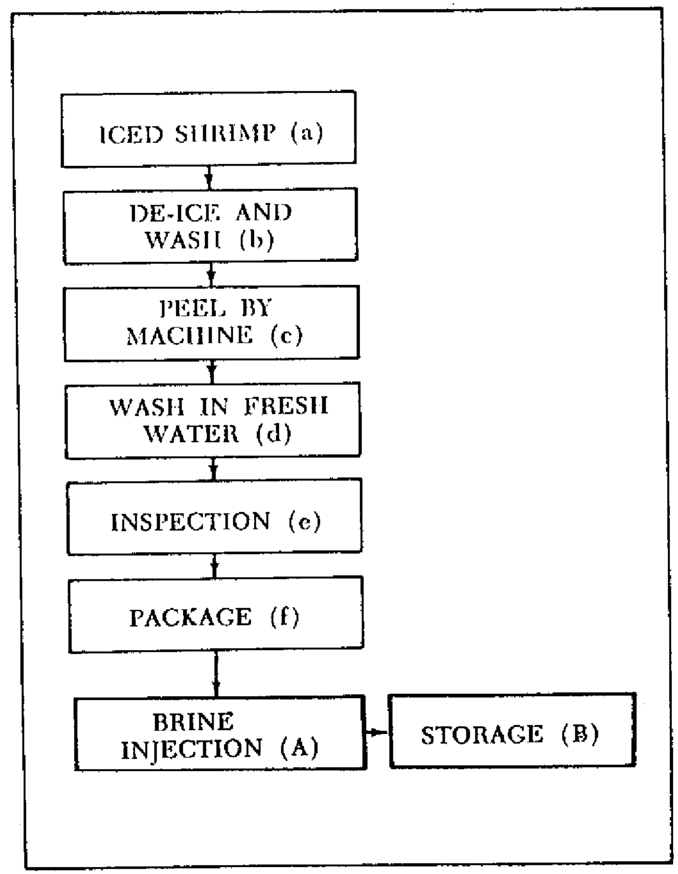


Figure 3. Cooked and peeled shrimp processing

development of HACCP, has grouped food ingredients into five hazard categories shown in Table 1. Unfortunately, no seafood ingredient is shown in this example.

Seafoods are basically protein foods that can be enjoyed by all age groups. Therefore, no seafood item would be classified as a category solely intended for infants or the elderly. Nevertheless, if a seafood processor is filling an institutional order that is for the nursing home or the hospital, he should be aware that this will increase the risk factor.

Most seafoods fall into hazard categories two or three of Table 1 where there is some degree of risk involvement. Table 2 lists seafood items in decreasing order of risk.

Thermally retorted products such as canned tuna and canned smoked oysters are excluded because they are already regulated under Good Manufacturing Practices Regulations, 21 CFR (Code of Federal Regulations, part 128 b) of the Federal Food, Drug, and Cosmetic Act (Federal Register 3d, 2398, Jan. 24, 1973), which make safety assurance procedures mandatory for these items.

Seafood products may be divided into raw seafoods, processed raw foods, processed foods, and formulated products. Examples of raw seafoods are oysters in the shell, live crabs, and live fin fish. Processed raw foods include gutted salmon, fish fillets, and shucked oysters. Processed foods include peeled shrimp and picked crab meats. Examples of a formulated product are the fish sticks and breaded shrimp.

Seafood products may be frozen, refrigerated, or stored at ambient temperature. While no fresh seafood should be stored at ambient temperature, some products may be exposed to ambient temperatures for varying legths of time during processing or packaging.

Seafoods may also be consumed after cooking or without further cooking.

Discounting environmental factors and the influence of harvest and onboard handling variables, which incidentally cannot be ignored when formulating an individual HACCP program, the rule of thumb is as follows:

the risk increases

1. with more handling

2. with higher storage temperature

3. and if the product is not to be cooked further by the consumer.

These considerations are incorporated into developing the hazard categories of seafoods shown in Table 2.

Foods and their ingredients may also be assigned a hazard classification that identifies the source of hazard (Table 3). Sources are broken into three areas and listed in order of the hazard inherent in a food or ingredient, the hazard that is introduced during processing, and the hazard that may be

TABLE 1. Food ingredient hazard categories in order of decreasing risk

CATEGORY	DESCRIPTION	EXAMPLE
1	Special foods intended for special populations	Infant and geriatric foods
2	a. Sensitive ingredients	Eggs, milk products
	b. Compound ingredients (30% or more sensitive)	Spray-dried shortening with more than 30% milk products
	c. Ingredients stored in a plant where sensitive ingredients are processed	Chicken fat premix stored in an egg plant
	d. New ingredients	
3	Compound ingredients (30% or less sensitive)	Spray-dried flavor with 24% non-fat dry milk
4	Ingredients of agricultural origin not previously shown to be a source of harmful microorganisms or chemicals	Wheat, starches
5	Ingredients historically free of pathogens or residues	Citric acid, sugar, salt

Adapted from Bauman, H. E., Food Technol. 28:30, 1974 (1).

TABLE 2. Seafood hazard categories in order of decreasing risk

CATEGORY	DESCRIPTION	EXAMPLE
1	Heat processed foods usually consumed without additional cooking	Crabmeat, peeled shrimp & smoked fish
2	Non-heat processed raw foods often consumed with additional cooking	Shucked molluskan shellfish eaten raw
3	Formulated foods usually consumed after cooking	Fish sticks & breaded shrimp
4	Non-heat processed raw foods usually consumed after cooking	Fresh or frozen fish fillets & cooked molluskan shellfish
5	Raw seafoods usually consumed after cooking	Live crustacean & molluskan shellfish

Table 3. Food product hazard class assignment

+	Hazard present (warning)
0	Hazard absent (minimum risk)

X X X

- First X ← Sensitive ingredient
- Second X ← Processing step
- Third X ← Consumer abuse potential

0	+	+	No sensitive ingredient
+	0	+	Heat processed product
0	0	0	No hazard present

Adapted from Peterson, A. C. and R. E. Gunderson. Food Technol. 28:37, 1974 (13).

Adapted from A.C. Peterson and R.E. Gunderson. Food Technol. 28:37,1974(13) introduced by consumer abuse. The + denotes presence and 0 denotes the absence of a hazard. Thus, each food can be assigned a hazard classification as shown in the third column of Table 3.

Some of the seafood products can be classified according to the hazard class assignment system as follows:

		sensitive ingredient	processing step	consumer abuse potential
1.	Smoked fish	+	+	+
2.	Cooked and peeled shrimp	+	+	+
3.	Fish stick	+	+	+
4.	Salmon in round	+	0	+
5	Oyster in shell	+	0	+
6.	Dried fish or jerky	+	+	0

In essence it is difficult to find any seafood product absolutely free of potential hazard as a raw material, or any that can be assumed to withstand the extreme abuse of the consumer. Even bone dry jerky containing sufficient salt could become hazardous if one imagines some extreme cases of abuse. Realistically, however, we have to determine the hazard on a relative rather than absolute scale. The International Commissiòn on Microbiological Specifications for Foods (ICMSF) has addressed this problem and published its seafood risk categories (16).

WHAT IS CRITICAL CONTROL POINT?

The critical control point (CCP) is defined as a point in the processing steps where the failure to effectively control it may create an UNACCEPTABLE HEALTH RISK. The time and temperature specified for smoking fish is an example of this and the control here should never fail. The CCP should be under CONSTANT CONTROL by humans or by machines and the performance of the control step must be monitored and documented.

All other processing steps that involve the control of microorganisms are the control points. Failure to control these points might not result in a definite health hazard but it would indicate a potential risk not to be ignored. Many steps in seafood processing fall into this category. These will be discussed individually in conjunction with the model HACCP for smoked fish, picked crab meat, and peeled shrimp.

MICROBIAL HAZARDS OF SEAFOODS

The microbial flora of seafood directly reflects the environment from which the seafood is extracted (14). Microorganisms come associated with the gill, intestine, and slime of the fish. The mud attached to bottom fish, crab, and shrimp is another source of microorganisms. If microbial buildup is allowed to occur in the fish hold it will further add to the microbial load of seafoods.

Since the microbial quality of seafood is so dependent on its environment, the sessile shellfish is especially vulnerable to pollutants introduced into its growing waters.

The following list of pathogenic microorganisms are characteristically associated with seafoods. Their control should be considered critical. The important characteristics of these microorganisms discussed below are summarized in Table 4.

1. CLOSTRIDIUM BOTULINUM

This anaerobic, spore-forming bacterium is found in soil, sediment, fish intestines, and water. Seven different types of C. botulinum designated from A to G are presently recognized. Types A, B and E are most commonly implicated in human botulism. Types A and B spores are heat resistant and require heating at or above 250°F for over 15 minutes to destroy them. Salt (NaCl) in excess of 10%, acidity below a pH of 4.6, or a temperature below 50°F will prevent the growth of types A and B.

Type E, C. botulinum is found abundantly off the Alaskan, Washington, Oregon, and Northern California coasts in sediment, intestines, and gills of fish and shellfish. It is less resistant to heat than types A and B, and could be destroyed by heating at or above 180°F for over 30 minutes. Type E cannot grow in seafoods that contain salt (NaCl) in excess of 6% or acidity below pH 4.8, but it can grow and produce toxin at temperatures as low as 38°F.

2. VIBRIO PARAHAEMOLYTICUS

This marine bacterium, closely related to the Vibrios that cause mortalities in salmonids reared in saltwater, occurs naturally in the marine environment. V. parahaemolyticus is heat sensitive and can be destroyed by heating at or above 140°F for 30 minutes. It does not grow at temperatures below 41°F or at a pH below 5.0, but it can tolerate salt (NaCl) in excess of 10%. It can, however, grow so rapidly under favorable conditions that a moment's relaxation could invite a disastrous consequence. A more detailed account of this bacterium is given in an earlier publication (8).

3. SALMONELLA INCLUDING S. TYPHI AND S. PARATYPHI

This group of organisms originates in diseased humans or other warm-blooded animals. They can be carried in apparently healthy individuals for varying time periods after recovery from the disease. Seafood can be contaminated directly or through polluted water.

TABLE 4. Growth and heat inactivation characteristics of food poisoning bacteria important in seafood processing

Bacteria	Growth Temperature (°F)			Lowest pH for Growth	Max. NaCl (%) Toler-ated	Heat Inact. (°F/min.)
	Minumum	Optimum	Maximum			
C. botulinum						
types A & B	50	95	118	4.6	10.0	> 250/15'
type E	38	86	113	4.8	6.0	> 180/30'
V. parahaemolyticus	41-46	95-97	108-111	5.0	9-10	> 140/30'
Salmonella	42	99	115	5.0	8.0	> 140/30'
S. aureus	44	95	117	4.8	17.0	> 145/30'
C. perfringens	59	113	122	5.0	5.0	> 212/100'

Data compiled from Liston, Matches and Baross, 1969, FAO, Tech. Conf., Halifax, Can. (12) and Hobbs & Christian, 1973, The microbial safety of food, Academic Press, London (6).

The organisms are heat sensitive and destroyed by heat at or above 140°F for over 30 minutes. It will not grow at temperatures below 42°F but will persist in either frozen or refrigerated seafoods almost indefinitely. Since small numbers of this organism could initiate the disease, a stringent control measure must be employed.

4. STAPHYLOCOCCUS AUREUS

This organism resides on human skin and mucous membranes. Seafoods are usually contaminated with this organism by human handlers through nose and throat discharges and infected skin lesions. The organism is extremely salt tolerant and can withstand 17% NaCl. Because of its salt tolerance this organism can be concentrated in the brine and contaminate the rest of seafood dipped in that brine (10). It cannot multiply at temperatures below 44°F but the toxin it produces is heat stable and cannot be destroyed even by boiling for an hour.

5. CLOSTRIDIUM PERFRINGENS

Although this organism is related to C. botulinum, it does not produce the potent neurotoxin that C. botulinum does. It is widely distributed in soil and its presence in seafoods itself does not constitute a hazard. The organism does not grow at temperatures below 59°F and is relatively easy to control by proper refrigeration. It also requires a massive growth in food prior to becoming toxic.

If a seafood dish is prepared from the contaminated seafood and left unrefrigerated, the spores of this organism, which cannot be destroyed by heating at 212°F for less than 100 minutes, then germinate, multiply, and produce toxin.

6. VIRAL HEPATITIS

This disease is usually caused by ingestion of the raw or undercooked shellfish harvested from polluted water. The hepatitus virus originates in diseased humans and not in domestic or wild animals. Although the virus is unnatural to the marine environment, it could survive in the sediment for years. Besides shellfish, contaminated water used for seafood processing could spread this virus.

7. OTHERS

There are other pathogens that can be transmitted by seafoods. Shigella causes dysentery and can be transmitted via seafoods if a person suffering from this disease contaminates seafoods. The erysipeloid skin infection has long been known as an occupational hazard as well, such as mercury and pesticides. Nematodes that cause eosinophilic enteritis in people through ingestion of pickled or smoked herring became known in Northern Europe. Ichthyosarcotoxins (puffer fish poison) that naturally occur in some fish, and scrombroid fish poisoning due to histamine released by microbial action, are also of concern. However, these are more isolated than the widely distributed and general hazards we have described earlier.

Table 5 lists the food pathogens and seafood items especially vulnerable to each pathogen. The table is constructed from the ICMSF recommended microbial sampling plan (16).

Table 6 lists the appropriate control measures for these pathogens as adapted from the United Nations Food and Agriculture Organization (FAO) booklet on Fish and Shellfish Hygiene (4). The tables are modified to accommodate specific needs of the Pacific Northwest seafood industry.

MODEL HACCP SYSTEM

HACCP is not confined to microbiological monitoring. The processing plant layout, construction, proper operations of processing machinery and refrigeration systems, conveyers, chlorination system, the brine strength and temperatures, etc., all need to be monitored and their proper operations recorded.

Sometimes, microbial testing may be needed to monitor the above. For example, the microbial load of the conveyer belt should be known before establishing a proper cleanup schedule. On the other hand, the microbial control measure may not require microbial testing. For example, proper control of cooking time and temperature during smoking is a control step to ensure safety from C. botulinum in a fish smoking operation, which eliminates the need to test for C. botulinum.

1. HACCP FOR HOT SMOKING FISH

Regulations that govern fish smoking are quite specific. Sanitation regulations for manufacture, processing, packing, or handling of human food that include specifications for plant and grounds, equipment and utensils, sanitary facilities and controls including water supply, sanitary operations and processing controls are spelled out in Part 128, Title 21 of the CODE OF FEDERAL REGULATIONS (Federal Register 34:6977, April 26, 1969). Sanitation recommendations in more readable form can be found in Fisheries Facts-8 published by J. P. Lane (7) and another by J. D. Clem and S. Garrett (2).

Regulations that specifically govern smoked and smoke-flavored fish are spelled out in Federal Register (35:17401, Nov. 13, 1970). The HACCP program described here will aid the processors to produce wholesome smoked fish, as well as to meet the requirements of this regulation.

Fish smoking is a single-product process. The component is fish, the product is smoked fish. Smoked fish is in the seafood hazard category I (Table 2) because of its potential hazard of C. botulinum. The major components of the critical control points are: 1) smoking temperatures and time; 2) the water phase salt (WPS)* content of the smoked fish; and 3) the storage temperature of the smoked fish.

---

*WPS (water phase salt) =

$$\frac{\%\ \text{salt in finished product}}{\%\ \text{salt} + \%\ \text{moisture in finished product}} \times 100$$

TABLE 5. Bacteria pathogens and the most sensitive seafoods

PATHOGEN	SENSITIVE SEAFOOD
C. botulinum	a. Smoked fish, including kippered and cold smoked, eaten uncooked
V. parahaemolyticus	a. Cooked picked crabmeat
	b. Frozen cooked shrimp, prawns, and lobster tails
	c. Fish eaten raw
	d. Frozen raw shrimp, prawns, and lobster tail
	e. Frozen raw breaded shrimp and prawns
Salmonella	a. Freshwater fish from warm waters
	b. Contaminated shellfish
Viral infections including hepatitis	a. Raw or undercooked shellfish from contaminated waters
S. aureus	a. Smoked fish eaten uncooked
	b. Frozen cooked shrimp, prawns, and lobster tails

Adapted from ICMSF sampling plans for fish and fishery products (16).

TABLE 6. Control measures against seafood pathogens

PATHOGEN	CONTROL MEASURES
C. botulinum	a. Correct processing
	b. Cooking just prior to eating food
V. parahaemolyticus	a. Sanitary handling and processing
	b. Adequate refrigeration or freezing
	c. Cooking just prior to eating food
Salmonella	a. Proper sewage disposal
	b. Sanitary handling and processing
	c. Adequate cooking
	d. Prohibit seafood harvesting from the polluted waters
Viral infections including hepatitis	a. Proper sewage disposal
	b. Adequate cooking
	c. Prohibit seafood harvesting from the polluted waters
S. aureus	a. Sanitary handling and processing
	b. Prohibit person suffering from cold or open infected wound from handling food
	c. Frequent brine change or adapt spray or injection system
C. perfringens	a. Rapid cooling of food after cooking

Adapted from FAO, Fish and Shellfish Hygiene (4).

Two alternate smoking processes are permitted. Fish smoked at or above 180°F for not less than 30 minutes shall contain water phase salt level in excess of 3.5% and must be stored below 38°F. Or, fish smoked at or above 150°F for not less than 30 minutes shall contain water phase salt level in excess of 5.0% and must be stored below 38°F.

The smoking process diagram is shown in Fig. 1. The control measures for 3 CCPs (brining, smoking, and finished product storage) are described below:

CRITICAL CONTROL POINTS

A. BRINE

- Prepare brine in sufficient strength so that the brine level of fish will reach the desired level within 12 hours at 38°F. More specifically, measure and record the amount of salt added, the volume of water, the salometer reading and the temperature of the brine.

- A guide on brine preparation is available from the Oregon State University Sea Grant Office (5).

- The relationship between salt concentration and the brine concentration of smoked fish needs to be experimentally determined.

B. SMOKING

- Regulations specify that the internal temperature of fish and the oven temperature during smoking be continually monitored and recorded.

- The smoking process of not lower than 180°F for not less than 30 minutes is based on the coldest part of the fish in the oven. At least a sample from each oven load should be analyzed for water phase salt (WPS) level and recorded.

C. STORAGE

- The smoked fish should be kept below 38°F and the storage temperature should be continually monitored.

OTHER CONTROL POINTS

a. RAW FISH

- Examine for freshness and wholesomeness.

- All eviscerated fish or fish in the round not being used immediately should be kept below 38°F.

b. FROZEN FISH

- Check for wholesomeness.

- Frozen fish should be kept frozen until used. Defrost at or below 45°F.

c. EVISCERATION, CLEANING AND FRESHWATER RINSE

- The entire gut content must be cleanly removed and the fish thoroughly rinsed with approved fresh water.

d. DRAIN

- Excess water should be drained at or below 45°F for no longer than 2 hours.

e. FRESHWATER RINSE AFTER BRINING

- Rinse to prevent salt crystallization on the skin of smoked fish and drain to facilitate proper drying in oven.

f. COOLING SMOKED FISH

- The smoked fish should be cooled to 50°F or below within 3 hours and subsequently cooled to 38°F or below within 12 hours after smoking.

g. PACKAGING

- Package should be labeled with plant name and location, the date of packaging and the oven load. Record should be kept to provide positive identification.

See Lane (7) and Clem and Garrett (2) for plant and equipment cleaning procedures.

2. HACCP FOR DUNGENESS CRAB PROCESSING (9)

Cooked and picked Dungeness crabmeat belongs to the seafood hazard category 1 (Table 2). Crabs are extracted from an environment known to harbor _C. botulinum_ spores and the marine environment has to be assumed to contain _V. parahaemolyticus_. Crab processing requires excessive human handling, which increases the opportunity for contamination of the finished product with bacteria of the raw crab and those from the human handlers (_S. aureus_). In addition the picked crabmeat is usually consumed without further cooking.

When landed, crab is alive. The processor starts out with a raw product of microbiologically ideal quality. The flesh of the living animal is theoretically sterile. The processor, therefore, has full control over the microbial quality of the crabmeat that bears his label.

The key to proper crab processing is: 1) to avoid contamination of the picked crabmeat from the raw crabs; 2) to minimize contamination from the processing environment; and 3) to refrigerate promptly the picked crabmeat at temperatures below 38°F.

The crab processing diagram is shown in Fig. 2 and the control measures for CCP and CP are shown below:

CRITICAL CONTROL POINTS

A. PICKING

- Picking tables should be cleaned and sanitized with 50 ppm chlorine at each shift change.

- Pickers should wear clean clothes, apron, head cover, and gloves. Apron should be cleaned and sanitized with 50 ppm chlorine at each shift change.

- Cooked and cooled crab should be picked within an hour of cooking. Never pile up cooked crabs on picking table that cannot be picked in an hour.

- No picker should be allowed to handle raw crabs.

B. STORAGE

- Packaged crabmeat shall be stored at temperatures below 38°F at all times or quick-frozen.

OTHER CONTROL POINTS

a. LIVE CRAB

- To prevent active crabs from damaging each other, place the live crabs at 45°F for 12 hours before handling.

b. BUTCHERING AND CLEANING

- Check the condition and cleanliness of brush. Brush should be washed and sanitized at the end of each shift or every 2 hours.

- Remove carapace cleanly.

- Cut in halves.

- Brush off intestinal content as completely as possible.

- Wash and rinse the halves in running water or by spray.

c. COOKING

- Check water temperature at 2-hour intervals for the continuous cooker (before each load is added for batch system).

- Cook at 212°F for 15 minutes.

- Air-cool the cooked crab for an hour in an isolated location removed from raw crabs and heavy traffic.

- NEVER HANDLE COOKED CRAB WITH UTENSILS AND BASKETS USED FOR HANDLING RAW CRABS.

- Cooked crabs should not be handled by those who handle raw crabs.

- Do not cook more crabs than the pickers can handle in an hour after cooking.

d. BRINE

- Fresh and chilled brine should be prepared at each break or every 2 hours of operation.

e. FRESH WATER RINSE

- Brine should be rinsed off in fresh potable water spray within minutes of brining.

f. PACKAGING

- The packaging table should be cleaned and sanitized with 50 ppm chlorine at each break.

- Picked crab should be packaged within 10 minutes.

- Packaged crab shall be chilled immediately to temperatures below 38°F.

- Packaging should be done so that the package cannot be mishandled. Each package should display "store below 38°F" warning.

See Lane (7) and Clem and Garrett (2) for plant and equipment cleaning procedures.

3. HACCP FOR PACIFIC SHRIMP PROCESSING (11)

The cooked and peeled shrimp belongs to seafood hazard category 1 (Table 2). Pacific shrimp comes from the same environment as the Dungeness crab. Therefore, C. botulinum hazard cannot be discounted. Shrimp, in contrast to Dungeness crab, is mostly harvested during the warmer summer months and this increases the V. parahaemolyticus risk. The mechanical peeler has largely replaced hand-picking and reduced the chance for human contamination to a degree. However, it has increased the chance for equipment-related contaminations.

The condition of shrimp received at the plant can vary depending on the age of the shrimp out of water, onboard handling practices and the degree and care in icing.

Control of raw material and the proper care and sanitization of the processing equipment is even more critical for shrimp than for the crab due to seasonal and handling factors. The key to sound shrimp processing is: 1) to avoid contamination of the picked shrimp from the raw shrimp; 2) to eliminate the microbial buildup in and on the processing machinery; and 3) prompt refrigeration of the peeled shrimp to below 38°F. Quick-freezing is preferable to refrigeration.

Shrimp peeling steps and the control measures for CCP and CP are shown in the diagram to the left and discussed in the following explanations.

CRITICAL CONTROL POINTS

A. BRINE INJECTION

- Brine is used to flavor the shrimp. It can best be done by injecting brine in the finished product. The brine tank quickly accumulates bacteria so the salt-tolerant and rapid-growing V. parahaemolyticus presents a special threat for shrimp dipped in old brine at ambient temperatures.

B. STORAGE

- Chill the packaged shrimp to below 38°F by 10 minutes after packaging.

- Never expose the peeled shrimp to above 38°F temperature. Quick freezing is preferable to refrigeration.

OTHER CONTROL POINTS

a. ICED SHRIMP

- The shrimp should have been well iced and the temperature of shrimp at any point should not exceed 40°F.

- De-ice the shrimp. Do not de-ice and re-ice.

b. DE-ICE AND WASH

- Iced shrimp should be de-iced just prior to peeling by immersion in potable tap water. Wash the shrimp as thoroughly as possible before cooking.

c. MACHINE PEELING

- Peelers and transport ducts should be cleaned and sanitized with 50 ppm chlorine at each break or every 2 hours of operation.

- Peelers and ducts should be inspected every 10 minutes during operation to ensure no peeled shrimp accumulates on the line.

d. WASHING

- Wash the peeled shrimp in a sufficient quantity of fresh water.

e. INSPECTION

- The inspectors should wear clean clothes, aprons, and head cover. Inspection should be done along the conveyer belt with the running water. If a table is used, the table top should be cleaned and sanitized with 50 ppm chlorine at each break, or every 2 hours of operation.

f. PACKAGING

- The packaging table should be cleaned and sanitized with 50 ppm chlorine at each break, or every 2 hours of operation.

- The peeled shrimp should be packaged within 10 minutes of peeling.

See Lane (7) and Clem and Garrett (2) for plant and equipment cleaning procedures.

LITERATURE QUOTED

1. Bauman, H. E. 1974. The HACCP concept and microbiological hazard categories. Food Technol. 28:30-34.

2. Clem, J. D. and S. Garrett. 1968. Sanitation Guidelines for the Breaded-shrimp Industry. U.S. Dept. of Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries Circular 308.

3. Craig, J. M., S. Hayes, and K. S. Pilcher. 1968. Incidence of Clostridium botulinum Type E in salmon and other marine fish in the Pacific Northwest. Appl. Microbiol. 16:553-557.

4. FAO. 1974. Fish and Shellfish Hygiene. Food and Agriculture Organization of the United Nations, Rome.

5. Hilderbrand, K. S. 1973. Preparation of salt brines for the fishing industry. Oregon State University, S.G. No. 22.

6. Hobbs, B. C. and J. H. B. Christian. 1973. The Microbiological Safety of Foods. Academic Press, London.

7. Lane, J. P. 1974. Fisheries Facts - 8 Sanitation Recommendations for Fresh and Frozen Fish Plants. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington, D.C.

8. Lee, J. S. 1973. What seafood processors should know about Vibrio parahaemolyticus. J. Milk and Food Technol. 36:405-408.

9. Lee, J. S. and D. K. Pfeifer. 1975. Microbiological characteristics of Dungeness crab (Cancer magister). Appl. Microbiol. 30:72-78.

10. Lee, J. S. and D. K. Pfeifer. 1973. Aerobic microbial flora of smoked salmon. J. Milk and Food Techol. 36:143-145.

11. Lee, J. S. and D. K. Pfeifer. 1977. Microbiological characteristics of Pacific shrimp (Pandalus jordani). Appl. and Environ. Microbiol. 33:853-859.

12. Liston, J., J. R. Matches, and J. Baross. 1969. Survival and growth of pathogenic bacteria in seafoods. FAO, Technical Conference on Fish Inspection and Quality Control. Halifax, Canada, May 28.

13. Peterson, A. C. and R. E. Gunnerson. 1974. Microbiological critical control points in frozen foods. Food Technol. 28:37-44.

14. Shewarn, J. M. 1971. The microbiology of fish and fishery products - A progress report. J. Appl. Bact. 34:299-315.

15. Smith, C. A. and J. D. Smith. 1975. Quality assurance system meets FDA regulations. Food Technol. 29:64-68.

16. The International Commission on Microbiological Specifications for Foods (ICMSF). 1974. Microorganisms in Foods. 2. Sampling for microbiological analysis; principles and specific applications. Univ. of Toronto Press, Toronto, Canada.

Preparation of salt brines for the fishing industry

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

The use of salt brine for refrigerants and fish curing is common in the seafood industry. It is important to understand a few basic principles in order to make and use brines properly. This bulletin attempts to point out some basic concepts and principles and provides some charts which are useful to anyone who uses brines frequently.

Be sure to mix thoroughly!

PROPERTIES OF SALT BRINE

When added to water, salt lowers the freezing point of water by a known and predictable degree, making it useful as a secondary refrigerant (freezing solution). Figure 1 shows the relationship of a brine's freezing point to its concentration of salt. Note that the lowest freezing point obtainable in a salt-water mixture is about –6°F at 23.3% salt. This is called the eutectic point and any concentration of salt above or below this point will result in a solution with a freezing point higher than –6°F. Table 1 gives specific data on freezing point, concentration, and relationships useful in preparing salt brines.

PREPARING SALT BRINES

After selecting the desired brine concentration for any desired purpose, use Table 1 to determine how much water and salt are needed. Column 2 in Table 1 gives freezing points while Column 3 is computed in percent salt by weight. Salometer degree (°SAL) is a useful way of describing and measuring brines and is explained later under "MEASURING SALT SOLUTIONS."

An easy way to prepare a brine solution of any given strength is to refer to Column 4 in Table 1 and then add the proper amount of salt per gallon of water. Salt will increase the volume of the solution, however. Thus, if an exact quantity of brine is needed, use Columns 5 and 6 to determine the weight of salt and

Oregon State University
Extension Marine Advisory Program
A Land Grant / Sea Grant Cooperative
SG 22 Reprinted January 1979

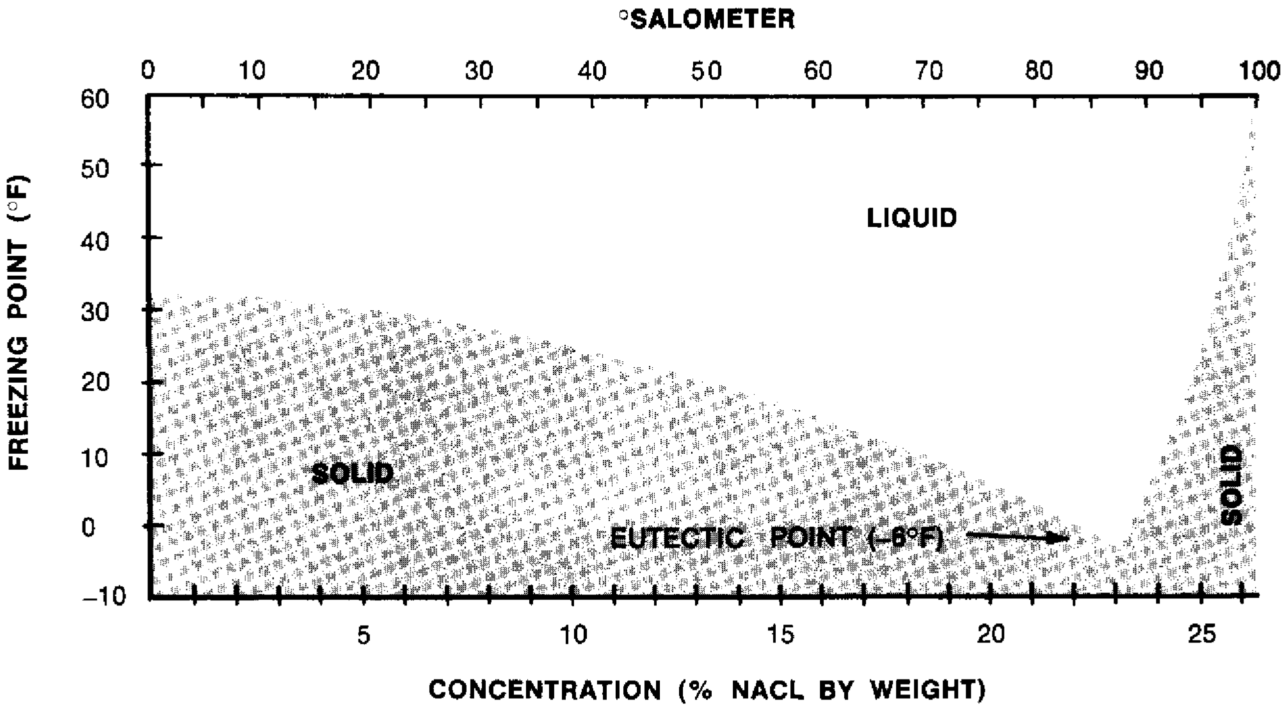


Figure 1. Freezing point of salt brine mixtures.

volume of water needed to make a gallon of brine at the desired concentration.

EXAMPLES

About twenty (20) gallons of brine are needed at 15.8% salt (60°SAL) to brine salmon for smoking. If it isn't necessary to have exactly 20 gallons, simply find 60°SAL (15.8% salt) in Column 1 and note that 1.568 pounds salt/gallon of water (Column 4) is needed. Put 20 gallons of water in a tank and dissolve 31 1/3 pounds of salt (20 gallons x 1.568 pounds salt/gallons water).

The result will be a solution which has exactly 15.8% salt by weight (60° SAL). It will be found, however, that the resulting solution is more than 20 gallons; it will be more like 21 gallons. This increase in volume is usually insignificant; if precision is needed and an exact quantity desired, use the data in Columns 5 and 6.

For example, if *exactly* 500 gallons of 88° SAL brine (–5.8F freezing point) is needed for a brine freezing tank on board a vessel, Column 5 in Table 1 will show that each gallon of 88° SAL brine needs 2.279 pounds of salt and .904 gallons of water (Column 5). Adding 1140 pounds of salt (500 gallons x 2.279 pounds salt/gallon brine) to 452 gallons of water (500 gallons x .904 gallons water/gallon brine) would give exactly 500 gallons of brine at 88° SAL (23.3%) with a freezing point of –5.8°F.

MEASURING SALT SOLUTIONS

Although careful attention to proportions will give good control of salt concentration in brine, the best way to be sure is to measure it. Sometimes, after a brine has been used and possibly diluted, it is useful to be able to measure its concentration.

Figure 2 shows the basic tools used to measure salt solutions. These may be purchased at most scientific supply houses for about $15. A salometer is a device that measures brine density saturation (26.4% salt at 60°F) on a convenient scale of 0 to 100. Each °SAL would therefore represent about .26% salt by weight as fully saturated brine contains about 26.4% salt.

To read a salometer, place it in a vessel, like the graduate cylinder shown in Figure 2, and allow it to float. The depth that it floats measures the brine concentration. Readings are taken by noting the point on the scale where the salometer emerges from the surface of the brine solution. These readings in °SAL can then be used with Table 1 to obtain data such as freezing point and percent salt by weight.

The thermometer is used to determine the temperature of the brine as it is being tested with the salometer. If the temperature varies more than a few degrees from 60°F, then a correction factor should be used for accurate work.

A rule of thumb states that for every 10°F the brine is above 60°F, one degree salometer should be added to the observed reading before using Table 1, which is standardized for 60°F. For each 10°F the brine is below 60°F, one degree salometer should be subtracted from

TABLE 1: SODIUM CHLORIDE BRINE TABLES FOR BRINE AT 60° F

(1) Salometer Degrees	(2) Freezing Point Deg. F.[a]	(3) Percent Sodium Chloride By Wt.	(4) Pounds Salt Per Gallon Of Water	(5) Pounds Per Gallon of Brine		(6) Gallon Water Per Gal. Of Brine	(7) Specific Gravity	(8) Salometer Degrees
				NaCl	Water			
0	+32.0	.000	.000	.000	8.328	1.000	1.000	0
2	+31.5	.528	.044	.044	8.318	.999	1.004	2
4	+31.1	1.056	.089	.089	8.297	.996	1.007	4
6	+30.5	1.586	.134	.133	8.287	.995	1.011	6
8	+30.0	2.112	.179	.178	8.275	.993	1.015	8
10	+29.3	2.640	.226	.224	8.262	.992	1.019	10
12	+28.8	3.167	.273	.270	8.250	.990	1.023	12
*14	+28.2	3.695	.320	.316	8.229	.988	1.026	14*
16	+27.6	4.223	.367	.362	8.216	.987	1.030	16
18	+27.0	4.751	.415	.409	8.202	.985	1.034	18
20	+26.4	5.279	.464	.456	8.188	.983	1.038	20
22	+25.7	5.807	.512	.503	8.175	.982	1.042	22
24	+25.1	6.335	.563	.552	8.159	.980	1.046	24
26	+24.4	6.863	.614	.600	8.144	.978	1.050	26
28	+23.7	7.391	.665	.649	8.129	.976	1.054	28
30	+23.0	7.919	.716	.698	8.113	.974	1.058	30
32	+22.3	8.446	.768	.747	8.097	.972	1.062	32
34	+21.6	8.974	.821	.797	8.081	.970	1.066	34
36	+20.9	9.502	.875	.847	8.064	.968	1.070	36
38	+20.2	10.030	.928	.897	8.047	.966	1.074	38
40	+19.4	10.558	.983	.948	8.030	.964	1.078	40
42	+18.7	11.086	1.039	.999	8.012	.962	1.082	42
44	+17.9	11.614	1.094	1.050	7.994	.960	1.086	44
46	+17.1	12.142	1.151	1.102	7.976	.958	1.090	46
48	+16.2	12.670	1.208	1.154	7.957	.955	1.094	48
50	+15.4	13.198	1.266	1.207	7.937	.953	1.098	50
52	+14.5	13.725	1.325	1.260	7.918	.951	1.102	52
54	+13.7	14.253	1.385	1.313	7.898	.948	1.106	54
56	+12.8	14.781	1.444	1.366	7.878	.946	1.110	56
58	+11.8	15.309	1.505	1.420	7.858	.943	1.114	58
60	+10.9	15.837	1.568	1.475	7.836	.941	1.118	60
62	+9.9	16.365	1.629	1.529	7.815	.938	1.122	62
64	+8.9	16.893	1.692	1.584	7.794	.936	1.126	64
66	+7.9	17.421	1.756	1.639	7.772	.933	1.130	66
68	+6.8	17.949	1.822	1.697	7.755	.931	1.135	68
70	+5.7	18.477	1.888	1.753	7.733	.929	1.139	70
72	+4.6	19.004	1.954	1.809	7.710	.926	1.143	72
74	+3.4	19.532	2.022	1.866	7.686	.923	1.147	74
76	+2.2	20.060	2.091	1.925	7.669	.921	1.152	76
78	+1.0	20.588	2.159	1.982	7.645	.918	1.156	78
80	-.4	21.116	2.229	2.040	7.620	.915	1.160	80
82	-1.6	21.644	2.300	2.098	7.596	.912	1.164	82
84	-3.0	22.172	2.372	2.158	7.577	.910	1.169	84
86	-4.4	22.700	2.446	2.218	7.551	.907	1.173	86
88	-5.8	23.338	2.520	2.279	7.531	.904	1.178	88
88.3[b]	-6.0[b]	23.310	2.531	2.288	7.528	.904	1.179	88.3[b]
90	-1.1	23.755	2.594	2.338	7.506	.901	1.182	90
92	+4.8	24.283	2.670	2.398	7.479	.898	1.186	92
94	+11.1	24.811	2.745	2.459	7.460	.896	1.191	94
95	+14.4	25.075	2.787	2.491	7.444	.894	1.193	95
96	+18.0	25.339	2.827	2.522	7.430	.892	1.195	96
97	+21.6	25.603	2.865	2.552	7.417	.891	1.197	97
98	+25.5	25.867	2.906	2.585	7.409	.890	1.200	98
99	+29.8	26.131	2.947	2.616	7.394	.888	1.202	99
99.6	+32.3	26.285	2.970	2.634	7.386	.887	1.203	99.6
100[c]	+60.0[c]	26.395[c]	2.987	2.647	7.380	.886	1.204	100[c]

The above table applies to brine tested at 60°F. For other brine temperatures the observed salometer readings must be converted before using them in the table. For practical purposes, add one degree salometer for each ten degrees above 60°F and deduct one degree salometer for each ten degrees below 60°F.

* Approximate salinity range for sea water.

[a] Temperature at which freezing begins. Ice forms, brine concentrates and freezing point lowers to eutectic.

[b] Eutectic point. For brines stronger than eutectic, the temperatures shown are the saturation temperatures for sodium chloride dihydrate. Brines stronger than eutectic deposit excess sodium chloride as dihydrate when cooled, and freeze at eutectic.

[c] Saturated brine at 60°F.

the observed salometer reading. For instance, if a salometer reading was observed to be 80°SAL in a brine which was 40°F, the corrected salometer reading would be 78° SAL (subtract 1°SAL for each 10°F below 60°F).

IMPORTANT POINTS TO REMEMBER

Dissolving salt: Finely ground salt such as canner's salt or table salt dissolves much faster than coarsely ground salt (rock salt). It is essential that all salt added is dissolved if a solution is to have the proper strength.

Salt dissolves much faster in hot water than in cold water. It may take days for salt to dissolve in a brine freezer at 0°F.

Salt dissolves much slower as the salt concentration increases. The last bit of salt in a 90°SAL solution may take a long time to dissolve.

Agitation greatly increases the rate at which salt dissolves. A layer of salt on the bottom of a tank may take days to dissolve if left undisturbed.

In summary, try to dissolve salt in a warm, well agitated container or tank and make sure it is all dissolved before using it or measuring its concentration.

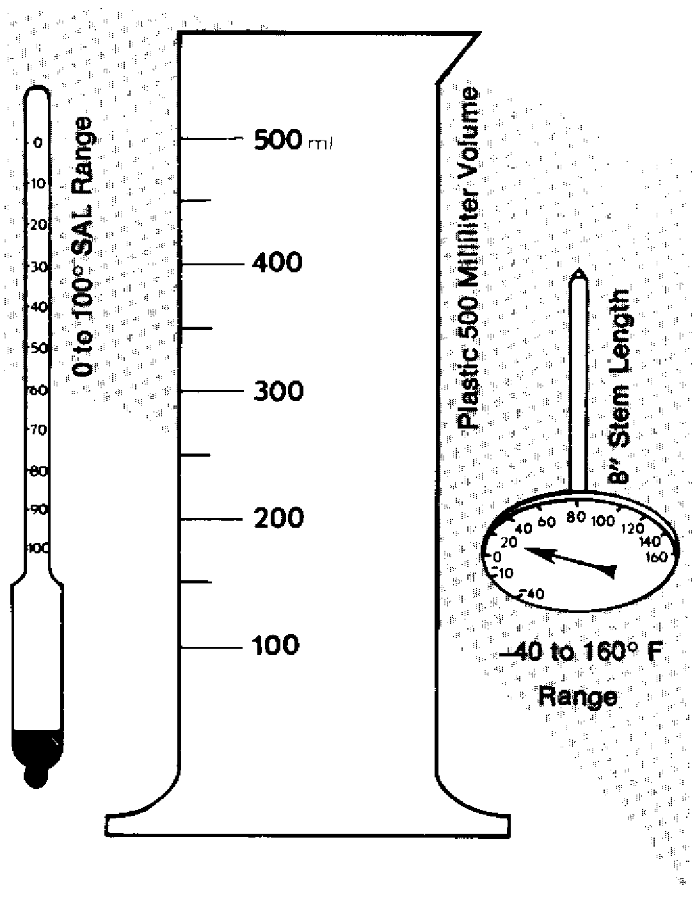


Figure 2. Equipment for measuring salt concentration in brine. Left, salometer; center, graduate cylinder; right, dial thermometer.

Brine refrigeration: Always make up a brine to be used for refrigeration so that its freezing point is well below the temperature you want to maintain. If you don't, it may freeze to the refrigeration coils or heat exchanger surfaces as they usually run 5 to 10°F colder than the operating temperature of the brine.

Using sea water for brines: Sea water may contain as much as 3 to 3.5% salt (12 to 14°SAL), which is equivalent to about .3 pounds of salt per gallon. Take this into consideration when making brine from sea water and deduct it from the amount of salt needed to make up a brine.

Adding salt to existing brines: If you want to increase the concentration of salt in a brine (decrease its freezing point), be sure to measure its strength and estimate its volume first. Then use the data in Table 1, Columns 5 and 6, to calculate how much more salt needs to be added.

Appendix.—*Metric/customary conversion factors (approximate) for the units cited in this bulletin*

To convert	to	multiply by
liters	gallons	0.26
gallons	liters	3.78
kilograms	pounds	2.20
pounds	kilograms	0.45
grams per liter	pounds per gallon	0.0083
pounds per gallon	grams per liter	119.8
degrees Celsius (formerly Centigrade)	degrees Fahrenheit	9/5, then add 32
degrees Fahrenheit	degrees Celsius	5/9, after subtracting 32

1-79/3M

OREGON STATE UNIVERSITY
EXTENSION SERVICE

Extension Service, Oregon State University, Corvallis, Henry A. Wadsworth, director. This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties. Extension's Marine Advisory Program is supported in part by the Sea Grant Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

Extension invites participation in its activities and offers them equally to all people, without discrimination.

QUICK DETERMINATION OF SALT CONTENT OF SEAFOODS

OSU Seafoods Laboratory
phone 325-4531
Marine Advisory Program
phone 325-6138
250 - 36th Street
Astoria, Oregon 97103

It is important to know the salt content of seafoods for many reasons. For instance, proper salt levels in smoked fish is critical for safe extended shelf life. The salt content of picked crab and shrimp meat is important for good flavor.

Unfortunately, the Official Analytical Chemists Association (AOAC) procedure for salt analysis is difficult to do in many situations. A high skill level is needed to set up and perform this test.

A much simpler (but less accurate) test is available in the form of a "chloride titrator." The Seafoods Lab has tested this method and found that it compares well with salt values found by the AOAC method in smoked fish and crab meat. The test is simple, easy to do, and generally accurate enough for salt control purposes.

Equipment & Materials		Approximate Cost 1980
1. Chloride titrators No. 1176 .03 to 1 percent range available through Ames Co.		$16.00
2. Food blender "Oster" type with small wide mouth "fruit" type jars. Available through drug and discount stores		$57.00
3. "Triple beam" gram scale Ohavs 760 or similar V.W. & R. 1969 cat. No. 12341-010 S.P. 1969 cat. No. B1770		$55.00
4. 250 ml beakers (Pyrex) Griffin type - Pyrex or kimax V.W. & R. 1969 cat. No. 13912-207 or 13910-201 S.P. 1969 cat. No. B2650-250 or B2652-250	5 @	$ 1.00
5. 250 ml graduate cylinder Nalgene TPX plastic or similar V.W. & R. cat. No. 247680-108 S.P. 1969 cat. No. C9075-250		$ 6.00

Equipment & Materials	Approximate Cost 1980
6. Distilled water	
7. Filter paper (500 sheets) Whatman No. 11 cms or similar V.W. & R. 1969 cat. No. 28450-105 S.P. 1969 cat. No. B7895-250	$ 5.00

Equipment Sources

The following companies are among many who supply the equipment and materials needed for this test. The use of their names here is for example only and does not imply any endorsement.

Ames Company
1127 Myrtle Street
Elkhart, Indiana 46514

Scientific Supplies Company
Div. of Van Waters & Rodgers
3950 N.W. Yeon Avenue
Portland, Oregon 97210

Scientific Products Company
14850 N.E. 36th Street
Overlake Industrial Park
Redmond, Washington 98052

Procedure

A. SAMPLE PREPARATION

1. Place small dry blender jar (Mason type) on scale and adjust tare weight.

2. Add representative sample of at least 50 grams.

3. Chop with blender.

4. Remove 10 grams for moisture analysis--place lid on the jar and store for salt analysis.

B. MOISTURE ANALYSIS

1. Place 10 grams sample on drying dish.

2. Dry to constant weight in a drying oven or use a moisture analyzer.

3. Divide grams of weight lost by starting weight (10 grams) to get starting percent moisture.

$$\% H_2O = \frac{\text{weight loss}}{\% \text{ starting wt. (10 grams)}}$$

C. SALT ANALYSIS

1. Remove enough sample from jar to leave 10 to 20 grams sample. Add hot distilled water to jar to bring total weight to 10 times the sample weight (actual size of sample will be limited by jar size). Hot tap water will work if it is free of salt as determined by salt titrator analysis.

2. Blend one minute.

3. Place salt titrator in sample (enclosed in filter paper) as prescribed in titrator instructions and read accordingly.

4. Multiply percent salt in sample by 105 times to get actual salt content of sample before dilution with water.

D. CALCULATION OF WATER PHASE SALT CONTENT

$$WPS = \frac{\% \text{ salt} \times 100}{\% \text{ moisture} + \% \text{ salt}}$$

Notes

a. "Oster" food blenders with small wide mouth "fruit jar" type jars work best as they do not require transfer of blended sample and insure good mixing.

b. Any clean containers will suffice for determination, although glass is easiest to clean.

c. Clean paper towels will suffice instead of filter paper if a "blank" sample is run to insure that the towels do not contain salt.

d. Use of "squirt bottle" makes addition of the last few grams of water easy and insures accuracy.

e. Hot tap water can be used instead of distilled water as long as a "blank" control is run at the same time to insure that the water is salt free.

CHART I

3.5% WATER PHASE SALT (WPS)

	Raw Brined Fish Salt Content					
	Moisture Content of Raw Brined Fish					
Final Moisture	55	60	65	70	75	80
40%	1.09	.96	.85	.72	.60	.48
45%	1.33	1.18	1.03	.89	.74	.59
50%	1.63	1.44	1.27	1.09	.91	.72
55%	1.99	1.76	1.55	1.33	1.11	.88
60%		2.18	1.91	1.61	1.36	1.09
65%			2.36	2.03	1.69	1.35
70%				2.54	2.12	1.69
75%					2.72	2.18
80%						2.90

CHART II

5.0% WATER PHASE SALT (WPS)

	Raw Brined Fish Salt Content					
	Moisture Content of Raw Brined Fish					
Final Moisture	55	60	65	70	75	80
40%	1.57	1.40	1.2	1.05	.87	.7
45%	1.94	1.71	1.5	1.3	1.1	.86
50%	2.36	2.10	1.9	1.6	1.3	1.1
55%	2.89	2.55	2.3	1.9	1.6	1.3
60%		3.16	2.8	2.4	2.0	1.6
65%			3.4	2.9	2.4	2.0
70%				3.7	3.1	2.5
75%					4.0	3.2
80%						4.2

ESTIMATING SALT AND MOISTURE CONTENT NEEDED IN SMOKED FISH TO MEET GOOD MANUFACTURING PRACTICES

INTRODUCTION

Food and Drug Administration regulations* on hot smoked fish require certain minimum levels of salt and moisture. Expressed as water phase salt (WPS), these minimums are a ratio of salt to moisture. Mathematically, WPS is expressed simply as:

$$\frac{\%\ \text{salt}}{\%\ \text{moisture} + \%\ \text{salt}}$$

Depending on the heat treatment given a hot smoked fish product, the minumum WPS is 3.5 percent or 5.0 percent.

Because the amount of total salt needed to meet the minimum standards depends on the final moisture content of the product, it is hard to estimate in advance how much salt is required in the raw brined fish before it is smoked. This bulletin provides some charts which will be useful in estimating the required raw brined fish salt concentration. The same charts will also help to estimate the amount of dehydration needed to bring WPS concentration up to the standard if insufficient salt was present after the smoking cycle was begun.

ESTIMATING SALT REQUIRED IN RAW BRINED FISH

The amount of salt needed in raw brined fish to meet the minimum water phase salt (WPS) in the finished smoked product can be estimated from Figures 1 and 2. To use these charts it is necessary to estimate the moisture content of the raw fish. This can be done with good results after a few moisture analyses have been performed on representative lots of fish.

Once the raw fish moisture is estimated, the salt concentration needed in the fish after brining can be read directly off the charts for any finished product moisture content desired. Because there are two minimum WPS concentrations possible, depending on the desired time and temperature of the cooking cycle, two figures are included in this bulletin--one for 3.5 percent WPS and another for 5.0 percent WPS.

Example A: It has been determined that a lot of raw salmon contains an average of 75 percent moisture. A final moisture concent of 60 percent is considered desirable with 3.5 percent WPS.

---

*As of April, 1981, the FDA Regulations for Hot Process Smoked Fish are not in effect (in regards to salt level and time/temperature).

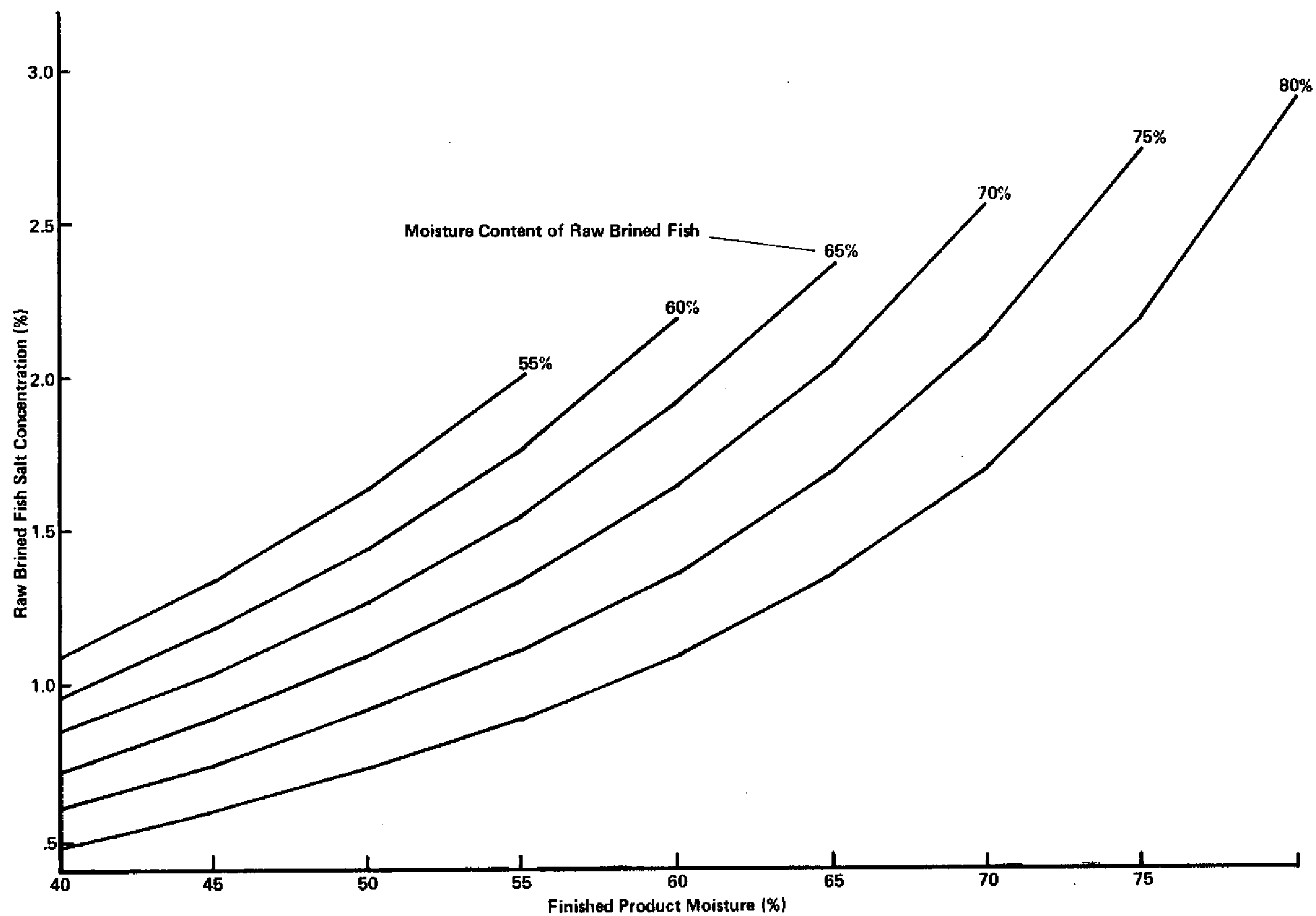


Figure 1. 3.5% water phase salt smoked fish.

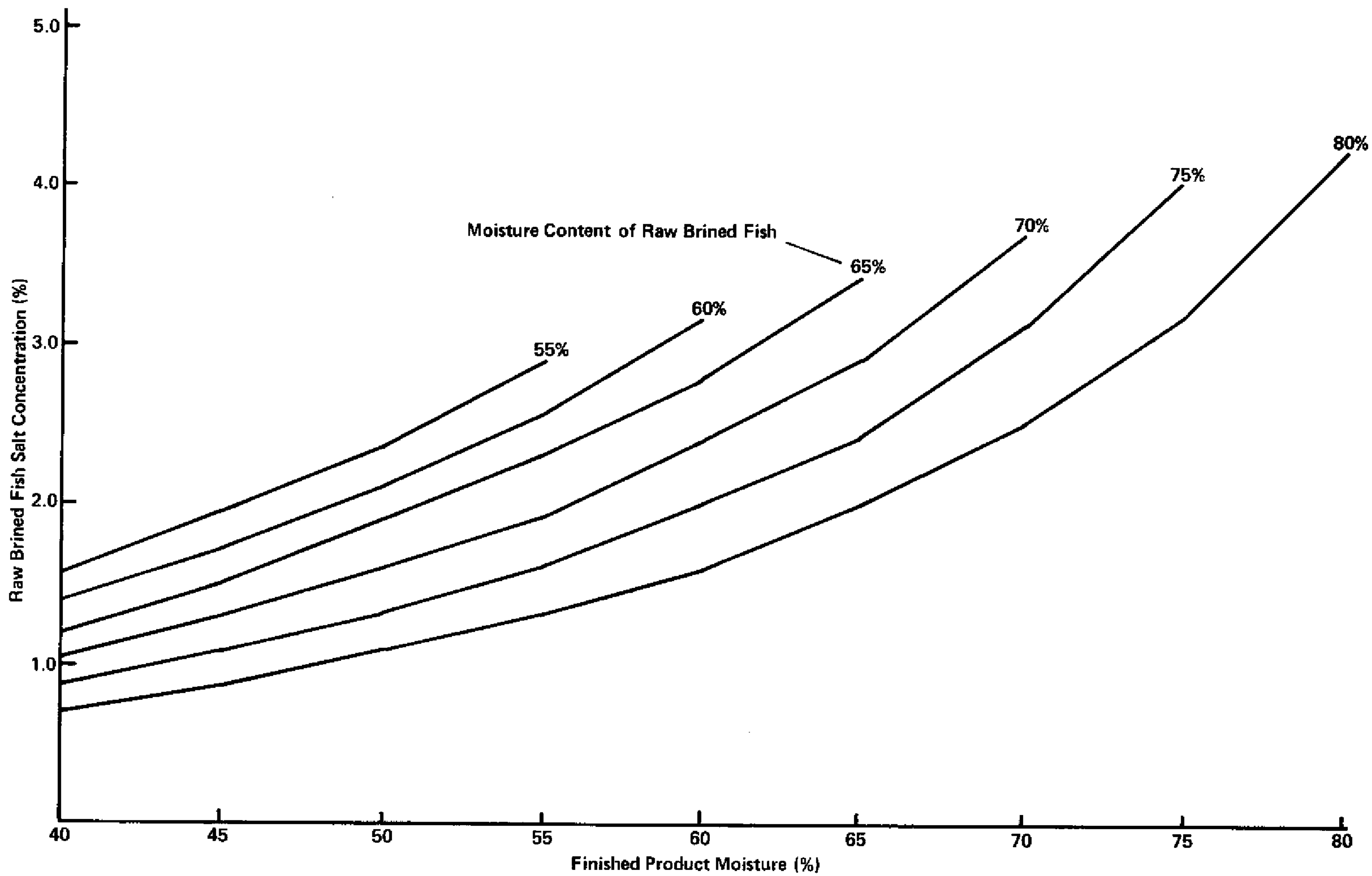


Figure 2. 5.0% water phase salt smoked fish.

Step 1: Find the 75 percent raw brined fish moisture curve on Figure 1.

Step 2: Follow the 60 percent finished product moisture content line up to the point where it crosses the 75 percent curve.

Step 3: Read the required raw brined fish salt concentration directly off the left side of the figure. It should be approximately 1.34 percent salt.

Step 4: When salt analysis shows that the raw brined fish have reached at least 1.34 percent salt, the smoking cycle will assure a final WPS content of 3.5 percent when 60 percent final moisture is reached. See the sections on salt and moisture for techniques of analysis.

ESTIMATING FINISHED PRODUCT MOISTURE CONTENT REQUIRED IN SMOKED FISH

A lot of fish, which has been brined or partly smoked and does not meet the minimum salt standards, can be dried to increase the water phase salt content (WPS). Figures 1 and 2 make it easy to estimate the final moisture content required to bring the WPS up to standard.

Example A: An analysis lot of smoked fish was found to contain 2.5 percent salt and 65 percent moisture (3.7 percent WPS). Water phase salt content of 5.0 percent was desired so an estimate of the necessary final moisture content was needed. Figure 2 can be used to obtain this estimate using the following steps.

Step 1: Find 2.5 percent raw brined fish salt concentration on the left of Figure 2.

Step 2: Follow to the right to the 65 percent raw brined fish moisture content curve.

Step 3: From that point follow down and read directly from finished product moisture. In this case it would be 57 percent final moisture.

In other words, a partly smoked fish containing 2.5 percent salt and 65% moisture (3.7 percent WPS) contains 5.0 percent WPS when dried to 57% final moisture.

ESTIMATING MOISTURE CONTENT OF SMOKED FISH BY NON-DESTRUCTIVE MEANS

It is possible to obtain a reasonable estimate of the moisture content of smoked fish during the smoking process without destroying the sample. The estimate is obtained by weight difference but must assume two things. First, you must assume that you know the beginning moisture content and that there is no loss of solids, particularly oil. If these two assumptions are reasonably correct, then simply weigh a representative piece of fish before beginning the smoking cycle. An estimate of its moisture content at any later time is obtained by again weighing the same piece and performing the following calculation:

$$M_f = \frac{(W_i \times M_i) - (W_i - W_f \times 100)}{W_f}$$

M_f = % final moisture content

W_i = initial weight

M_i = % initial moisture content

W_f = final weight

A similar calculation can be used to estimate the final weight needed to obtain a predetermined moisture content for any given piece of fish. Simply weigh a piece of fish and smoke it until it reaches a predetermined weight calculated as follows:

$$W_f = \frac{(100 - M_i)\ (W_i)}{100 - \%M_f}$$

W_f = final weight

M_i = % initial moisture content

W_i = initial weight

M_f = % final moisture content desired

Remember, both of these calculations assume a known initial moisture content and that no solids (such as oil) are lost in drying. Given those cautions, both formulas can be useful in quality control checks. Just don't forget they are estimates and are not a substitute for testing data.

FISH SMOKING PROCESS

SMOKING FISH: SPECIAL CONSIDERATIONS

George M. Pigott
Institute for Food Science and Technology
University of Washington
Seattle, WA 98195
(206)543-4281

INTRODUCTION

From an engineering point of view there is no such process as smoking fish. Smoke is used as a condiment and claimed as a preservative but smoke alone does not give us the so-called smoked products. The basic food process called drying, combined with the effects of salt and smoke particulates, results in such a product. Therefore, a discussion of the process that results in smoked fishery products must cover a variety of mechanical and chemical operations. A major emphasis of this discussion must include an analysis of what we mean by smoke being used as a preservative. Preservation can mean anything from increasing shelf life a few hours to complete sterilization. Smoke used alone is in the few hour shelf life extension category.

It is not our purpose to discuss exact processing techniques since this has been covered by other presentations, but to delineate some of the effects of processing on the final product.

Drying, a term known to everyone, is one of the oldest recorded methods of preserving food. Two-thirds of the nutrients consumed by humans (cereal grains) are dried in the field by Mother Nature before harvest. High moisture products such as fruits, vegetables, and meats require man-operated processes to remove moisture and thus stabilize the food.

Seafood drying is still an art rather than a science in many parts of the world where it is practiced. It is impossible to standardize the many processes used given the present degree of record keeping in all areas of the field, including species used, processing methods and conditions, market forms and product quality. However, perhaps we can touch on some of the common variables that affect the process of removing varying portions of water, and adding condiments such as smoke, to give varying degrees of flavor and stability to fish.

It is estimated that as much as 25 percent of the world's fish catch destined for human consumption is dried in some manner, often combined with salting, brining and/or smoking. Since there is no clear separation between drying, salting, and smoking, it is difficult to define precisely the some 8 million, or metric, tons of live-weight fish so treated. Table 1 shows an estimate of world product volume and Table 2 summarizes that of the U.S. While we are trying to estimate the amount of fish that is dried, it is well to point out that some 30 million metric tons of "industrial" fish is reduced (dried) to fish meal for animal feed. Hence, well over 50 percent of the world's fish catch ends up as some form of dried product.

Since fishery product smoking began, the general procedure has remained almost unchanged. The methods used still depend largely upon the personal

Table 1. Dried salted or smoked fish (production by country)

Country	1972	1973	1974	1975	1976	1977	1978
U.S.	31.5	20.9	31.3	24.9	24,5	22,0	19.2
Brazil	41.7	44.9	49.3	36.5	34.9	34.9	34.9
Colombia	2.8	4.0	2.5	12.6	11.1	8.9	8.9
Venezuela	6.2	7.1	8.9	6.3	5.4	5.8	5.8
India	3.5	3.0	1.8	2.1	4.9	5.4	10.8
Indonesia	268.1	269.3	282.8	288.8	319,4	264.2	378.1
Japan	664.4	698.0	720.1	778.8	753.2	722.4	793.0
S. Africa	--	--	--	--	5.7	7.3	9.7
France	40.8	19.4	18.8	17.9	16.9	16.2	15.7
Iceland	39.5	41.5	44.7	61.0	67.7	69.8	63.3
Norway	115.1	95.7	96.8	74.0	95.4	101.3	87.1
Denmark	8.9	10.3	12.4	13.8	15.2	13.9	14.0
Spain	82.6	68.2	53.5	53.6	58.8	52.1	52.1
U. Kingdom	55.7	56.6	88.8	78.1	35.5	35.5	35.5
GRAND TOTAL	3030.0	3030.0	3100.0	3120.0	3140.0	3030.0	3190.0

SOURCE: FAO 1978

Table 2. Production of principal cured fishery products in the United States

Species		Smoked	Salted	Pickled	Dried	Total
		Production in millions of pounds and millions of $				
Salmon	weight	13.15	7.02	0.40		20.57
	value	35.40	19.02	0.54		54.96
Herring, sea	weight	3.39	10.27	3.98		17.64
	value	1.70	9.61	2.61		13.92
Chub	weight	5.54				5.54
	value	6.39				6.39
Sablefish	weight	2.91	0.27			3.18
	value	3.33	0.21			3.54
Whitefish	weight	2.39				2.39
	value	3.13				3.13
Cod	weight	0.15	1.42[1]			1.57
	value	0.20	1.00			1.20
Alewives	weight	0.53	1.01			1.54
	value	0.16	0.25			0.41
hiting	weight	0.32				0.32
	value	0.38				0.38
Sturgeon	weight	0.78				0.78
	value	2.50				2.50
Mullet	weight		0.44			0.44
	value		0.12			0.12
Halibut	weight	0.42				0.42
	value	0.32				0.32
Shrimp	weight				0.32	0.32
	value				1.25	1.25
Carp	weight	0.30				0.30
	value	0.16				0.16
Shad	weight	0.09				0.09
	value	0.03				0.03
Tuna	weight	0.02	0.06		0.03	0.11
	value	0.03	0.12		0.06	0.21
All other	weight	1.34	2.81		0.12	4.27
	value	0.95	1.08		0.16	2.19
Total	weight	31.33	23.30	4.38	0.47	59.48
	value	54.68	31.41	3.15	1.47	90.71

[1]reponderantly (>95%) lutefisk

opinion or prejudice of the operator, resulting in each individual having different ideas about the kind of wood to use, time and temperature of smoking, and so on.

Although smoking cannot be used to significantly extend shelf life, it does have some preservation effect on the product through the combined affects of drying and of bacteria-killing chemicals in the smoke. However, the 2 percent of 3 percent salt content in most products has only a slight affect on the bacteria that spoil smoked fish.

Fish and marine mammals were a major food of early man. Judging from the marine fish bones found in far inland refuse heaps dating from 40,000 B.C., one can certainly surmise that the fish had to have been preserved by drying. Salt preservation probably did not occur until the Bronze Age when the great urban civilization of ancient Egypt, Mesopotamia and the Indus Valley (about 4,000 B.C.) developed techniques for salting and drying fish along with improved techniques for harvesting the raw material from their river systems.

Beginning about 1,000 B.C., Greece developed major trade in dried, salted, and smoked fish with colonies in the eastern Mediterranean. During the Middle Ages, one finds the more prolific North Sea countries developing extensive fisheries. Salting, drying, and smoking were developed to such a degree that their techniques have persisted almost unchanged up to the present time. Only during recent years have we begun to define and understand the science and technology involved with this preservation technique is used for more than half of the world's catch.

DRYING MECHANISMS

The basic effect of removing water is to create an environment deleterious to spoilage. The basis for defining this environment, as shown in Tables 3 and 4, is water "activity" or the equilibrium relative humidity (ERH). This is a measure of the free or available water in the fish upon which microorganisms depend for their growth. If this available water can be reduced to a point that inhibits the growth of microorganisms, then the shelf life of the resulting product is substantially increased. If, at the same time, salt or products from smoke are added to the fish, the inhibition of microorganism growth increases.

The increasing cost of energy will dramatically increase the use of drying and smoking as processing methods. Furthermore, people like smoked flavor. New and innovative ways of removing water are certainly becoming a major field of inquiry in food science and technology research. Whether drying is economical depends on drying rates, which are not constant throughout the cycle.

Two fundamental and simultaneous processes occur during drying: heat transfer to the evaporating liquid, and mass transfer as the liquid moves toward the surface and subsequently evaporates. The rates of these processes are governed by a number of factors, among them: temperature, humidity, air velocity, area of drying surface, and atmospheric pressure, or vacuum and direction of air.

Table 3. Definition of water activity

$$\frac{p_A}{p'_A} = X_A \gamma_A = a_w = ERH$$

where a_w = water activity

ERH = Equilibrium relative humidity

where p and p' are both strongly dependent on temperature,

$\frac{p}{p'}$ is relatively temperature insensitive

IDEAL SOLUTION

$p_A = p'_A X_A$ Raoult's Law

where: p_A = vapor pressure of component A at t_1

p'_A = vapor pressure of pure A at t_1

X = mole fraction of component A

$$\frac{p_A}{p'_A} = X_A$$

NON-IDEAL

$\frac{p_A}{p'_A} = X_A \gamma_A$ where γ_A = activity coefficient

Table 4. Importance of water activity in foods

a_w	Phenomena	Food examples[a]
1.00		Water-rich foods ($0.90 < a_w < 1.0$)
0.95		Foods with 40% sucrose, or 7% NaCl, cooked sausages, bread crumbs
0.90	Lower limit for bacterial growth (general)	Foods with 55% sucrose, or 12% NaCl, dry ham, medium age cheese
		Intermediate moisture foods ($0.55 < a_w < 0.90$)
0.85	Lower limit for growth of most yeasts	Foods with 65% sucrose, or 15% NaCl, salami, "old" cheese
0.80	Lower limit for activity of most enzymes Lower limit for growth of most molds	Flour, rice (15-17% water), fruit cake, sweetened condensed milk
0.75	Lower limit for halophilic bacteria Maximum heat resistance of vegetative bacterial cells	Foods with 26% NaCl (saturated), marzipan (15-17% water), jams
0.70	Lower limit for growth of most xerophilic ("dry loving") molds	
0.65	Maximum velocity of Maillard reactions	Rolled oats (10% water)
0.60	Lower limit for growth of osmophilic or xerophilic yeasts or molds	Dried fruits (15-20% water), toffees, caramels (8% water)
0.55	DNA becomes disordered (lower limit for life to continue)	
0.50		Dried foods ($0 < a_w < 0.55$) Noodles (12% water), spices (10% water)
0.45		
0.40	Minimum oxidation velocity	Whole egg powder (5% water)
0.35		
0.30		Crackers, bread crusts (3-5% water)
0.25	Maximum heat resistance of bacterial spores	
0.20		Whole milk powder (2-3% water) Dried vegetables (5% water) Corn flakes (5% water)
0.15		
0.10		
0.05		
0.00	Maximum oxidation velocity	

There are two distinct periods in drying. The first, or constant rate drying, occurs when the surface is wet and essentially all energy is used to evaporate water. If we add heat at a faster rate, water will evaporate faster, but at a constant rate directly proportional to the heat added. We can sum this up by saying that faster air flow over the fish's surface, higher air temperature, and drier air (lower humidity) remove water at a faster rate. Hence, factors external to the fish control drying rates at this point.

The second, or falling rate, drying period occurs when the water cannot migrate to the surface as fast as the heat is absorbed. Therefore, the drying rate decreases and the product begins to heat. During this period, slowing air speed and humidity are not major factors. Higher air temperatures cause fish flesh temperature to rise and increase drying by causing faster capillary diffusion. Water will diffuse to the surface faster in leaner and thinner fish, while increasing salt content decreases this water movement. Final water content attainable depends on the relative humidity of the air as shown in Table 5.

SMOKED FISH PRODUCTION

Smoking is a combination of drying and adding the chemicals from the smoke to the fish, thus preserving and adding desired flavor. Much of the fish currently smoked is exposed to the smoke long enough to give the added flavor and there is little drying. This type of product of "kippered" fish has a short life under refrigeration since the water activity normally remains high enough for spoilage organisms to grow.

PRODUCT PREPARATION

Each person has his/her own special treatment for the fish preparatory to smoking, but the general steps of the smoking process being discussed in detail by other speakers include:

Splitting and Cleaning

The whole fish are gutted, the gut cavity scraped and all blood removed. This fish are then usually beheaded and filleted, although the long bones are often left on the fillets to give the finished product a better appearance.

Salting

This is almost always done by soaking the fish in a strong brine. One of the permitted dyes is added if color is desired. The duration of the brine dip depends on brine strength and on the size and the fattiness of the fish.

At the University of Washington, we have carried out some tests to determine the effect of oil content on salt pick-up in the brine. Table 6 shows the difference in final salt content between a batch of king salmon (2.4 percent oil) and coho salmon (8.9 percent oil) at different brine concentrations and brining times. The king salmon absorbed approximately 50 percent more salt than to coho salmon under the conditions of the experiment.

A 70 to 80 percent saturated brine is usually employed for all the common types of smoked fish. During salting the fish picks up 2 to 3 percent salt.

Table 5. Humidity vs. minimum water content

Relative Humidity of the Air (%)	Min. Water Content Obtainable in Fish
20	7
30	8
40	10
50	12
60	15
70	18
80	24

Table 6. Effect of oil content on salt pick-up

BRINE CONCENTRATION	BRINE TIME (HR)	KING SALMON (2.4% OIL)		COHO SALMON (8.9% OIL)	
		gm NaCl / gm dry fish	% NaCl	gm NaCl / gm dry fish	% NaCl
36° (9.5% NaCl)	16	0.264	7.0	0.193	4.9
60° (15.8% NaCl)	3	0.234	6.1	0.158	4.0
80° (21.1% NaCl)	1.5	0.234	6.1	0.157	4.0

Brine becomes weaker during use. Water on the surface of fish dilutes the brine and the fish also absorb its salt. Brine strength is usually maintained by adding solid salt or by using a large volume of brine in relation to the volume of fish.

Normal brining procedures do not produce a uniform salt content even in fish of uniform size. Better results are obtained if the brine is stirred during the dip. A mechanical process would improve matters as well as allowing continuous control of brine strength.

Hanging (Removal of Excess Surface Water)

Brined fish is conventionally hung or laid on racks to drip and partly drying after brining. If fish are smoked while too moist, the smoke does not absorb evenly, and a "streaky" product results.

However, as will be discussed later, if the surface is too dry the smoke is not adequately absorbed. The hanging is often done overnight before smoking. Also, during the hanging, proteins dissolved in brine dry on the cut and produce the familiar glossy skin, which is one of the commercial criteria for quality.

Forced drying, raising the temperature to 90 to 100°F and drawing a current of air through the smokehouse with the blower, results in considerable time saving. Fish can be dried sufficiently to take the smoke well in 3 to 4 hours or less, and a complete smoking can be finished well within one day. In fact, we have produced excellent smoked products in a few hours.

SMOKING

Smoking is carried out by using one of the following two processes:

- Cold smoking: the temperature of the smoke does not rise above about 85°F, or the fish will begin to cook.

- Hot smoking: In this process the intention is to cook the fish as well as smoke it. The smoke reaches 250°F or so and the center of the fish may be 140°F or more. Most of the smoked product available at the market is hot smoked. However, the temperatures of the fish during and at the end of the process vary tremendously among processors.

The equipment used for smoking, whether hot or cold smoking, is either traditional or a mechanical kiln as has been discussed during earlier sessions.

In the traditional kiln the fish are hung over a fire of smouldering sawdust. Although experienced smokers can usually produce good results from them, traditional kilns nevertheless have a number of disadvantages. Controlling the heat and smoke produced is difficult. One moment the warm smoke will follow one path and the next a quite different one. Uniformly drying the fish is impossible, because the smoke is practically saturated with water after it has passed over the first few rails and cannot therefore dry any fish higher up the kiln.

On warm, humid days it may even be impossible to use a traditional kiln. The speed of the draught and the capacity to dry fish depend largely upon how much the air entering the kiln is warmed by the fires. If very cold air enters and is warmed to 85°F, then it will be very much lighter than the cold air outside and will rapidly travel up the kiln. If already warm air enters on the other hand, it still cannot be warmed above 85°F, or the fish will cook and drop into the fires.

The drying capacity of the air is also a minimum in warm, humid weather. The amount of water vapor that air can hold depends upon the temperature. If warm air is cooled, it can hold less water vapor and the excess condenses. If cold air is warmed on the other hand, it can hold more water vapor and its drying capacity is therefore increased.

The mechanical kilns of numerous designs were developed in an attempt to improve the process.

Loss in Weight During Smoking

Unfortunately, it is not possible to calculate from the water content of the final product how much drying has occurred in the kiln. Fish, for example, contains 70 to 80 percent water and there are considerable variations in a single batch of fish. Different parts of the same smoked fish can give quite different results due to the salt or oil content, the geometry and the condition of the flesh. Table 7 shows the varying moisture content in a batch of haddock that were cold smoked, hot smoked, and force air dried (Griffiths and Lemon 1934). Note the variation between samples.

Smoke Composition

Application of smoke to foodstuffs essentially is a physical process which is based on such phenomena as diffusion, absorption, dissolution, and deposition in force fields. It is accompanied by chemical processes wherein smoke compounds interact with food components. Despite the immense amount of analytical work done within the past 20 years only a few basic facts pertaining to the processes involved in smoke formation and application are known. This is particularly true concerning the products of oxidative thermo-destruction of the raw materials used for developing smoke (Husz 1977).

Wood, the material most widely used for smoke production, consists of many groups of polymers which, for the sake of simplicity, are referred to as cellulose, lignin, and hemicellulose. Lignin is particularly complicated as there is much uncertainty about some functional groups (carbonyls, keto-enol forms, etc.) and so the structures proposed differ from each other. The most widespread opinion is that these three groups of polymers in wood are partially linked with each other by chemical bonds. While the structure of carbohydrates is a more or less regular repetition of the structure of the respective monosugars, that of lignin is complicated and is formed at random during its biosynthesis. The biosynthesis of lignin starts from phenylalanine and shikimic, ferulic and p-coumaric acids and yields the respective 4-hydroxy-phenylpropane derivatives. The ratio of these derivatives changes from one wood variety to another (Reiner 1977).

Table 7. Moisture content of haddock samples

Kind of smoking	WATER CONTENT			Loss in weight %
	Fresh %	Salted %	Smoked %	
1. Hot smoke	79.3	75.0	63.8	42.8
2. " "	80.0	74.3	63.0	46.0
3. " "	82.5	79.0	63.3	52.3
4. " "	82.3	75.8	64.0	50.9
5. " "	80.1	74.3	63.3	45.5
6. Cold smoke	80.5	78.2	73.4	26.7
7. " "	80.5	76.0	69.4	36.3
8. " "	78.0	75.0	70.2	26.2
9. " "	80.5	71.8	69.3	36.5
10. " "	81.6	78.2	73.8	29.8
11. " "	80.6	78.2	77.2	14.9
12. " "	82.2	78.2	78.0	19.1
13. " "	80.0	76.0	73.6	24.3
14. " "	82.7	80.3	76.3	27.0
15. " "	79.6	77.7	74.2	20.9
16. Force dried	79.4	76.9	71.7	27.2
17 " "	79.0	78.0	71.7	25.8

The formation of smoke starts with the breakdown of these bonds where the vibrational energy is equal or almost equal to the bond energy. Although temperature will always be the decisive factor, the actual path of thermal breakdown of the wooden substance will depend highly on wood variety and even on the degree of disintegration of wood. Hence, the determination of the general composition of smoke is difficult.

Wood smoke contains a tremendous number of compounds formed by the pyrolysis of wood constituents. More than 300 substances have been detected by many more exist. Many of these smoke components can be found in smoked foods. The most important classes of chemical compounds detected in smoke and liquid smoke preparations are phenols, carbonyls, furans, alcohols and esters, lactones and polycyclic aromatic hydrocarbons. Presently the approximate numbers of identified compounds of the several chemical classes present in smoke are as follows: 45 phenolic compounds, more than 70 carbonyls such as ketones and aldehydes, 20 acids, 11 furans, 13 alcohols and esters, 13 lactones and 27 polycyclic aromatic hydrocarbons.

The desirable effects of smoking on foods are flavoring, preservation and coloring. Undesirable effects are contamination with toxic components of smoke and some destruction of essential amino acids of food proteins which are attributed to certain classes of components of smoke and liquid smoke. The typical aroma of smoked foods seems to be due mainly to the effect of certain phenols, carbonyls and acids. These compounds also cause, at least in part, different flavors in smoked foods (Barylko-Pikielema 1977).

As to the toxic components of curing smoke and smoke condensates, the polycyclic aromatic hydrocarbons (PAH) such as benzo(a)-pyrene have received particular attention because some of these compounds are carcinogenic. However, certain phenols are supposed to be toxic because of a co-carcinogenic effect in the presence of PAH. Polynuclear amounts are affected by many factors of smoke generation such as temperature of combustion and oxidation and air supply, density, length and temperature of the smoke cure, characteristics of the product surface and composition.

It has been firmly established that curing smoke is free of benzo(a)-pyrene when the thermal decomposition of the wood does not exceed 425°C and the oxidation temperature 375°C. Heating to higher temperatures leads to polynuclears. Polynuclear free smoke can be obtained by two-step smoke generation. In the first step, thermal decomposition of each wooden macroparticle takes place in the form of an "internal mantle" without oxygen contact. In the second step the oxidation of the volatile decomposition products occurs in the diffusion zone, i.e., in the external part of the "mantle." So smoke generated at lower temperatures imparts a good flavor to food products but contains less PAH than smoke generated at higher temperatures. Filtration or cooling of smoke also lowers the PAH concentration without a detrimental effect on the flavoring properties.

All processes which cause a removal of the larger smoke particles (soot) cause a reduction in the amount of benzo(a)-pyrene and other PAH. By the use of such smokes for the production of liquid smokes and also by certain treatments of smoke condensates it is possible to produce preparations containing essentially no PAH. However, such liquid smokes often lack the desirable flavor components such as phenols. Generally, it can be said that the PAH content of commercial preparations of liquid smoke varies over a wide range.

The smoke phenols contribute essentially to the typical flavor of smoked foods. Apparently certain phenolic compounds such as guaiacol, syringol and eugenol play a predominant role in this flavoring effect of smoke. However, adding such phenols to food products does not give a smoke flavor comparable to that of freshly developed wood smoke.

The amount and composition of phenols in curing smoke are strongly influenced by the temperature of smoke generation and by smoking technology. The phenol composition of liquid smokes shows an extremely wide variation. During the normal smoking process, the phenols penetrate into the product only a few millimeters, but if liquid smoke preparations or other smoked ingredients are added to the curing mixture, phenols are found in the center of the product. An increasing amount of phenols is not necessarily connected with an increasing concentration of PAH. However, in the case of liquid smoke there is an increasing PAH content with rising content of phenolic compounds.

The function of smoke components is primarily to provide the desirable color, aroma and flavor of smoked products and to contribute somewhat to preservation by acting as an effective bactericide and antioxidant agent. However, the preservative properties are not nearly as important as strict hygienic requirements, modern packaging and continuous refrigeration (Tilgner 1977).

Aroma and flavor are a blend of smoke components. The influence of wood variety on smoke flavor is due to the basic pattern of smoke compounds formed during thermal degradation of the wood. This reflects more particularly the pattern of phenolic compounds.

Surface coloring involves complicated carbonyl-amino reactions and is directly connected with the loss of the carbonyl groups of smoke. The more carbonyls, the higher the intensity of the color. The role of phenols is insignificant, but at pH 7.25 phenols with ortho- and para-OH groups intensify color of proteins. Different factors such as interaction of some specific smoke components with some proteins or amino acids, exposure to light, heat and oxygen influence the shade and intensity of color formation.

In summary, the production of smoke is a very complicated process, highly difficult to control and yielding a product which, besides desired constituents, contains also a vast variety of unwanted compounds.

Effect of Microorganisms

Freshly caught fish typically carry populations of predominantly gram-negative psychrotrophic* bacteria on their external surfaces. The population

---

*Psychrotrophic refers to bacteria which grow well at temperature near 0°C but have an optimum temperature above 20°C with maximum in the range 30 to 35°C.

typically ranges between 10^2-10^3 cell/ml. The most predominant bacterial are of the general Pseudomonas, Acinetobacter-Moraxella (Achromobacter), Flavobacterium and Vibrio. Other bacteria generally are present in lower numbers. These include Coryneform bacteria, Micrococcus, Bacillus, and Clostridium (mainly C. botulinum type E).

Since the fish is transported from the harvesting area to the processing plants in ice or refrigerated sea water, the bacterial population, due to its psychrotrophic nature, may increase to 10^4-10^6 cell/ml. However, frequent handling of the product may lead to contamination with gram positive bacteria, especially staphylococci, and may introduce coliform bacteria.

Since fish smoking has two main purposes, adding desired flavor and preserving fish, the microbial aspects of the fresh and preprocessed fish along with the smoking process steps must be taken into consideration. As previously discussed, the smoking process helps preservation through the combined action of the chemical composition of the smoke, the salt content, the heat, and the drying effect, especially at the surface.

The processes which are used in preparing fish for smoking have a considerable influence on the microbial count of the smoked products. These include soaking the cured fish in fresh water overnight, draining, trimming, and finally hanging or racking in the smokehouse. Unless great care is taken in handling the materials during these stages, a contamination with microorganisms may be introducted:

- Salting. The effect of salt on microorganisms is widely variable. A small percentage of salt reduces the growth of many spoilage bacteria. On the other hand, some microorganisms can tolerate much greater quantities of salt and there are some stimulated by the presence of salt.

  Salt content of lightly salted and smoked fish ranges from 2 to 2.5 percent, whereas salt fish contain up to 10 to 12 percent salt. This can be clearly seen in Table 8 where the salt concentration used in brining haddock gave a wide range of effects. Basically it did not reduce the bacterial count materially. The bacterial count of some samples was increased. The reason could be that the salt is an important source of contamination (Roper 1934).

- Drying. Drying plays an important role in the reduction of bacterial count during the preparation of smoked fish. Considering the minimum values of a_w (water activity), 0.91, 0.88 and 0.80 for bacterial, yeast and mold growth, the effect of drying on the bacterial population would be greater than the effect on yeasts and molds. However, interesting data were obtained by a study on smoked salmon samples obtained from retail outlets along the Pacific Northwest coast. Despite the small number of samples, the data as shown in Table 9 point out the extreme variability among smoked salmon. The aerobic microbial count ranged from 1.3×10^2-2.2×10^6/g. In this study it was found that the count is inversely related to the moisture level (Lee and Pfeifer 1973).

Table 8. Bacterial change in haddock

SAMPLE NO.	DESCRIPTION	FRESH	SALTED	SMOKED
		bacteria/g	bacteria/g	bacteria/g
1	Hot smoked	66,000	17,000	(1)
2	" "	24,000	43,000	(1)
3	" "	60,000	68,500	104
4	" "	250,000	30,000	1,100
5	" "	15,000	5,000	2,100
6	No smoke	30,000	(2)	75,400
7	Cold smoke	23,000	(2)	4,900
8	" "	80,000	62,000	37,600
9	" "	48,000	14,000	460,000
10	" "	55,000	(2)	9,000
11	" "	14,000	76,000	300,000
12	" "	50,000	250,000	1,600,000
13	" "	70,000	650,000	3,000,000
14	" "	28,000	24,000	12,000
15	" "	18,000	150,000	5,300
16	" "	14,000	22,000	18,000
17	" "	16,000	430,000	17,000
18	Cold smoke force drying	64,000	36,000	10,000
19	" " " "	860,000	150,000	202,000

Table 9. Microbial load, NaCl, and water phase salt (WPS) of smoked salmon

Sample	Microbial load (count/g)	Moisture (%)	NaCl (%)	WPS[a]
A	2.2×10^6	48	4.3	8.2
B	1.9×10^3	61	3.7	5.7
C	5.5×10^4	56	2.0	3.4
D	1.8×10^2	64	2.1	3.2
E	4.1×10^4	53	4.2	7.3
F	2.7×10^4	61	2.7	4.2
G	1.2×10^2	60	2.2	3.5
RANGE	$1.3\times10^2-2.2\times10^6$	48-64	2.0-4.3	3.7-8.2

SOURCE: Lee and Pfeifer 1973.

[a]Water phase salt (% brine) = $\frac{NaCl(\%)}{H_2O(\%) + NaCl(\%)} \times 100$

• Smoking temperature and time. The temperature used in the two main types of smoking, cold smoking and hot smoking, helps reduce fish microbial count. The influence of hot-smoking temperature which reaches up to 250°F or so is much more than that of cold smoking, which ought not to rise above about 85°F.

All gram-positive cocci which are predominant on smoked fish are very sensitive to heat. It is noticeable from the Table 10 that the micrococcus spp. were slightly more heat resistant than staphylococcus spp. The average exposure time needed to inactivate 90 percent of micrococcus spp. at 52 ± 1°C was 24 minutes, while it was only 8.5 minutes in the case of staphylococcus spp. So their sensitivity to heat will not allow them to survive either 66 or 82°C smoking process formerly specified by GMP.

In another study it was found that smoking for 20 minutes at 160°F dry bulb and 140°F wet bulb (60 percent RH) followed by 40 minutes at 200°F dry bulb and 190°F wet bulb (80 percent RH) allowed sufficient heat treatment for the inactivation of C. botulinum type E and allowed sufficient smoke absorption for flavor (Chan, Toledo, and Demy 1975).

• Smoke composition. The number of different volatile compounds present in wood smoke (i.e., formaldehyde, phenols, and cresols) are known to have different levels of bacteriostatic and bactericidal effects. Formaldehyde is considered the most effective against molds, bacteria, and viruses. The effect of formaldehyde, probably due to its combination with free amino groups of the proteins of cell protoplasm, is to injure nuclei and coagulate protein. Smoke composition is more effective against the vegetative cells than against bacterial spores. The effect is heightened by increasing the smoke concentration and temperature. It also varies with the kind of wood used. It has been reported that the residual effect of smoke in fish is greater against bacteria than against molds.

In order to establish a relationship between smoke composition, temperature and microbial population, the following test on haddock was carried out. A brined haddock which was hung in the smokehouse for the same length of time as the smoked fish but which did not receive any smoke and heat had a bacterial count of over 200 million per gram. The smoked haddock of the same series had a count of 62,000. A trial was made under the same conditions but without smoke at higher temperature (195°F or 90°C) to determine whether or not the hot smoke was having any greater bactericidal effect. To do this it was necessary to cut off the supply of sawdust and then proceed with the heating as though the fish were actually being smoked. The fish showed a final count of 75,000 per gram as compared with only 104 bacteria per gram on a similar run with smoke. This demonstrated that the smoke, or some constituent of it, was more effective as the temperature was increased (Roper 1934).

Table 10. Selected characteristics of gram-positive cocci isolated from smoked salmon

STRAIN		IDENTITY	MAX. NaCl (%) TOLERATED	D_{52} (C) IN MIN.	4°C GROWTH
H-4	STAPHYLOCOCCUS	I	19	1.5	-
H2-1C		II	20	3.6	-
B-99		III	10	-	-
D-32		III	11	-	-
B1-1		IV	16	16.7	-
H-3		V	20	6.9	-
A2-58		V	19	-	-
B1-3		VI	16	-	-
D-38		VI	21	13.8	-
I-26	MICROCOCCUS	1	22	27.6	-
C2-48		1	11	-	-
A2-92		2	12	-	-
A2-158		2	20	26.1	-
C2-78		3	21	47.0	-
C2-82		3	22	-	-
B2-43		5	25	11.7	+
B2-49		5	24	-	+
I-7		6	21	-	-
B1-52		6	24	6.3	+

SOURCE: Lee and Pfiefer 1973.

- pH. A series of pH determinations was made on the fresh, brined and smoked haddock to find out the effect of smoking on pH value and, therefore, its relation to microbial count. As shown in Table 11, no pronounced change in pH value was determined.

  In another test where the acidity of a smoke solution was neutralized with NaOH, its antibacterial action was decreased about one-third. It was concluded that the preservative action of oak smoke solutions was due more to the acids and tarry matter components than to formaldehyde.

THE NUTRITIONAL QUALITY OF SMOKED PRODUCTS

The desirable effects of smoking are flavoring, preservation, and coloring. However, excessively heating proteins may destroy certain amino acids or render them unavailable for digestion. One of the most important changes which results from heating is the interaction of certain amino acid residues of the protein with reducing sugars such as glucose. Lysine is most frequently involved. Tryptophan, argine, and histidine may also enter into reactions with reducing sugars. In the early stages, melanoidin condensation, a bond is formed between the sugar and the amino group which interferes with the action of proeolytic enzymes but which may be broken by boiling with acid. In later stages browning and the subsequent loss of the amino acid occurs.

Moisture content plays a very important part in the browning reaction. Moisture content of 30 percent is most favorable for the reaction and hence the browning reaction is peculiar to dehydrated food products. The moisture of these foods is reduced usually by passing through the range conductive to protein damage. Low moisture or "jerky" type fish products fall into this very low moisture category.

During smoking, food products go through heating and drying. Non-enzymatic browning reactions definitely go on in smoked products. These reactions form the desired color of the finished product. The availability of lysine is lost during smoking due to non-enzymatic browning (Dvorak and Vognarova 1965; Chen and Denberg 1972). The extent of the reduction depends on the length and temperature of the heating process and the extent of the product dehydration. Loss of lysine increases with an increase in both of these parameters. It was found that an overall 43.7 percent lysine loss occurred in Hungarian salami with 15 percent water content. The product was cold smoked and stored at 20°C for one year. A 44.5 percent loss of lysine was discovered in 2 to 3 mm lean beef sirloin strips smoked for 10 hours at 65°C. In an unsmoked heat-treated sample, 15.2 percent loss was observed.

The amount of glucose normally present in animal flesh is sufficient to promote the browning reaction. Added sugars in meat do not significantly influence the amount of browning.

In dehydrated meat the reaction of amino groups with sugars occurs even at low temperatures. Freeze-drying is the mildest method for drying foods. However, loss of amino acids due to the browning reaction occurs (Regier 1956). The availability of lysine decreases with the degree of dehydration of the meat. The decrease is dependent on the time during which the reaction

Table 11. pH values of fresh, brined and smoked haddock

SAMPLE NO.	FRESH	BRINED	SMOKED	SAMPLE NO.	FRESH	BRINED	SMOKED
1	6.75	6.71	6.71	6	6.75	6.67	6.73
2	6.75	6.61	6.61	7	6.75	6.77	6.74
3	6.90	6.96	6.96	8	6.82	6.75	6.68
4	6.75	6.66	6.66	9	7.10	7.17	6.71
5	6.75	6.70	6.70	COMMERCIAL FILLET	--	--	6.43

SOURCE: Roper 1934.

takes place. Longer dehydration times promote increased lysine loss. The effect of the Maillard reaction on meat and meat products with reduced water content is also enhanced by long storage (Dvorak 1968).

As has been discussed, the effective constituents of smoke for flavoring and odor are phenolic and carbonyl compounds. Formaldehyde and acetaldehyde make up a substantial part of the carbonyl compounds. The free amino group in lysine is fixed in proteins by formaldehyde. It has been found that the relationship between the loss of available lysine and the log concentration of formaldehyde is linear (Dvorak and Vognarova 1965).

Coniferaldehyde and sinaldehyde are the major phenolic components of wood smoke. These components were also found to affect the availability of lysine in smoked foods (Barylko-Pikielma 1977).

Nitrites are used in meat salting to obtain a desirable color. The usual amount of nitrite added is 0.5 percent of the sodium chloride used. Nitrite ions in meat are reduced to nitroten oxide which forms the desirable color with myglobin. However, nitrite ions in acidified meat may react with the ε-amino group of lysine and destroy it. It has been found that the decrease in the amount of available lysine is proportional to the log concentration of nitrite (Dvorak and Vognarova 1965).

Strong salt solutions can denature proteins. By itself the denaturation may not be harmful to the nutritional value of the smoked food. However, denaturation of the proteins may make more active sites on the protein available for interaction with reducing sugars or smoke components.

As discussed, research is beginning to demonstrate mutagenic effects of non-enzymatically browned foods. The Ames test for mutagenic factors has shown that foods which have undergone Maillard reactions may be carcinogenic. This is an area that is just beginning to be studied (Iwaoka 1980).

Smoking indeed lowers the nutritional value of foods. The development of rapid cold smoke techniques could alleviate some of this loss.

SHELF LIFE OF SMOKED FISH

It cannot be overemphasized that most smoked fish products, unless canned and sterilized by retorting, have little more and often less shelf life than fresh fish. Table 12 shows some comparative data on shelf life for several species at 60°F and 32°F.

These data certainly have to impress one with the fact that smoked fish should be handled, packaged and stored like fresh fish, not a highly preserved product. A dried-salt fish containing more than 10 percent salt and perhaps 25 percent water or a "jerky" type smoked fish containing some salt and perhaps 2 percent water has a fairly long shelf life due to the low water activity. However, most smoked products demanded by today's markets are low salt, high water content items that are ideal substrates for growth of microorganisms.

Table 12. Storage life of smoked fish

SPECIES	SMOKED PRODUCT	STORAGE LIFE: ROOM TEMP. (60°F) in first class condition [days]	ROOM TEMP. (60°F) remains edible [days]	CHILL TEMP. (32°F) in first class condition [days]	CHILL TEMP. (32°F) remains edible [days]
COD	Single fillets, cold smoked	2-3	4-6	4-6	8-10
HADDOCK	Single fillets, cold smoked	2-3	4-6	4-6	8-10
	Black fillets, cold smoked (golden cutlets)	1-2	2½-3	4	6
	Finnans, cold smoked	2-3	4-6	4-6	10-14
	Pales, cold smoked	1-2	2½-3	4	6-7
	Smokies, hot smoked	1-2	2½-3	3-4	5-6
HERRING	Kippers and kipper fillets, cold smoked				
	Unwrapped	2-3	5-6	4-6	10-14
	Wrapped	1-2	3	3	3-4
	Bloaters, cold smoked	1-2	2-3	3-4	5-6
	Buckling, hot smoked	1-2	2-3	3-4	5-6
SALMON	Fillets, cold smoked	2-3	4-5	4	10
TROUT	Whole gutted, hot smoked	3	7	6	10

SOURCE: Burgess *et al.* 1967

If you are impressed with no other point during this conference, it should be that smoked fish are potentially one of the most dangerous products on the market. It cannot be hermetically sealed unless sterilized, or kept frozen or under refrigeration just above the freezing temperature. Vacuum-packed smoked fish makes a beautiful package to impress the consumer but if the seller or the buyer is not aware of the potential danger there will be some disasters involving human life as the production of smoked fish increases.

SMOKED FISH PRODUCTS

People like the taste and odor of smoked products. That they will pay prices far above that for fresh fish is indicated in Table 13. Also, a processor, especially one not knowledgeable in the preparation of good smoked products, has to be impressed with the profit potential of smoked products. Therefore, one asks the obvious question, "Why are there not more producers of smoked fish products, and why are there not new and innovative items being marketed?"

A partial answer has been discussed in this and other talks being presented at this conference. Fish smoking is still more of an art than a science. The wide diversity of product quality, market presentation, and availability does not appeal to a large portion of the consuming public. Often a buyer is disappointed with a smoked product, particularly the boat-packaged items found in supermarket fresh meat counters. Poor quality control of smoked seafood items is the factor holding back rapid market expansion, not lack of consumers. This poor quality is caused by many factors including low quality raw material, spoilage occurring during processing, variations in salt content and smoke flavor, uniformed processors and improper packaging.

SPECTRUM OF SMOKED PRODUCTS

There are relatively few preservation states in which smoked products can be presented to the consumer, namely those of all foods:

- Smoked and handle as fresh product
- Smoked and held frozen (Upon thawing product is handled like a fresh product.)
- Hard smoked and dried, then held for considerable periods at room temperature
- Smoked and canned products

These four processing techniques can be used for whole fish or shellfish, sides, fillets, miscellaneous portions (i.e., "cheeks" of fish, broken shrimp, or oyster trimmings), minced flesh and formulated products that are formed or extruded. Liquid smoke can be used in all of the items but is probably most effective in the latter categories.

Table 14 is a list of smoked items that can be found in the marketplace. It essentially covers all raw material from the sea that is consumed by humans. The degree of smoking varies from a lightly smoked, cooked fish to a hard

Table 13. Wholesale and retail prices of various salted fish products (FOB Seattle, WA)

COMPANY	PRODUCT	PRICE ($/LB)	OBSERVATIONS
1	Salted cod	1.70-2.80 (whsl)	
	Mild cured salmon	3.00 (whsl)	
2	Raw cod	.13 (round)	
		.25 (head/ cleaned)	
3	Salted cod	1.50 (whsl)	Package of 1 lb skinned and boned
		3.30 (retail)	
	Salted herring	1.40 (whsl)	Retail price depends on delivery, qty, etc.
4	Salted Sockeye salmon	2.75	
	Raw (fresh) salmon	2.25-2.50	
5	Salted herring	2.49	
	Salted salmon	5.79	
6	Light cold smoke		
	a) sliced	8.90/lb (whsl)	
		9.70/lb (retail)	
	b) side	7.40/lb (whsl)	
		8.40/lb (retail)	
	Hard smoke		
	a) Squaw Candy (strips)	6.40/lb (whsl)	Byproduct of Nova Scotia
		7.40/lb (retail)	
	b) Jerky	9.00/lb	Backbone
	Smoked cod:		
	a) side	2.35/lb (whsl)	
		2.70/lb (retail)	Restaurant
	b) 5/2 fillets	3.00/lb (whsl)	
		3.50/lb (retail)	

Prices current for April 1981.

Table 14. Some smoked fishery items currently on the market

SALMON	CHUB
COD	SHELLFISH
STURGEON	OYSTERS
ALBACORE TUNA	CLAMS
MAHI MAHI	SHRIMP
WHITEFISH	CRAB
BLACK COD	ALEWIVES
MULLET	CARP
HALIBUT	SQUID
SHAD	OCTOPUS
HERRING	CAVIAR

NOTE: These products originate from a variety of species and portion and are prepared in a wide variety of sauces and oils.

smoky "jerky" product. A wide variety of sauces, oils and other packing media are used in canned specialty items which are often used in gift packs.

Many of the above items are currently sold on relatively restricted markets and could be considered "products of the future" in many geographical areas. The minced flesh or formulated products, other than a few canned smoked spreads, represent an unlimited potential for high quality new products that can be made from inexpensive raw materials. These raw materials can be extruded from waste and scraps now discarded or sold for cheap animal feed. Furthermore, a volume of minced flesh equal to that of the fillets will become available as the high seas 200-mile limit fisheries develop.

At the University of Washington, we have been actively developing some of these formulated-extruded products, both canned and dried. A good example is a smoked-dried patty utilizing minced flesh as the base (Bello and Pigott 1979, 1980).

SUMMARY

For many centuries smoke was used in combination with water removal to preserve fish. Today, properties of smoke being desired by consumers are used to enhance flavor and odor. It is only recently that the processing techniques and the smoking-drying facilities for producing smoked products have included modern scientific principles. It is important to control:

1. the temperature and composition of the smoke,
2. the heat content, humidity, and composition of the smoke-air mixture,
3. the flow rate and geometric flow pattern of the smoke-air mixture, and
4. the final deposition of the smoke components.

As you have witnessed over the past two days, knowledge of the variables controlling the final product and mordern engineering principles applied to smokehouse and facility design are rapidly bringing the art of smoking to a science. This approach has made the United States the most important food producer in the world. Why not add smoked fishery products to the list?

LITERATURE CITED

Barylko-Pikielna, N. 1977. "Contribution of Smoke Compounds to Sensory, Bacteriostatic and Antioxidative Effects in Smoked Foods." Pure and Appl. Chem. 49:1667-1671

Bello, R. A. and G. M. Pigott. 1979. "A New Approach to Utilizing Minced Fish Flesh in Dried Products." J. Food Science 44(2):355-358.

Bello, R. A. and G. M. Pigott. 1980. "Dried Fish Patties: Storage Stability and Economic Considerations." J. Food Proc. and Pres. 4:247-260.

Burgess, G. H., C. L. Cutting, J. A. Lovern, and J. J. Waterman, ed. 1967. Fish Handling and Processing, Chemical Publishing Co., New York, NY, pp. 71, 263.

Chan, W. S., R. T. Toldeo and J. Demy. 1975. "Effect of Smokehouse Temperature, Humidity and Air Flow on Smoke Penetration into Fish Muscle." J. Fd. Sc. 40(2):247.

Chen, L. and P. Denberg. 1972. "Interactions of Some Wood Smoke Components with ε-amino Groups in Proteins." J. Agr. Fd. Chem. 20:1113-1115.

Dvorak, Z. and I. Vognarova. 1965. "Available Lysine in Meat and Meat Products." J. Sci. Food Agr. 16:305-312.

FAO. 1978. <u>Yearbook of Fishery Statistics</u>, vol. 47.

Griffiths, F. P. and J. M. Lemon. 1934. "Studies on the Smoking of Haddock." Bureau of Commercial Fisheries, Dept. of Commerce, Washington, D.C.

Husz, J. 1977. "Physical and Chemical Processes Involved in the Production and Application of Smoke." Pure and Appl. Chem. 49:1667-1671.

Iwaoka, W. Personal Communication. University of Washington, Seattle, Washington. April 20, 1980.

Lee, J. S. and D. K. Pfiefer. 1973. "Aerobic Microbial Flora of Smoked Salmon." J. Milk and Fd. Tech. 36(3):143-145.

Regier, L. and A. Tappel. 1965. "Freeze-dried Meat III. Nonoxidative Deterioration of Freeze-dried Beef." Food Research 21:630-639.

Reiner, H. 1977. "Analysis of Smoke and Smoked Foods." Pure and Appl. Chem. 49:1655-1666.

Roper, C. D. 1934. "Studies on the Smoking of Haddock." U.S. Dept. of Commerce 1:2-10.

Tilgner, D. J. 1977. "The Phenomena of Quality in the Smoke Curing Process." Pure and Appl. Chem. 49:1629-1638.

DESCRIPTION OF THE SMOKING PROCESS: HOT SMOKING

Vern Swanes
Northern Fish Products, Inc.
3911 So. 56th Street
Tacoma, WA 98409
(206)838-1220

Northern Fish Products Company was founded in Tacoma in 1912 by my father and grandfather. In 1945, I went to work with my father and two other employees. From that little company, we have grown to 14 employees--and that is where we plan to stay. There are a lot of advantages in staying small. If you have less than 14 employees, many federal regulations do not apply, hiring rules are different, and we have some advantages in purchasing. For example, we buy only about 300,000 lbs of salmon a year, which is peanuts compared to some of the large companies. We can buy that amount in bits and pieces over the season at advantageous prices. If we were to need more than this quantity, we would be forced buy on the open market and pay top dollar. This would require us to raise the price of our kippered fish, and then it probably would not sell.

Our kippered fish competes in the marketplace with chicken and hamburger. We are not trying to be a gourmet producer--we are trying to make our kippered fish as much an everyday product as possible. We have not raised our prices in two or three years.

If the retail price is low enough, and the product of satisfactory quality, you do not need any other strategies or a lot of salesmen. If consumers can be induced to buy the product and if they enjoy it, they will come back and buy again.

I should talk about prices for a minute. We sell our kippered salmon product to wholesalers at $1.95 per lb, and the market will add perhaps another dollar to make it $2.95. Well, $2.95 for salmon is pretty low for a product in the meat department. I think some of the fishermen here will confirm that they often get more than $2.95 for their fish at the dock. And our product is processed! Our kippered salmon is priced lower than the sliced salmon or unprocessed halibut and is in the same refrigerator cabinet. That pretty well takes care of our marketing theory. Let me now talk about our plant.

When I went to work with my father, we had an old two-story building with floor sills laid in mud. On the first floor we dressed the product and prepared it for smoking. Clean-up was a pretty tough job since we could not use hoses. The product was put on an elevator and sent to the second floor where it was put into the smokehouses. After smoking, we had to bring it back down in the elevator for packaging and shipping.

Bob Cavanaugh, who was the Seattle-King County health inspector then, and I got started in business at the same time. Bob and I always got along well. He came down, had a look at the plant, and said it was bad. When I asked him what I should do with it, he said, "Burn it down." So I did.

Well, really, about 25 years later we had a very severe fire that destroyed the plant. Since I was the only person in the plant at the time, the first inspectors and insurance people looked pretty closely at things. But they looked at our profit margin and decided I did not have a reason for arson, and paid on the policy. With 25 years of business behind me, the fire was like having a second chance to do things correctly and as we wanted do. We could now build ourselves a modern, efficient plant. Incidentally, I did not burn it down!

Looking for advice, we went to the Food and Drug Administration and the Washington Department of Agriculture. The federal Good Manufacturing Practices (GMP) were just then coming out, and we paid a great deal of attention to them. We built a 10,000 sq ft plant (100 ft by 100 ft). After the little cubbyhole we had been in, we thought we would never fill it. We did not have a forklift before, and now we have three.

The plant was built with the smoke ovens walled off from the rest of the processing area. Not only does this separate the raw fish from the processed fish, reducing the chances of cross-contamination, but it helps keep the plant clean. The hoods used to catch the smoke escaping from the ovens do not work very well, and soon the entire plant becomes smoky and grimy. By putting up a wall and separating the ovens, the rest of the plant stays clean. In fact, we have white walls and ceilings, and they stay white. That white paint really pays off when a health or FDA inspector comes in, since that first favorable impression is valuable. We spend about one hour a day cleaning it.

The smokehouse portion has three ovens, each with its own smoke and heat generator. Each oven takes two carts of product, weighing about 5,000 lbs. Beneath each oven is a 6 ft deep pit. At the bottom of it is a gas-fired ring burner that heats a pant of sawdust. The sawdust chars and creates the smoke. Just below the carts of fish are two gas burners that supply heat for the process. Although our property is zoned as heavy industrial, we are not allowed to emit any smoke, so we have a smoke reburner.

Mel Eklund helped us solve our processing problems and kept us clear of any botulism problems. One thing I should bring out is that I suspect we are the only processor complying with the 5 percent salt rule, as specified by the FDA. We do not like it, but the FDA said that for our product we have to have a final salt content of 5 percent. Those regulations are not in effect now, and we are working with Mel to lower that salt level. But in the meantime, we get nasty letters from people who do not like that much salt. But at least we are shipping a product that is safe to eat.

Earlier today, I said to Dr. George Pigott that there certainly is a lot more to being in business than simply learning how to hot smoke fish. Do not misunderstand me, it is not easy to hot smoke fish and do a good job. But if you go into business, I think you will find that it is the easiest thing you have to learn. For example, I was a pretty naive person to think everybody would work together to get the job done in the cheapest and best possible way. And then I learned about politics! We have politics and internal strife inside the company. There are politics between my company and other companies we deal with, or do not deal with. There are politics with the government--local, state, and federal. There are all the inspectors, auditors, fee collectors, permit givers, soothsayers, and whatever. You would be shocked at all the taxes and taxing agencies--city, county, state, and federal. It is always $5,000 for this and $5,000 for that. Sometimes I wonder how we can possibly make a profit. Like I said, smoking is the easiest part of the business.

Let me talk about plant equipment for a few minutes. We have a fork truck with an attachment on the front end that allows us to rotate and dump totes and tubs of product. That is probably the best piece of equipment we ever bought. It saves a lot of broken backs and really speeds up our product handling.

We use five pickup trucks. They bring in raw material and distribute the finished product. About half of our product dollar volume is in supermarket distribution.

We have gas-fired, 450 gal hot water tanks. We use a lot of hot water for thawing the raw product and cleaning the plant.

We had aluminum storage bins built for us several years ago. These bins have closed channels on the bottom so the rotating forklift can lift and turn them. That saves the labor of two people.

We also have a 45 kw auxiliary generator. We think it's a pretty important insurance policy. Its cost is small when compared with 200,000 lbs of product in the freezer lost during a power outage. Our generator has an exercise period every Thursday at 1 p.m., when it takes off and runs.

We have a thermometer on each of our smoke ovens continuously recording its internal temperature for a week. Then we file the chart. As Ken Hilderbrand said, you must have proof of the temperatures at which you smoke, cool, and freeze the product. These charts have come in handy a few times. Also, we use them for our own information so we know what is going on. It is to your advantage to keep good records of everything: species, source, seller, age, condition, and so on.

We cut most of our raw product on bandsaws. We try to use all the parts and pieces: tails go for salmon snacks, bellies and tips are separated and go for other products. Our storage freezer holds about 200,000 lbs of raw product. In our finished-product freezer we generally keep about 15,000 lbs each of kippered salmon, kippered halibut, and cod. We keep somewhat smaller quantities of various other products. By keeping this amount of inventory on hand, we do have to add people when business gets hot and we do not have to lay them off when things get slow. It is amazing that we have never laid off any of our regular crew. We kipper the same amount every day, and it all balances out.

We use a cooler to help us in the brining process. When the GMPs came in, we bought an injector machine like that used to inject brine into bacon and ham. We desperately needed to find a way to get 5 percent salt into the fish. The injector machine did not work at all. Then Dr. Eklund helped us, and we now put our fish in tubs with brine and hold them in the cooler until they equilibrate--or until the salt works its way through every part of the fish.

We mix our salt in a tank equipped with a Lightnin' mixer. We mix salt brines of 20 to 40 percent--depending on product thickness, species, and how long it will be sitting in the cooler. We check the brine with a salinometer. Each batch of fish requires a different strength of brine, so rather than brining in large tubs, we use small pans that hold only about 50 lbs of fish. This can get complicated, and you need to watch it carefully.

Halibut is about the only fish that we do not saw and cut while it is frozen. I am sure that all of you know that worms are not uncommon in bottomfish. Most, or all, of these worms are not parasitic to humans but they are pretty bad aesthetically. One pregnant woman said she found a worm, felt sick and, "That will be $25,000 please." So to avoid that sort of thing, we candle our halibut. That is, we pass each piece of halibut over an opaque glass with a strong light underneath it and use scalpels to remove the worms.

We have an automatic stitcher for making boxes and an automatic strapping machine. We do not do any vacuum packaging in any form because of the botulism danger. We wrap our finished product in a breathing sheet of cellophane, then put it in the box and overwrap it.

Well, that is about all I have to say. But, as I said earlier, smoking is the easy part of the business. I am anxious to hear your questions since that is often the best way to get at the specific information you really want.

QUESTION: What is your freezing technique?

ANSWER: We wrap the product in cellophane, then put it in a box with a poly-liner. The unlidded boxes are stacked on a cart with spacers between each layer of boxes, then wheeled into the freezer. In 24 hrs the product temperature is down to 0°F. We are planning to build a new building with a blast tunnel. Then we will put the fish on racks and freeze them in less than an hour.

QUESTION: How long does smoked fish keep in the freezer?

ANSWER: I can only talk about a hot-smoked product. We wrap it in cellophane, put it in a carton with a liner and close it up. That pretty well limits any dehydration and we feel it will hold up for three months in our freezer. The grocery store may keep it for an additional two months. If it was a good product when it went into the freezer, if it was well wrapped, and if the freezer temperature was low enough and held steady, it will be a good product after five months.

QUESTION: How do you keep your product from dehydrating in the freezer?

ANSWER: Proper packaging. We first put a breathable wrap around it, then we put it in a poly-bag. The poly-bag is not sealed but wrapped all around the product. Then we put it into a carton and put a slip-on lid over it. So the product has at least three layers of material protecting it.

QUESTION: Wouldn't your products have a better shelf life if you put them in vacuum packages?

ANSWER: Most likely we could get six to eight months shelf life in our freezer if we used vacuum bags. Then the retail outlet could get a few more months, and the product would have a better appearance. However, we cannot control product mishandling by other people. Suppose the freezer unit on the truck goes out, or an overzealous clerk stacks the bags above the frost line in the store cabinet, or someone leaves the bag out of the cooler too long. There are lots of mistakes that could happen and any one of them could produce a case of botulism.

One large supermarket demanded we vacuum pack all their product. I told them to check into it, and now we are selling them a non-vacuum packed product.

QUESTION: Do you buy fish that have been frozen in the round?
ANSWER: We will not accept fish frozen in the round.

QUESTION: Do you buy direct from fishermen?
ANSWER: No, we buy from wholesalers. We buy only dressed fish, either fresh or frozen. We do not buy round fish because we are not set up to clean and dress them.

QUESTION: Do you ever buy salted salmon?
ANSWER: In 1950 we could not get our hands on any fresh salmon so we bought several pieces of mild cure. It was a real tragedy for us because we just could not make a good hot-smoked product out of it. We won't buy any more.

QUESTION: Do you hand fillet any product?
ANSWER: No. Except for halibut, we cut everything on bandsaws. The reason is that we lose less. It is hard to get people who are good with knives and if you get someone who is not, you wind up with a product that is all slashed. We have good sawers and they cut the frozen fish right down the middle so each side gets a piece of the backbone. The ribs are also left in. We get a nice, cleanly cut product with very little waste.

QUESTION: Do you salt your salmon in the round or as fillets?
ANSWER: We cut all our salmon on the saw into 5 to 8 oz chunks and salt it that way.

QUESTION: What do you do with salmon bellies?
ANSWER: If they are thin, they do not look good in the market, so we cut them off and use them for tips. Unfortunately, that brings a lower price.

QUESTION: Can you tell us anything about the quality of the salmon you purchase?
ANSWER: Well, you really have to be careful when you buy a lot of fish. Just because one or two fish in a lot are of top quality does not mean the whole lot is.

We have some employees with 20 to 30 years of experience who can tell at a glance whether the fish are good or not. They examine each fish as they saw it. If the quality is bad, out it goes.

Do not take any poor quality products unless you can get them for a really low price and can afford to throw them out--or send them back. Those details must be worked out in advance or you will have a real argument on your hands.

We have built up a trust with some of our suppliers and often they will send us a lot of top grade fish only.

QUESTION: What kind of salmon are best to kipper?
ANSWER: We prefer large red or white kings, but we cannot afford it because we only get a 60 to 70 percent yield. That is, from 1,000 lbs of frozen, head-off salmon we get 700 lbs of kippered product.

Troll pinks are good fish but because the belly is so thin, it must be cut away. They give us a 30 to 40 percent yield. Sockeye are good and so are chums. In other words, it really does not matter which species you use.

QUESTION: Do you use hatchery fish--that is, spawned-out fish?
ANSWER: No. They just will not work.

QUESTION: Do you smoke pen-reared salmon?
ANSWER: We have never had any sea farm fish but I cannot see why they would be bad. They go through a life cycle just like the wild fish do.

QUESTION: Do you color all your products?
ANSWER: Yes, we do. We have found it very difficult to produce if we do not use color. As you know, many food products are purchased on the basis of eye appeal. If a product looks unappetizing, chances are it will not be bought. Salmon is easy to make look good, but when you take black cod, halibut, or any of the white or light colored fish and smoke it, it turns a dirty gray. It looks pretty bad and it doesn't sell. So we color it.

In the past, we used the colors on the FDA's Generally Recognized as Safe (GRAS) list. Now, we are trying to shift over to natural colors. With a great deal of work and time, I found we could use beet color. It is difficult and you have practice with it or you will get some pretty strange results.

QUESTION: How long do you brine your fish?
ANSWER: Generally, we keep the fish in the cooler in brine for 24 hours, then pour off the brine, and let them dry for another 24 hours so the salt can equilibrate. Then, on the third day we put them into the smokehouse. This procedure varies somewhat depending on the fish.

QUESTION: Do you control your brine temperature?

ANSWER: Yes. We put the product to be brined in small tubs and store it in the 35°F cooler until it is equilibrated. If you do not do that, the bacteria will grow and cause trouble.

QUESTION: Why do you keep your salt level at 5 percent if the smoked fish GMPs are not in effect?

ANSWER: Well, we have changed it somewhat. We are shooting for 3.5 percent salt on the average. Then, if we get a thick piece, it may get a little less salt but we hope not less than 3.0 percent. We feel that is a safe product.

We are gun shy on salt content for another reason. One time, when the GMPs were just getting started, the FDA checked some of our product in Los Angeles and San Francisco. They said it was only 1.5 percent to 2.5 percent salt and that we were in violation of the GMP. I am not sure exactly how they said it, but they wanted us to voluntarily withdraw the product from the market and destroy it. So we brought $10,000 worth of product back from Los Angeles and hauled it to the city dump. That got my attention and we watch our salt contents pretty closely.

QUESTION: Couldn't you have done something else with the fish rather than destroying it?

ANSWER: Perhaps. I do not know. We did not argue with them. We considered going to court but felt we would lose. We decided to do what they wanted and get on with business.

QUESTION: Why do you even bother with the GMPs on smoked salmon now that they are no longer enforced?

ANSWER: It is the salt/time/temperature relationships that are not currently being enforced. These are being reworked and rewritten and we expect they will be published soon. On the advice of Dr. Eklund we maintain our salt levels no lower than 3.0 percent and higher if possible. This salt level plus adequate refrigeration will prevent any problems with botulism. So, we follow his advice in order to keep our customers healthy and our business going.

No, as far as the rest of the GMPs are concerned, they deal with product handling, plant layout, and sanitation. All of those regulations are enforced whether you smoke fish or not. We keep our plant sanitary because we can put a higher quality product on the market and because it keeps us out of trouble with the health inspectors.

QUESTION: Do you rinse the fish after brining?

ANSWER: No, that would be another process and checking procedure we would have to go through.

QUESTION: Do you agitate the fish while it is being brined?

ANSWER: Yes. We use a stainless steel stirrer for agitation. We also turn the top pieces over so they are skin side up. We fill our brine tubs one-half to three-fourths full of fish and then fill with brine. This way the fish pieces all float freely.

QUESTION: Do you use hot water to make your brine?
ANSWER: We used to. Now that we have an electric mixer we find room temperature water is better. After we make the brine, it goes into the 35°F cooler.

QUESTION: How many times do you use your brine and how to you dispose of it?
ANSWER: We use it once and then dump it into the sewer. However, before putting it into the sewer we screen it so no fish chunks go in. We never reuse brine.

QUESTION: How do you thaw your fish?
ANSWER: We adjust the temperature of a tank of water to 45°F. Then we dump the fish in and let it stand for two to three hours and it is just right.

QUESTION: What can you tell us about raw material costs and yields?
ANSWER: Well, it is different for every batch. If we get a batch of river chums, we cut the bellies and put them into tips. You get less for the tips than for kippered salmon, and that changes the cost. If we get a batch of troll-caught kings, we leave the bellies on because they are nice and thick. Then our costs go down. We try to keep our costs down to about $1.50. We weigh each batch of fish as it comes in and as it goes out. We add our fixed costs or overhead and then we can figure what the fish really cost us.

QUESTION: What do you do when you buy too many fish in a season?
ANSWER: That situation never really happens to us. We are buying all the time, or at least making offers. We are also only buying at a certain price range. If we do get more than what our freezers will hold, we put it into public cold storage. I have never thought we had too much fish on hand.

QUESTION: What kind of market outlets do you have?
ANSWER: We try to distribute through grocery chains. Then we can ship directly to their central warehouses. That way we can sell large lots of fish and deliver to just one place. We also sell directly to supermarkets, but that is a fairly small portion of our sales.

QUESTION: How do you clean your ovens?
ANSWER: The oven ceilings and walls get smoky but they do not pick up any dirt or fish. The floors get all the drippings. About once every two weeks we climb down into the pit and shovel the drippings out. Then we use a chemical floor cleaner and heat up the oven to dry it all out.

QUESTION: How do you treat your screens or racks to keep the fish from sticking?

ANSWER: That is a big problem. Many people dip the racks in various solutions that take everything off--right down to bare metal. Then the product sticks worse than before. We take wire brushes and scrub off all the loose and big pieces of material. Then we put them back into the oven and cook them at the very highest temperature possible. That leaves a little bit of grease on the racks, just enough so the fish does not stick. We do that about three times a week.

We also put vegetable oil on the racks with a paint roller everyday. We tried spraying but that does not work. We just roll it on and it works fine.

QUESTION: Do you use any liquid smoke?
ANSWER: Not now, but we are experimenting with it and perhaps some day we will.

QUESTION: Can you describe the design of your ovens?
ANSWER: Each oven is about 30 ft by 12 ft square and about 8 ft high. It will accept two racks of fish. Beneath each rack is a perforated gas pipe which we light to produce an open flame. Below the oven is a 6- ft deep pit. At the bottom of the pit we have a ring burner and on top of that is a pan in which we put sawdust for smoke.

The ovens are built so we have tremendous air circulation. We do not dry our product all night like some people do because drying temperatures are the same as bacterial incubation temperatures. We put the fish in the oven in the morning, dry it, smoke it, and cook it all at the same time.

QUESTION: Do you have any problem controlling moisture or the even distribution of heat?
ANSWER: We do not have a heat distribution problem. We also test for moisture all the time, and it is not a problem.

QUESTION: What is your opinion of the smoke ovens currently on the market?
ANSWER: Today's ovens are so good that even someone who does not know a lot about smoking can produce a good product. In 1970, ovens were available but none were as large as we wanted, and they did not have certain features we wanted--so we built our own. If we were to start over, I would go right out and buy a stainless steel oven that could be pressurized. I think the new stainless steel ovens are really good.

QUESTION: How long does it take your people to fill the racks?
ANSWER: If we put 12 people on the job, it takes 2.5 hrs.

QUESTION: How do you clean up your plant?
ANSWER: We use lots of hot water, chemicals, and elbow grease. We use one kind of chemical on the tables and another on the floors. You need to find a good supplier and follow his recommendations.

You must do a good job. It is all spelled out in the GMPs. With a clean plant, you will produce a better product and have fewer problems.

A fish plant does not have to smell bad, and if you are doing a good job, it won't.

THE TORRY KILN

ITS DESIGN AND APPLICATION WITH PARTICULAR REFERENCE TO THE COLD SMOKING OF SALMON, HERRING, AND COD

Alex McK. Bannerman, MBE A.I.F.S.T.
Independent Consultant
Swanland, North Ferriby
Yorkshire
HU14 3QT
England
(144) 0482-633124

In 1933, I was privileged to join the Torry Research Station in Aberdeen, Scotland. I worked for the director, the late Dr. G. A. Reay, investigating fish proteins, freezing, cold storage, salting, and dehydration of herring and cod, and the analytical techniques to test these processes.

In 1936-37, I became involved in smoke curing fish, working with Dr. Charles Cutting. We started a research program to investigate the process of curing fish in traditional kilns. Some of these kilns were 800 ft square and 30 ft high. We measured air flow, temperatures, humidities, and weight loss of fish during smoking. From the data, we built a picture of the irregularities and disadvantages of smoking in these old kilns. However, this also led to improving the process. After several attempts, we developed a simple tunnel design in which fish could be smoked under controlled conditions. The process was more economical, faster, and the product more uniform. This is a bit of history, but it was from this work that we built our expertise and knowledge of fish.

A previous speaker suggested that with modern, programmable smoking equipment it is only necessary to push buttons, and "witch doctors" are no longer needed. I would agree with this for products such as salami, sausages, and other products manufactured from uniform ingredients in skins of uniform length and thickness. However, fish come in all shapes and sizes, with differing fat, protein and water content. In any smoking process, these differences have to be considered by the processor. Based on my knowledge of the old kilns, I became one of the "witch doctors" of modern smoking equipment.

Only very fresh or good quality thawed fish should be used for smoking since modern methods will not preserve flesh or mask off-flavors. All fish have to be prepared for smoking as in Figure 1. Whole fish are first washed in fresh or chlorinated water to remove any blood, loose scales, and other debris. With few exceptions (Table 1), fish are cut. Herring with the head on the gut in are used to produce bloaters and buckling. A buckling is a German herring cure which is hot-smoked. There is a little buckling production in the United Kingdom, but the herring are prepared by nobbing: removing the head and long gut, but retaining any roe or milt. This is done by cutting the fish behind the head, stopping before going through the gut cavity, then pulling off the head with the long gut attached. The Russians use "nobbed" herring and mackerel for freezing, canning, smoking, and fried products.

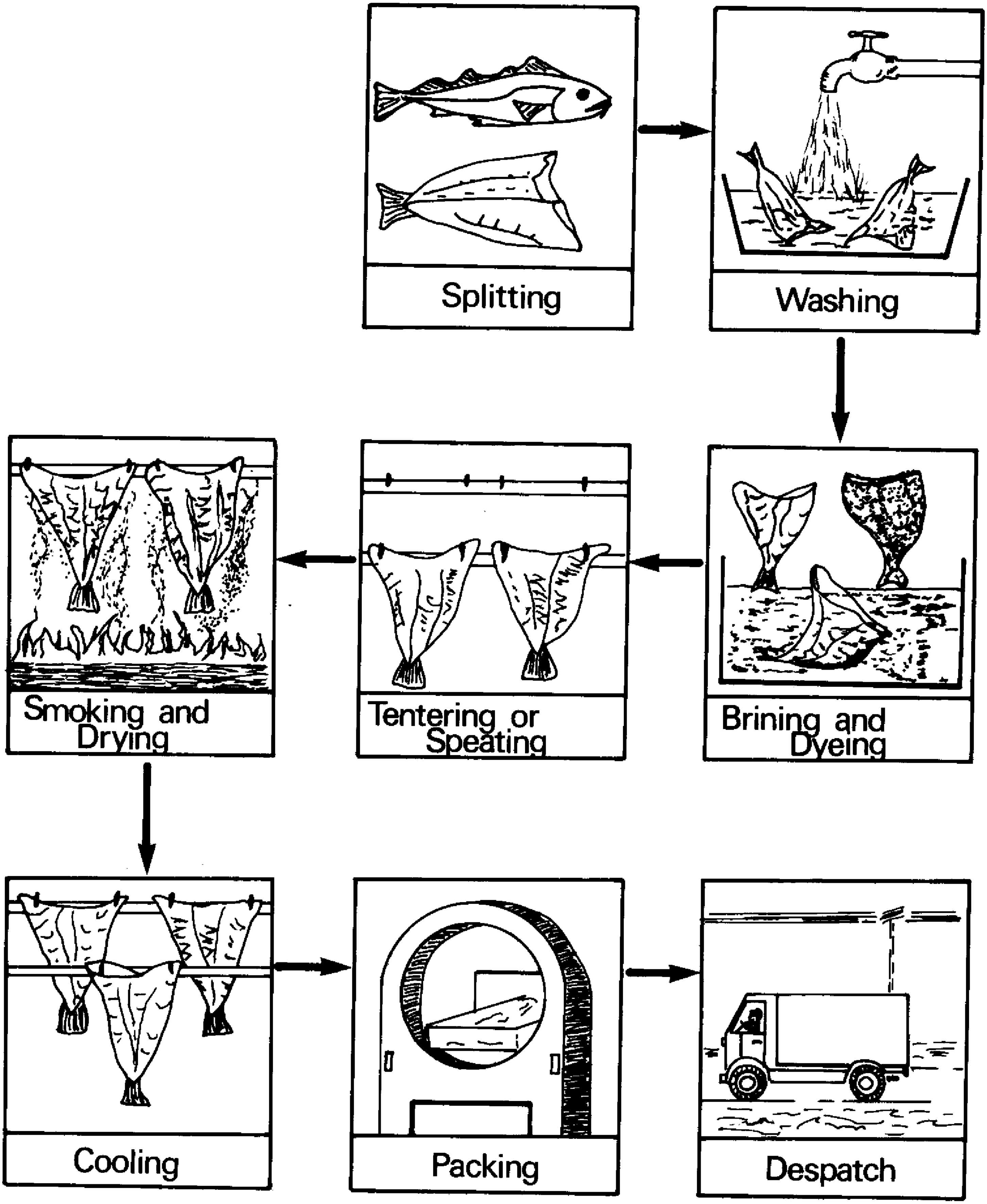


Figure 1. Basic steps in the processing procedure.

Table 1. Preparation of fish for smoking

Treatment	Species	Finished Cured
washed (loose scale removed)	all	
washed (loose scale removed)	herring	bloaters and buckling
head on, gut and gills removed	trout and mackerel	for hot smoking
"gibbed"	herring	red herring
"nobbed"	herring	buckling
head on "split"	herring	kippers
head off "split"	haddock	"Finnan"
"block," "butterfly") or boned fillet)	any small white fish, herring and mackerel	golden cutlets boned kippers
filleted (lug bone on)	salmon) large sea trout)	for cold smoking
filleted and trimmed	all white fish, mackerel	for cold smoking for hot smoking
washed, cooked, and shucked	mussels and oysters	for hot smoking

All cut fish to be washed free of any loose scales, blood and pieces of gut.

"Gibbing" is a Scottish term for herring which have gills and gut removed by cutting into the throat with a small knife. "Gibbed" herring are used for salting, and subsequently for red herring, probably the oldest commercial form of smoked cure. The herring are salted for weeks or months, desalted in running water, and hung in the kiln where they are smoked for 24 hours, cooled, then smoked again. This process repeats for several weeks. The cooling forces internal moisture to the surface where it is dried off with the warm smoke. Red herring are heavily smoked, very salty, dried, and usually exported to tropical countries.

For more popular kippers, herring are split along the backbone and the gut and roe removed, usually by machine. Boneless kippers and block haddock fillets are prepared by cutting behind the head, continuing the cut down either side of the backbone, removing the head and backbone so the two side fillets are left, still joined down the back. The "boneless" kipper was introduced after World War II, when iced herring were shipped overland in boxes. This resulted in some deterioration in the belly walls. Gut enzymes caused the walls to burst, producing a high proportion of second-class kipper. Most of the white fish cures are prepared from fillets, apart from "finnan" haddocks and Arbroath smokies.

Salmon are gutted, the gut cavity scraped, and all blood removed. The fish are then beheaded, but the lug bones are left intact, and the fish filleted. String should be threaded through the shoulder of each fillet under the lug bone to form a loop. This helps when handling the fish during further processing. Fillets from thawed fish can be very soft and must be handled carefully.

All fish have to be quickly washed in running water after cutting. After that, most fish are ready for salting. Prior to smoking, all fish are either dry salted or brined. Most fish which have been cut open are brined. Salmon is the exception in the United Kingdom, where it is always dry salted.

Salmon processing has, over the years, been looked upon as a mysterious ritual and a closely guarded secret. From time to time, various ingredients have been used in addition to common salt. These include brown sugar, molasses, spices, and rum. I personally would use only salt, put the brown sugar in my coffee and drink the rum.

In the United Kingdom, only fine, vacuum-dried salt is used. The salmon fillets are laid skin side down on a bed of salt about one-half to 1 inch thick. The cut surface of the fillet is then covered with salt about one-half inch deep at the thick end tapering down to the tail. At the thinnest part of the tail the salt is only lightly sprinkled over, in order to prevent the tail from becoming too salty and dry.

Salting time depends on the size and fat content of the fish. A rough guide would be six to eight hours for a 2 lb side and up to 24 hours for a 6 lb side. It is only from experience that a processor will get to know how much salt and salting time will be required. Salmon fillets can be brined, but the fillets will not lose any weight in brine, and may even gain some. This extra water has to be removed in further processing so the fillet will have the texture for slicing. Dry salting can remove from 6 to 9 percent of water.

After salting, any excess salt is washed off and the fish are allowed to drain before they are smoked. The salt content in a finished side of smoked salmon averages 5 percent. In general, the tail will have 7 percent, the middle section about 5 percent, and the thickest part of the fillet about 2.5 to 3 percent. It is not possible to equalize the concentration of salt throughout the fillet by either method of salting and this applies to all fish, either whole or filleted.

An 18 to 25 percent brine solution is used for salting smaller fillets from cod, haddock, herring, and mackerel. The fillets were usually soaked in tanks of brine with added coloring in batches of 56 lbs of white fish and up to 112 lbs of herring split for kippers. This bulk brining resulted in variations in salt uptake between batches, and also within a batch. There is now an automatic brining machine manufactured to handle these smaller fillets (Figure 2). The fish are fed into one end of the brine tank in a single layer and moved along by paddles to an off-take mesh belt which allows the surplus brine to drain back into the tank. This allows a uniform salt content in the fish.

Mechanical brining can reduce the brining time from one-half to one-third of the bulk brining time. For example, herring fillets with a 12 percent fat content could be bulk brined for up to 5 minutes, whereas only 1.5 minutes is required in the mechanical briner. This particular briner has a solid salt make up tank, variable paddle speed, complete recirculation system, and a filter for removing most of the debris. This briner is constructed of stainless steel and at the end of a day's production can be emptied out, washed down, and sterilized.

Most of the cold-smoked fish produced in the United Kingdom is colored with a dye added to the brine. This color, in some people's opinion, gives the finished product a more attractive appearance, however, some of these dyes do contain carcinogens and are being investigated by food additives committees.

The fish are all either brined or salted, hung on various pieces of equipment, or laid on wire mesh trays on trolleys, and allowed to drain for at least two hours. If the trolleys of fish can be stored at 3°C, so much the better. The fish's surface will develop a good gloss, and the smoking time could be reduced slightly.

I have digressed from the title of this talk, but I feel that the preparation and salting of the fish is as important as the smoking. I would now like to show a film entitled The Torry Kiln. This film was produced mainly in one of the largest fish smoking plants in Grimsby where up to 42,000 lbs of smoked fish were produced every 24 hours. The film is now 20 years old, but the kilns shown are still manufactured by the same company. The original principle of the kiln has not been changed. More sophisticated control equipment has been added, but the ghost of the "witch doctor" probably still has some influence!!

As already stated the Torry Kiln is, in effect, a simple wind tunnel operated by an electric fan (Figure 3). To go through the system briefly; smoke, from an external sawdust burning automatic smoke producer, is drawn into the kiln. Fresh air can also be sucked into the kiln and mixed with smoke. This smoke/air mixture passes over a thermostatically controlled electric

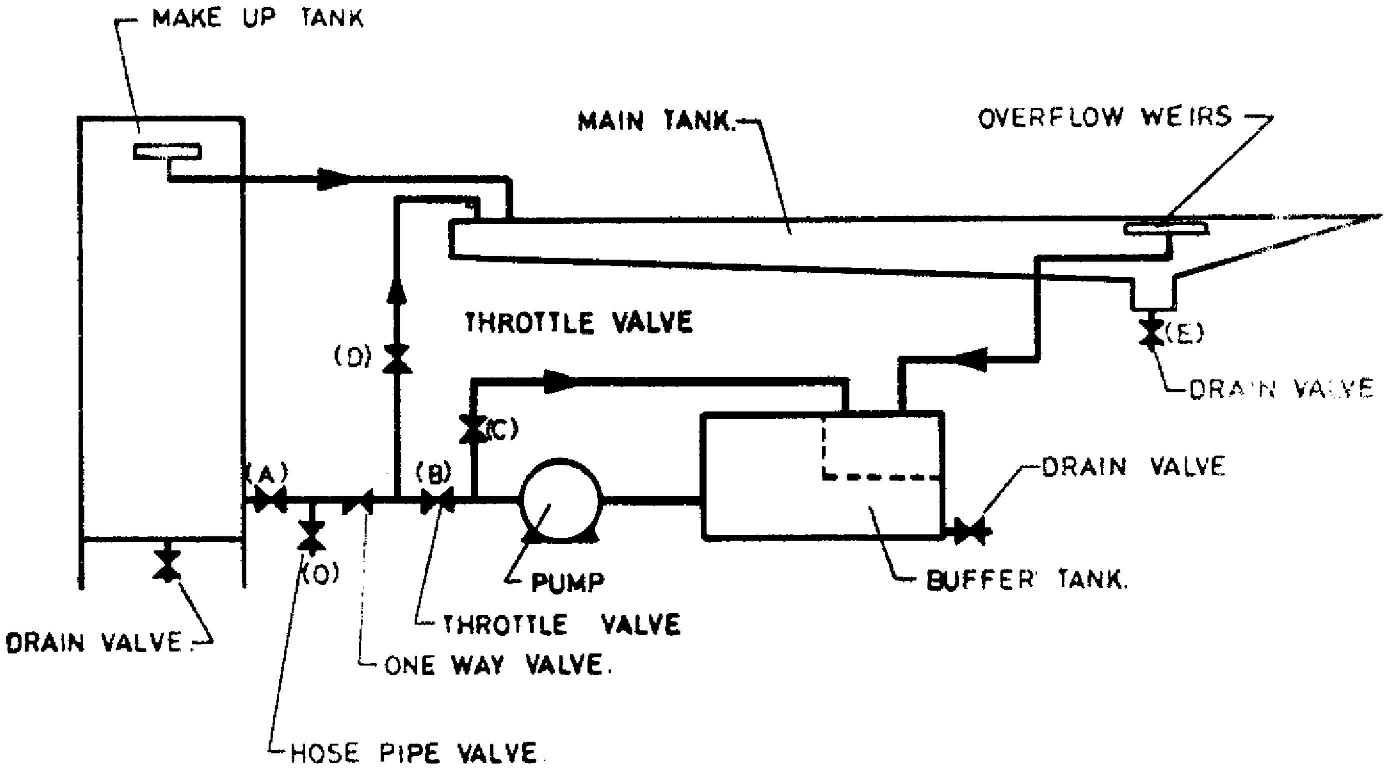


Figure 2. Digrammatic flow of brine

A)

B)

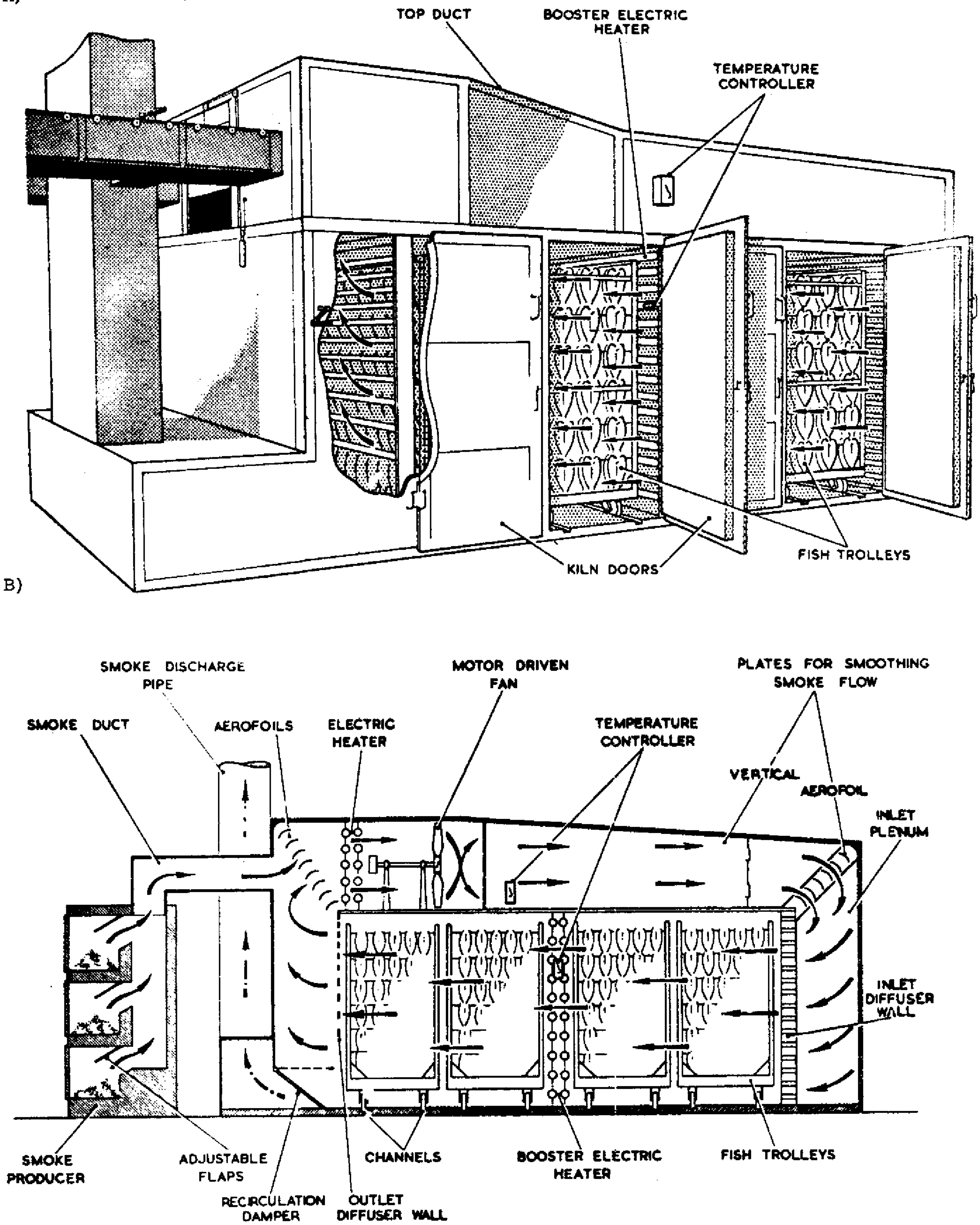


Figure 3. The Torry kiln; A) the smoke curing chamber in a Torry kiln, B) sectional view of Torry kiln and smoke producer

heater battery. The warm smoke/air mixture passes through an aero-roto fan and along the top duct. Splitters installed in this duct remove the whirl from the smoke and help to keep it in evenly distributed straight lines. At the end of the duct the smoke is diverted by aerofoils through an angle of 90° into a plenum. A diffuser wall in this plenum prevents the smoke from just flowing along the floor of the chamber. The diffuser wall is designed to even out smoke distribution so it is at a controlled temperature and a uniform speed from top to bottom and from back to front within the smoking chamber before it passes through the trolleys of fish. After the smoke has passed over the first two trolleys in a four-trolley kiln it has cooled, but is reheated by a thermostatically controlled heater battery, before it passes through the other two trolleys. The smoke picks up moisture when passing over the fish and a proportion of this wet smoke is vented up the chimney. The rest of the smoke is recirculated into the top duct and replenished with fresh smoke and air.

The smoke flows from the diffuser end of the kiln, therefore, the trolley of fish nearest this wall will always receive the freshest, driest smoke compared to the last trolley where the smoke is wet and contains less of the original smoke constituents. This is evened out by interchanging and reversing the trolleys at half time. For example, a kippered herring can be produced in four hours. At the two-hour stage, the two outer trolleys are interchanged and reversed. This is repeated with trolleys at either side of the center heater battery. In a one-trolley kiln, the trolley is reversed. I will explain the reason for this procedure shortly. In two hours, the fish in the first trolley may lose 10 percent of their weight, in the second trolley, about 7 percent. The smoke then passes through the center heater and the third trolley may lose 8 percent and the last trolley as low as 4 percent. Two hours after the cure is completed, all the fish will not only have lost the same 14 percent weight, but will also have the same flavor and color.

After smoking, the fish are removed from the kiln and cooled to at least room temperature or, if possible, chilled to 3°C before packing. The approximate smoking times, temperatures, and target weight losses are shown in Table 2. Apart from the temperatures, the other parameters have to be decided by the processor for his particular product. The Torry Kiln has a wide range of application in either hot- or cold-smoking foods such as fish, meat, poultry, and game.

I would now like to explain how a side of smoked salmon is sliced. The lug bone is cut off and the side is trimmed by cutting a thin sliver of skin along either side of the fillet, and by cutting out the small piece of the anal fin. The pin bones down the center of the fillet are pulled out using a pair of forceps or small needle-nosed pliers. These bones must be pulled out towards the head otherwise the flesh will tear. The side is then frozen down to -7°C. The skin is pulled off the frozen side by hand.

The side is placed head downwards into the slicing machine with the cut surface of the fillet facing the blade. The machine resembles a meat slicer. One person operates the machine and another reforms the slices on the skin, interlaying each slice with a small piece of grease-proof paper. The process can be completed in up to four minutes per side. The reformed side is placed on a backing board and vacuum packed in a plastic sleeve. Vacuum

Table 2. Fish smoking in a Torry Kiln

Cure	Time in Kiln (hours)	Temperature (°F)	Target Wt Loss %
kippers	4	85	12-14
kippers for canning	2½	85	12-14
kipper fillets	2½-3	85	10-12
cod and haddock fillets	3-5	80	10-12
"butterfly fillets"	2½-3	80	10-12
"Finnans"	3-5	80	12-14
bloaters	3-4	90	14-16
salmon	4-12	80-85	10
cod's roe	8-12	100	20-25
buckling	3	80-180	10-12
trout	2¼-3	80-180	10-12
eels	1½-3	80-180	12-15
mackerel fillets	2½-3	80-180	12-14

packs of sliced smoked salmon weighing 1 to 2 lbs are on sale in the United Kingdom.

QUESTION: What kind of wood would you use?

ANSWER: In the traditional kilns and in the smoke boxes shown in the film, there is a layer of whitewood shavings (pine) with hard wood sawdust banked on top. The hardwood recommended was oak, but this is no longer available, so mixed hardwoods are used.

In the film, the operator lights the front of the fire. It is kept burning by air sucked in through hit-and-miss holes in the door which the operator can adjust as the fire bed burns toward the back of the box. In an automatic smoke producer, only sawdust is burned. We found in the initial tests that if only hardwood sawdust is used, the product lacks the color and flavor required. Whitewood was mixed with the hardwood and eventually a 50:50 mixture was recommended.

In the United States, pine wood cannot be used, therefore, I can only recommend that you use the wood burned in your traditional kilns. I should mention that the sawdust should have a little water added, otherwise it will get so hot that instead of smoldering, it will burst into flames and produce more heat and less smoke. In the cold-smoking process too much heat from the smoke producer could override the thermostat setting for the heater batteries, and then you have no control.

QUESTION: During dry salting why are the sides of salmon left on benches at room temperature?

ANSWER: If a side of salmon is cooled, it will not absorb sufficient salt in the allotted time. Perhaps I should qualify "room temperature." In countries with higher ambient temperatures than Britain the room may have to be cooled.

QUESTION: What type of treatment do you use with your wash water?

ANSWER: Only fresh water from the main supply. In the United Kingdom the water is chlorinated at the source and I believe there are 0.5 parts per million free chlorine in our fresh water.

QUESTION: Why do you allow the smoked product to cool at room temperature?

ANSWER: If warm fish are packed straight from the kiln into boxes and then either chilled or frozen, they will deteriorate and go "moldy," especially the fish in the center of the box.

I should mention that there are several publications on fish smoking available from the Torry Research Station. One is The Kiln Operators Manual. This booklet details the principle and operation of the kiln with some recipes of smoked cured products. There are also Torry advisory leaflets which cover most aspects of fish handling and processing. The address for these is:

The Director, Torry Research Station, P.O. Box 31, 135 Abbey Road, Aberdeen, Scotland.

DESCRIPTION OF THE SMOKING PROCESS: COLD SMOKING

Ken Hilderbrand
Marine Advisory Program
Marine Science Center
Newport, OR 97365
(503)867-3011

INTRODUCTION

This presentation is based on the 1944 paper written by N. D. Jarvis, "Mild curing, pickling, dry salting, and smoking salmon" (U.S. Fish and Wildlife Service fisheries leaflet 60). Although this publication has been out of print for years, it contains a good background for smoking in general and cold-smoking in particular.

Other publications such as "Fish smoking: A Torry kiln operator's handbook" by Burgess and Bannerman have good information on other products. (See bibliography at the end of this publication.)

The purpose of this presentation is to point out the difference between hot and cold smoking and to encourage the art of cold smoking. Cold smoked products rely on salt to denature, or cook, protein. Hot smoking relies on heat to cook protein. As a consequence, cold smoked product contain some of the normal "indicator" bacteria when finished. The hot-smoking process kills these. For this reason, cold-smoked product will normally spoil before botulism flora can grow and develop toxin. In contrast, the hot-smoked product, if abused during handling, can have botulism develop unnoticed.

Even though cold-smoking is still very much an art, understanding of the physical principles involved will prove beneficial. Water phase salt, good sanitation, refrigeration, and good handling practices are all very important. The paper by N. D. Jarvis will help describe these principles.

MILD CURING, PICKLING, DRY SALTING, AND SMOKING SALMON

Norman D. Jarvis
Technologist
Bureau of Commercial Fisheries

(Ed's. note: Reprinted from Bureau of Commercial Fisheries leaflet 60, U.S. Fish and Wildlife Service, out of print, circa 1944.)

Mild-cured salmon is a lightly salted product which is largely dependent on refrigeration for preservation. This method of curing was first introduced on the Pacific coast in 1889 when a shipment was prepared for the German market but the experiment was unsuccessful. Salmon was not mild-cured in large quantities until 1898, when two small plants were established on the Columbia River. Packing of mild-cured salmon began on Puget Sound in 1901. While a few tierces were occasionally packed in Alaska prior to 1906, it was not until then that mild-curing was established on a commercial basis. A large part of the king salmon taken in southeastern Alaska is now mild-cured.

This product must be regarded as an intermediate or half-finished one, since a large proportion of the cure is used in preparing smoked salmon. Some of the pack was formerly sent to Germany and to Scandinavian countries for this purpose. Two world wars have disrupted foreign trade, but meanwhile, markets in New York, Philadelphia, Chicago, Milwaukee, and other large cities, have absorbed a considerable amount of the pack.

GENERAL INSTRUCTIONS

Mild-cured salmon must be handled more carefully than any other salmon product. In few food products is handling so important in determining the quality of the manufactured product. Red-fleshed king salmon is used almost exclusively and dressed fish weighing 18 to 20 pounds are the smallest sizes suitable for mild-curing. There is some variation in this minimum, as at Astoria, Oregon, fish of less than 30 lbs. in weight are rejected by mild-curers, while in Vancouver, Canada, the minimum size is 18 lbs. dressed weight. From time to time, packs of mild-cured chum and pink salmon have been put up, but have not found a market. Coho or silver salmon is the only other species utilized to any extent for the manufacture of mild-cured salmon and is usually prepared to fill market demands for low-priced smoked salmon. In 1943, according to the Pacific Fisherman, 611 tierces of silver salmon were packed in North America. Tierces average 825 pounds net weight.

Salmon intended for mild-curing must meet certain requirements as to quality. Fish must be (1) strictly fresh, (2) reasonably fat and in good condition; thin fish are not wanted, (3) the skin must be bright--there must be no "water marks" or other blemishes, (4) the flesh must not be bruised or broken--there must be no pew marks or other signs of rough handling, (5) they must not be belly-burnt, that is, show signs of softening in the abdominal region.

For this reason troll-caught salmon intended for mild-curing are always gutted when caught and packed in crushed ice aboard ship. Salmon taken by other gear are often gutted, or at least packed three or four together in a box filled with crushed ice, which not only acts as a refrigerant, but also aids in drawing out the blood. The boxes may be piled up in several tiers in the hold of the boat, but the weight is distributed, and individual fish are not weighted down more heavily than by the remaining contents of the box.

BUTCHERING

The first step in preparing mild-cured salmon is known as butchering. The butcher first removes the head, cutting from the back and leaving as much as possible of the bony structure just above and below the gills. With this preparation the fish stands up better under handling. If the bony structure were cut away, the sides would break easily in curing, and the hooks on which the fish are hung during smoking would be more likely to tear out.

The fish is then scored with three or four cuts along the lateral line. These are made just through the skin, but should not penetrate into the red meat. Scoring allows the salt to penetrate more rapidly, insuring a better cure. A specially designed, star-pointed wheel is sometimes used for this purpose. It makes a series of small cuts varying from half an inch in length at the tail to one and one-half inches at the shoulder. A number of extra cuts or scores are made if the salmon is large. After scoring, if the fish is not already gutted it is split down the belly to the vent. The viscera or entrails are removed as are most of the belly membranes, and a cut is made along either side of the kidney, the dark red mass found just below the backbone at the top of the belly cavity.

After dressing, the salmon is ready for the splitter, who holds the most important position in any mild-cured establishment. The grading of mild-cured salmon depends largely on the skill of the splitter. An unskilled or careless workman is often responsible for considerable losses. A specially shaped knife is sometimes used in splitting, the end of the blade being nearly square, but the type of knife used depends on the preference of the splitter and varies with individuals. The splitter turns the fish on its side, nape to his right and with the open belly toward him, and then forces the shoulder down on a sharp-pointed nail protruding from the table so that the fish will not slip. Short incisions are then made under the anal fin and just above and below the backbone. Then, with the upper lung or shoulder tip of the fish in his left hand, the splitter enters his knife at the shoulder above the backbone and holding the blade steady with the edge at a slight downward angle touching the bone, takes the whole side off with one sweep of the knife. If the work has been well done, little flesh will be left on the backbone and the side will be smooth. A thin line of bone will show down the center of the side which increases the value of the finished product.

To cut the second half loose from the backbone, a cut is made at the shoulder just under the bone. With the edge of his knife resting against the bone at a slight upward angle; the splitter separates the backbone from the flesh down to the root of the tail without removing the fish from the nail, again with one sweep of the knife. As with the first half, little flesh should be left adhering the bone, and a film of bone should show down the center. In other words, the two sides should be exactly alike.

WASHING

The sides are washed thoroughly in cold water and then passed to the sliming table where they are laid skin side down with the thin or belly edge toward the front. All blood clots, loose membranes, and fragments of bone are removed. Any blood remaining in the veins along the abdominal cavity is scraped off by pressing it toward the back of the fish either with the fingers or the back of a knife blade. If the blood is not squeezed out in this way, the salt will harden it during the process of curing, causing discoloration of the flesh, and lowering the value. Any slight necessary trimming may also be done at this time. Great care must be taken in handling the newly split sides as they are very tender and may be easily broken or bruised. In lifting them by the lug or collar bone, the curer should have his fingers to the inside and his thumb to the outer or skin side, otherwise the flesh may be broken.

From the slimers the sides are taken to a tank of ice water or iced brine. Warm water tends to loosen up the muscle flakes and if the salmon is left too long in cold water the effect is the same. This tank is known as the "chilling", or more commonly, the "sliming" tank. The latter name is a misnomer as all slime should be removed before the sides go into this tank. The object of this step is to prepare the sides for curing and it may be likened to case hardening. Unchilled sides would absorb too much brine, and the penetration of brine would be too rapid during the first portion of the cure. But this is not the only reason for chilling. It has two other important purposes. Chilling serves to draw out the blood, thus improving the color and also helps to prevent oil from oozing out of the flesh, which is apt to occur where such an amount of cut surface is exposed, especially under pressure during curing. There is some variation in the time the sides are left in the sliming tank. In some localities, the period is for two hours, in others from one-half hour to one hour. The temperature of the brine will vary from 30° to 40°F., and its salinity from 60 to 70 percent. It should be made with fresh water, boiled and strained before use, and changed daily.

After sliming, the sides are drained. This is done in another tank, or the salmon may be placed on a two-wheeled cart or portable table to drain. The fish are transported more easily and it is claimed the water drains off better where the second method is used. On the Columbia River, a cart holds just a tierceful of sides--seven lengthwise of the cart, and three at the end, or ten sides to a layer. This arrangement helps in counting the number of sides going into a tierce.

SALTING AND PACKING

When the sides of salmon have been drained sufficiently, they are taken to the salter, who works from a special bin or box of convenient height, filled with fine salt of the "dairy" type. A special grade of salt known as "mild-cure" is usually required. It fulfills the requirements of low content of chemicals other than sodium chloride, contains no organic impurities and is of small, even grain. The salmon is taken one piece at a time and placed in the salt box, skin side down. Salt is scooped over the side with the hands but it must not be rubbed or pressed into the flesh of the fish as sufficient salt always adheres. The side is picked up by the tips and excess salt is allowed to fall back into the box. It is then packed in a container known as a "tierce".

A tierce is a large barrel, made from fir or spruce, and bound by six galvanized iron hoops. It holds between 800 and 900 pounds of fish with the average around 825 pounds, cured weight. The gross weight, including pickle, runs between 1,100 and 1,200 pounds. A few handfuls of salt are thrown on the bottom of the tierce, then a layer of salmon sides, skin side down. In packing two sides of fish, alternating head and tail, are laid close to opposite sides of the tierce, the back or thick part of each side being placed close up against the side of the tierce. Other sides of salmon are packed from the sides of the tierce toward the center, napes and tails alternately, the back of each side being drawn half way up and resting on the side already laid. When complete, the layer should be level, this depending a good deal on how the last or center piece is laid. A little salt is scattered over each layer before starting the next one, and each layer should be laid at right angles to the one preceding. The top layer should be packed skin side up, and a little more salt should be scattered on this layer than on the others. The amount of salt used varies from 85 to 120 pounds to the tierce. One of the leading Canadian mild-curers uses 90 pounds of salt to the tierce, and this may be taken as the average, but some curers use as much as 15 pounds of salt per hundred pounds of fish.

There is some variation in the curing process at this stage. The tierce is filled only to the croze and in some districts it is headed up at once and filled with a 90° to 95° brine until the tierce will hold no more. In others the tierce is left from 24 to 48 hours before heading, and is then headed and filled with 100° brine. The pickle or brine should be made from the same salt used for rousing and packing the fish. The water used in making the brine should be clear and pure--in fact, drinking water. Before using, the pickle should be strained through a fine sieve or piece of clean cheesecloth to free it from any froth, dirt, or sediment. The strength of the brine is then determined by a salinometer. A centigrade scale salinometer is used by most mild-curers. The brine is usually made up to a strength of 90°C., but during the first week or ten days of the cure while moisture is being extracted it sinks to 70°C. in strength. After repacking, the strength of the brine should not fall below 85°C., and it should hold this strength some time.

After the tierces have been headed and filled with pickle, they are usually rolled into a room where the temperature can be kept down to from 32° to 34°F. Here they are stored in rows one or two tierces in height and left to cure. The temperature of the storage room should not be allowed to fluctuate, as this causes the oil to exude from the flesh, and to escape into the brine. The tierces are not always rolled into the chill room immediately after packing. Some curers, especially those working in cooler climates, leave the tierces out in the packing room for four days, then send them to the chill room for 10 to 20 days before repacking.

If the tierces are not kept full of pickle the sides of fish are apt to get shaken about and broken when the tierces are shifted while being inspected at intervals to determine the presence of leaks. No tierce is perfectly tight at first, and the staves absorb some brine. If any part of the fish is left uncovered by the brine, yellow, discolored spots develop, so-called rust spots, which lower the quality of the finished product. Therefore, it is extremely important to see that the tierces are kept full of brine during the curing period and also after repacking. A tierce of salmon may absorb several gallons of pickle in the first two or three weeks of cure, especially if the fish are "dry."

The amount of shrinkage during the first three weeks before repacking may be estimated at about 30 percent. Less shrinkage occurs in fat, ocean-caught fish, but thin, "dry" fish, especially those caught when well on their way to the spawning ground, may shrink as much as 35 percent in weight.

After the salmon has been held in storage at least twenty, but not more than ninety days, it is repacked. The tierces are rolled out and unheaded. Each piece is taken out carefully, remembering to hold the sides with the fingers on the flesh side and thumb on the outer, or skin side. The sides are sponged or cleaned off, removing all salt or other material on the surface. Either ice water or chilled brine are used to wash the sides of salmon, depending on condition. If the fish are soft and rather poor, they should be washed in brine, but if the sides are firm and thick, ice water may be used. It is the opinion of some curers that chilled brine should always be used.

WEIGHING AND GRADING

The next step is weighing and grading the sides. Unlike curers in other districts, those on the Columbia River grade twice. While the fish are being dressed three chilling tanks are used, one for each size. A rough grading into large, medium, and small sides is thus obtained. This is an advantage in packing and curing as the time required for curing varies with the size of the side and much work is also saved in sorting for repacking. When repacking, a careful separation is made into from 6 to 10 grades. The designations of the grades depend on the number of sides needed to fill a tierce, and are expressed as 40 to 50, 50 to 60, 60 to 80, 80 to 100, and 100 to 120 (sides per tierce). Slightly broken sides are graded as "B" of that size, other more defective sides are placed in a third grade and called culls. Color of the sides is also considered in grading, and pale or off-color sides are segregated. The system of grading differs somewhat in various districts, but the description given indicates the general method.

In repacking, the sides of fish should be replaced as nearly as possible in their original position; those curved in shape being placed against the sides of the container, and straight pieces laid in the center of the layer. No salt is used in repacking, but as soon as the tierce is filled, the head put in, and an examination made to determine the tightness of the tierce, it is laid on the side opposite the bung, and filled with ice cold pickle made to a strength of 90 to 95° salinometer. The tierce will contain about 825 pounds of salmon after repacking, and some 14 gallons of brine may be required to fill it. The gross weight will average 1,100 pounds. The tierce is then put back into chill storage and filled up daily with pickle, through the bunghole, for a week or more. If mild-cured salmon is stored for any length of time, the tierces must be tested for leakage at frequent intervals.

The head of each tierce is marked to show: number of tierce (consecutively); the number of sides of salmon in the tierce; and the net weight and the initial or brand of the packer. In some districts the tierce is marked with the packer's initials, place where packed, number of tierce, number of sides of salmon in tierce, the tare, gross, and net weight, quality of fish (I, II, and III or T), and size of fish L (large), M (medium), or S (small). In Vancouver, Canada, thin or broken sides are designated by letter X. If the salmon is of first quality no special mark is necessary, but second and third quality fish are always designated.

STORING

Mild-cure salmon must be shipped under refrigeration and held at all times in cold storage. It is kept at a temperature of 32 to 34°F., after repacking, but some packers, if the salmon is to be held for more than three months, hold it at a temperature of 28°F. The salt cure is not of sufficient strength to delay spoilage for more than a brief period. At one time attempts were made to reduce or eliminate refrigeration in connection with the mild-curing of salmon, by adding various preservatives. These were usually preparations of salicylic or boric acid, and the benzoates or other chemical compounds now limited in use by food and drug administrations, here and abroad. The use of these agents was soon abandoned, however, as it was found that quality was affected and the product was becoming unfavorably regarded by the buyers of cured salmon, so artificial preservatives have not been used since the earliest days of the mild-cured salmon industry.

PICKLED OR HARD-SALTED SALMON

Pickling or brine salting was the first method of preservation followed in the commercial utilization of the Pacific salmons. Long before any permanent settlement was made, our ships visited the northern Pacific coast to put up cargoes of salted salmon, which were later traded in Hawaii for sandalwood, or in China for furs, silks, teas, spices, or other Oriental goods. Hawaii remains today one of the principal markets for hard-salt salmon.

The method is found on a commercial scale in Western Alaska. While pickled salmon has been prepared at other points along the coast, no commercial packs have been made elsewhere for some years.

All five species of salmon are used to some extent in the preparation of hard-salt salmon, but the red salmon is the principal species used and is regarded as yielding the highest grade product. A considerable amount of pink salmon and silver or coho salmon is also salted. While king and chum salmon are occasionally used to some extent, very little of those two species is hard-salted. Some pickled salmon bellies are still put up, but the pack is very small. This is a choice product, but under the present law, bellies may only be packed when the rest of the fish is used for food in some other way. The major portion of the belly pack is made from pink salmon.

Quality is an essential consideration in packing salt salmon. It is important to use only fresh fish, for if not of this quality, soft bellies are very evident after salting. If the fish are stale, the bones will come loose from the flesh and stand out, giving the fish a ragged appearance. Salmon approaching the spawning stage cannot be used because of discoloration of the skin. The use of pews in forking the fish about is also detrimental in curing a good grade of pickled salmon. The holes made by the prong cause spoilage to advance more rapidly and dark streaks are left in the flesh, detracting from its appearance.

BUTCHERING

When the salmon are brought in to the saltery, they are washed, slimed, and beheaded, after which they pass to the splitter. There are two methods of splitting. In the first, the fish is split along the back, ending with a curving cut near the tail. The abdominal side is left as a solid section. Some two-thirds of the backbone is then taken out, and all viscera, blood, and membranes are scraped away. In the second method the fish is split along the ventral side, eviscerated, and all membranes are scraped from the abdominal cavity. In splitting, the neck end of the salmon is toward the splitter, who makes a slight incision at the neck end, just above the backbone. The whole side is then removed with one sweep of the splitting knife, leaving as little flesh along the backbone as possible. The knife is usually held so that the edge of the blade is at a downward angle. A short cut is made under the backbone on each side, just about the region of the anal opening. Another slight cut under the neck end of the backbone, and one sweep of the knife removes the entire backbone and tail. The two cuts are made under the backbone to direct the course of the knife, preventing it from slanting too much in splitting. Slanting causes considerable flesh to be left on the backbone, which is of course wasted. Some curers make one or more longitudinal slashes in the flesh so that the salt will "strike" or penetrate more rapidly. The loss in weight in cleaning and splitting averages 25 percent.

WASHING

After splitting, the salmon passes to the cleaners. These men scrape out blood clots and the kidneys, and remove membranes, loose bones or other offal. After cleaning, the fish is scrubbed thoroughly inside and out. Care must be taken not to injure the flesh, however. A final cleaning is given in the washing tank and the salmon are then drained thoroughly, preparatory to salting.

SALTING

Both round and square salting tanks are used, but the capacity of a tank should be not more than one hundred barrels. If the tank is too large, pressure on the lower layers of fish is excessive, and as a result sides of fish in these layers are distorted or otherwise injured. A thin layer of salt is scattered over the bottom. A layer of fish is then laid in with the flesh side up. No special system is followed in packing, and the only rule is that the work must be done neatly, with the layers as level as possible. Each layer is covered with salt, using from twenty-five to thirty pounds of salt to a hundred pounds of fish. Care must be taken that each fish is completely covered. The tanks are filled several layers above the top, to allow for shrinkage and the top layer is laid with the skin side up. The tank should be covered at all times, however, to prevent "rusting", that is, discoloration caused by oxidation. The fish are allowed to make their own pickle, which is formed as the salt extracts moisture from the flesh, bringing the salt into solution. From ten to fourteen days will be required for this curing process, though the salmon may be left in the tank for a longer period of time. Curers do not agree on the loss of weight in salting. The best estimate at present is that about fifteen percent of the moisture content is removed.

GRADING AND PACKING

The next step is repacking into barrels containing 200 lbs. net weight, exclusive of brine. In repacking, the fish is washed in brine and scrubbed well, usually with a stiff brush, though pieces of burlap have been used for this purpose. All slime, blood clots, excess salt, or other waste material should be removed. The salmon is then graded: (1) as to species (if one species only is being cured, this is not necessary); (2) the color of the flesh and skin, according as the flesh is of good color and the skin bright, or the flesh pale in color, with the skin murky or discolored; (3) as to quality--good or poor, that is, fish which were not strictly fresh when packed, and have a characteristic odor and flavor, must be separated from the rest of the pack.

After sorting, 200-lbs. net weight of fish is weighed out for each barrel to be packed. The sides are packed in, flesh side up, except for the top layer. A liberal sprinkling of salt is scattered at each end, but only a little is thrown between the layers. From 8 to 10 lbs. of salt should be a sufficient amount for repacking a barrel of salmon, if the fish have been properly cured. After the barrels have been headed they are filled with 100° (salinometer) brine, through the bunghole. One one end of each barrel is stenciled the packer's name or brand, the species of salmon, and grade.

SALTING SALMON BELLIES

A few salteries also pack bellies which are merely the ventral sections, the fattest and choicest portions of the fish. So much salmon was formerly wasted by this method, that the preparation of this article was forbidden under the Alaska fishery regulations unless some economic use is made of the remaining portions of this fish. (Section 8, Act of June 26, 1906, 34 Stat. 480; 48 U.S. Code 236.)[1]

In preparing salmon bellies, the curer first cuts off the two pectoral fins and then removes the head, taking care to follow the curve of the body until the backbone, which should be cut straight across, is reached. With smaller salmon, the fish is then turned on its back, a knife is inserted vertically in the body just above the backbone, and a vertical cut is made through the body, the knife coming out just in front of the anal opening. If properly done, the cut will come close to the upper wall of the abdominal cavity. With large king (also known as spring or chinook) salmon it is sometimes necessary first to make a cut on one side, then turn the fish over and cut through on the other side. The belly is then laid flat on the cutting table and the membrane at one end cut so that the belly will lie flat.

The bellies are washed thoroughly in clear, cold water, or in iced brine. The remainder of the process is identical with that just described for hard-salted salmon. Bellies are sent to the Seattle market in barrels holding 200 pounds net weight of fish, but are usually repacked for distribution to the retailer in small kits or tubs of various sizes.

---

[1]Also included under Section 201.17 of the Laws and Regulations for the protection of the commercial fisheries of Alaska. Fish and Wildlife Service, Department of the Interior, Washington, D.C.

DRY SALTING SALMON

Large quantities of salmon are dry-salted every year on the Pacific coast, mostly for export to the Orient. The greater portion of the pack is prepared in British Columbia. Little interest in this method of curing salmon has been shown in the United States for a number of years, but occasionally, when chum salmon are in little demand for canning purposes, quantities are available for dry salting at a price which should show a profit on the finished product.

Chum (dog) salmon is largely used in the preparation of dry-salted salmon though other species are sometimes used. In Siberia, where an increasing quantity of dry-salted salmon is put up every year, red and coho salmons are used to some extent.

In preparing dry-salt salmon, the heads are cut off, the fish split down the belly and eviscerated. The blood is scraped out as thoroughly as possible and the fish split again, if large. The backbone may or may not be removed, depending on the custom of the individual curer. As a rule, it is removed when the salmon is split. Small fish may be split almost through to the skin, but are left in one piece, and the backbone is not removed. The dressing and splitting process is the same as that already described in the method for hard-salted or pickled salmon, but is done with less care.

When the salmon are cleaned and split, they are laid down in stacks, with a heavy layer of salt between each layer of fish. All layers are piled flesh side up, with the exception of the top layer, which is laid skin side up, for the purpose of better protecting the fish against dirt or other contamination. If packed in large salting tubs or vats, the salmon sides are arranged as neatly as possible alternating heads and tails with the thick edge toward the side of the tub, small pieces being packed in the center to make the layer even. If cured in stacks or kenches, the salmon are laid down in rows, alternating heads and tails. The amount of salt required in dry salting is approximately 35 pounds of salt per 100 pounds of fish.

When the fish appear thoroughly cured, they are packed in boxes holding 400 to 500 pounds of fish, with salt scattered between the layers. No particular system is followed in packing, except that the packers endeavor to make even layers without large air spaces. From five to 10 pounds of salt per 100 pounds of fish will be used in repacking. The product receives no further processing, but if it is to be held any length of time before shipping, it should be repacked.

SMOKED SALMON

Several different methods of smoking salmon are used. Formerly a large proportion of the pickled or hard-salted red salmon from Alaska was shipped to Europe and the eastern part of the United States for smoking. Today, mild-cured chinook or king salmon is most used in salmon smoking, but varying quantities of silver, or coho salmon, are cured for this purpose, especially for the low-priced markets. Fresh salmon, lightly salted, is occasionally used for smoking, but the quantity so employed does not compare with the amount of mild-cured salmon used for the same purpose, with the exception of kippered salmon, for which fresh or frozen salmon is invariably used.

In preparing smoked salmon from mild-cured fish, the sides of salmon are taken out of the tierce and soaked overnight in a tank of fresh water, changing the water two or three times. Ten or twelve hours freshening should be sufficient, but a more thorough soaking may be required by some markets. Certain smokers freshen salmon for 10 hours in a tank with running water, especially if a large quantity is to be smoked. When properly freshened, the salmon is washed with a stiff bristle brush, to remove all traces of blood, slime, or encrusted salt.

The next step is draining and trimming. Draining is often done by water-horsing--that is, the salmon is placed on a pile, flesh side down and a weight placed on top of the pile to press out the water. After enough moisture has been drained from the flesh, the sides are trimmed of any ragged edges and wheeled on barrows or hand trucks to the smokehouse.

Wire hangers are used for hanging the salmon on sticks in the smokehouse. These are made of steel wire or light iron, and have six points at right angles to the frame at the lower end, and a curving hook at the top to hang over the smoke stick. A side of salmon is laid out flat, skin side up. The points of a hanger are pressed through the skin at the nape or neck end. Another workman in the smokehouse hooks the handle over a round smoke stick. In hanging the salmon, care is taken to leave sufficient space between sides and to guard against crowding or overloading the smokehouse, which would result in an inferior product with a shorter period of preservation.

The time required for the smoke cure depends primarily on the length of the period of preservation desired. If the product is for immediate consumption, 10 to 12 hours cure over a dense smoke should be sufficient. However, in most cases a longer cure is required as the smoked salmon may not be consumed within the next 24 or 48 hours. So, in these instances, after the smokehouse has been filled, a fire is started in the pit below and for some hours the fish is smoked over a clear fire with the ventilators left open so that moisture can escape, preventing the salmon from sweating in this initial period of smoking, which is really more or less of a drying process.

When the first period of the smoke cure has been finished, that is, after about 48 hours, the ventilators in the top of the smokehouse are closed, and the fire smothered with sawdust. A dense smoke is thus created, in which the salmon is cured for an additional period of two to three days. If a still more durable article is desired, that is, one which may be marketed over a wide area, and one which will keep longest under average conditions of temperature, handling, and storage, the curing may require a week to complete. In such case, the fire is kept low and smoldering during the entire period of the cure, not forming dense smoke. The process is a dehydration as much as a smoke cure.

When the cure is completed, the smokehouse doors and ventilators are left open. After the smoked sides are sufficiently cooled, they are weighed, wrapped in oiled or parchment paper, and packed in boxes with a usual net weight of 30 pounds. Smoked salmon must be stored at temperatures of from 33 to 40°F., if it is to be held any length of time, especially in summer.

The length of the smoking period and other factors involved in smoking salmon vary with the locality, type of product demanded by the trade, temperature used in smoking process, humidity, and similar factors. The process must be altered to meet changes in these conditions. Exact data as to temperatures giving best results are lacking. However, this is a cold-smoking process; though the fire must be high enough to cure the salmon; it must not give off too much heat, or the product will be partially cooked, and soon spoiled. The temperature should not exceed 90°F., and in general should be somewhat lower. As to the best type of fuel, alder wood is most commonly used on the Pacific coast, but almost any nonresinous wood such as maple or beech gives satisfactory results. Oak and hickory are favorite fuels among salmon smokers in the Atlantic coast area.

A small amount of smoked salmon is sliced like bacon or ham, wrapped in cellophane and sold in half or quarter pound packages to the delicatessen and grocery trade. Sliced smoke salmon is also packed in quarter-square cans of the type used for small oil sardines. A little olive or cottonseed oil is added to each can which is then sealed hermetically but not sterilized. While this product is not so perishable as ordinary smoked salmon, it does not have an unlimited period of preservation, and should not be exposed to high temperatures, or other unfavorable storage conditions. The maximum of preservation is achieved by keeping this product in a refrigerator or refrigerated showcase.

BELEKE

Some attempts have been made on the Pacific coast to market a hard smoked and dried salmon known as beleke, or Indian cure. Though it is superior in keeping quality and equal in flavor to salmon smoked by other methods, it has not met with much favor outside of Alaska as it is dull in color and therefore does not have the attractive appearance of the more perishable smoked salmon products. It is prepared commercially in Alaska for distribution in the territory and to a small extent in the Northwestern United States. Beleke makes an excellent appetizer or relish to be served with beverages, and there are possibilities in developing a better market. Red and coho salmon are the species used in preparing this product. One authority states that the backs only are used, cut in two or three long strips, the bellies being pickled and sold salted. Packers of beleke have informed the writer that though this may be done, it is quite as usual to smoke whole sides of salmon by this method.

If the bellies are to be utilized, pickled or hard-salted, the remaining edible portion of salmon is split in two sides, the backbone is removed, and each side is cut into several strips, longitudinally. These may or may not be washed in salt water. The largest, thickest strips of back flesh are then placed in a tank of 90° (salinometer) brine, followed in an hour by strips of medium size, and after an interval of another hour by smaller pieces. This procedure is followed so that all sizes will have the same degree of pickle. The strips are removed and drained after a period of from 16 to 20 hours. If whole sides are to be used, after cleaning and dressing as described under the preparation of pickled salmon, the fish is brined overnight or for a period of 10 to 12 hours in a 90° brine.

After brining, whole sides are fixed on smoke sticks, while strips are usually suspended by cords, run through one end as in smoking bacon at home. The fish is given an air drying of 24 hours to remove the surface moisture. At the end of this time the salmon is placed in the smokehouse, the ventilators are left open, and the salmon is smoke-cured over a fire of green alder wood. The smoking is done very slowly at a low temperature, not more than 70° to 80°F. Two weeks is the average period of time required to smoke beleke. This product was first prepared around Kodiak, Alaska, but a similar process is used in smoking salmon in other sections of Alaska. Beleke is said to have better lasting qualities than any other smoked fish, remaining in good condition for two and even three years. If surface mold begins to appear in storage, the fish is taken out, scrubbed in brine, given an air drying of several hours, and is then smoked for from 24 to 48 hours after which it is restored to a cool, dry place.

KIPPERED SALMON

Kippered salmon probably has a larger sale than any other smoked fishery product on the Pacific coast. It is sold in a few large centers in the east and middle west, but the greater part of the production is consumed in the western part of the United States. Practically all kippered salmon is prepared from white-fleshed chinook (king) salmon. This fish has little sale in the fresh fish market where it is considered inferior to other salmon by reason of its paler color. However, it is equal to the brighter colored salmon in food value and often has a better flavor. A constant supply of fresh fish at prices making profitable operation possible cannot be assured throughout the year, while frozen salmon is available all the year round, giving the curer an assured supply of raw material without wide fluctuations in price. Therefore, frozen salmon is used during a great part of the year and is split before it is completely thawed. Fresh salmon is much softer in texture, requires more care and skill in splitting, and the smoking period must be somewhat longer.

The first step in the curing process is to thaw out the salmon in tanks of cold water. In some establishments thawing is done with running water, in others, with standing water, changed several times. The time required for thawing varies from eight to 15 hours depending on the size of the salmon, and whether or not running water is used. Smaller-sized fish placed in running water will be sufficiently thawed in eight hours. As the salmon has already been cleaned and dressed before freezing, it is split into sides when sufficiently thawed, the backbone is removed, and the sides are cut into a number of smaller pieces. These pieces usually weigh about one pound each after curing, and are separated according to thickness. The thinner pieces will cure more rapidly, which is one reason for separating them, while another is that the thickest pieces are considered best grade. There are three grades or sizes (chunks), the thickest part of the back flesh; thins, pieces of flesh not quite so thick, and strips, thin pieces from the bellies of the fish. The names used for the grades may vary with the locality and among different curers but the separation into three grades is followed by practically all establishments on the Pacific coast. The third grade or size--for there is little difference in the quality--usually goes to the lower price markets. The Jewish trade buys a considerable amount of the strips as this size has a much higher oil content than the other two, the richer flesh meeting favor among the Jewish population.

After cutting, the salmon is placed in a 90° to 95° salinometer brine for from 30 minutes to two hours and 30 minutes, the length of the brining period depending on the size and thickness of the pieces, local preference in the market for which the salmon is destined, and on the time required for shipment.

When sufficiently brined, the salmon is drained, then dipped into a tank or tub of coloring matter. The dye may be added to the brine, combining the two operations in one, in which case the amount of dye used is less than when the fish is colored by dipping. The dye most often employed is 150 Orange I, an aniline dye, the use of which is permitted under the Federal Food, Drug and Cosmetic Act. Other red or orange dyes on the permitted list may be used. The dye solution is made up in strengths dictated by the experience of the individual curer, and it is not possible to set down exact rules as to the mixing of the solution which will apply to every situation. Where the fish is dipped in the dye after brining, experiments, carried out at the College of Fisheries, University of Washington, indicate that dipping for 15 to 30 seconds in a solution made up in the proportion of one part of dye to 3,000 parts of water is sufficient. This is given only as a general formula, to guide those without practical experience. The curer must determine requirements by experiment, and according to the desires of his customers as to the shade of color. The fish is dyed owing to a popular prejudice against a lightly colored kippered salmon. The dye used is harmless and does not affect the quality of the fish in any way, while it gives it an attractive color. For certain markets, principally in States where all artificial food coloring is prohibited by law, no dye is used.

When the salmon has drained for a short time, it is put into wire mesh-bottomed trays, made of half-inch mesh with wooden frames. These trays should be thoroughly cleaned before use and the wire mesh rubbed with lard oil or some other edible oil to prevent pieces of fish from sticking to it. The pieces in a given tray are, as nearly as possible, of the same size and thickness. They must not touch each other, or an even, sufficient cure will not be obtained. The individual trays may be laid onto a rack holding several tiers of trays and moving on wheels, which is run into the smokehouse when it has been filled; or the trays may be placed directly in the smokehouse on fixed racks.

The salmon is allowed to drip and drain for a few hours in the smokehouse but a suggested procedure, which it is believed would shorten this period and result in a better product, is to dry the trays of fish for an hour or two under a strong current of air at a temperature of about 70°F. The fire is now lighted and the salmon is smoked lightly and partially dried over a medium fire (temperature in the section holding the fish should be about 80°F) for from seven to 12 or 13 hours. At the end of this time the fire is built up and the salmon is given a hot smoke by which it is partially cooked. Care must be taken that the salmon does not get overheated, or it will be softened and spoiled. When the fire is built up it must be regulated by means of drafts and ventilators so that the temperature will not be higher than desired. This hot smoking or barbecuing takes one hour at a temperature of from 170° to 180°F. In some establishments the time is 25 to 35 minutes at a temperature around 250°F.

When the process is finished the kippered salmon is thoroughly cooled, in some cases, by throwing open the doors of the smokehouses. In others, in plants which are equipped with movable smokehouse racks, the racks are run out on the wrappings of parchment and are then packed in a small box or basket. A container holding 10 pounds is the most popular size. Kippered salmon is perishable, spoiling after exposure of a few days at ordinary temperatures, so if not to be sold at once it should be kept in chill storage at temperatures of 35° to 40°F, and sold from refrigerated showcases. A certain amount of kippered salmon is intended for shipment to distant markets, or is stored to fill rush orders. For these purposes it is frozen and held in storage for use as required. The freezing temperature and length of time required for freezing are the same as for fresh fish. As in freezing fresh fish there is some variation, but in a typical instance kippered salmon is placed in the sharp freezer at -10°F, and left there for 10 to 12 hours when the temperature should be -25°F. The storage temperature is about 0°F.

NOTE: New U.S. Food & Drug Administration "Good Manufacturing Practice" requirements for "hot process smoked fish" recommend that commercially prepared smoked fish be subjected to one of the following conditions:

1) Center temperature must reach at least 180°F for 30 minutes if "water phase salt" content is a minimum of 3.5%. OR, 2) center temperature must reach at least 105°F for 30 minutes if "water phase salt" content is a minimum of 5%.

Most 1 to 2" thick pieces of fish will reach these conditions if salted 1 to 2 hours in 60° SAL brine (15.8% salt by weight) and smoked 4 to 5 hours at 180°F to 200°F followed by 4 to 8 hours of smoking without heat.

These "GMP" requirements are designed to help prevent unsafe products from reaching the consumer. However, only careful attention to good sanitary practices will insure complete safety.

SMOKING FISH AT HOME SAFELY

Ken Hilderbrand
Marine Advisory Program
Marine Science Center
Oregon State University
Newport, OR 97365
(503)867-3011

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. Interal 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 3½% WPS.

(The phrase "3½% WPS"—for "water phase salt"—means that the salt content is 3½% 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.)

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.

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 3½% WPS.

Without chemical analysis, it is hard to be certain that 3½% 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.")

Oregon State University
Extension Marine Advisory Program
A Land Grant / Sea Grant Cooperative
SG 66 Revised August 1981

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 3½% 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.

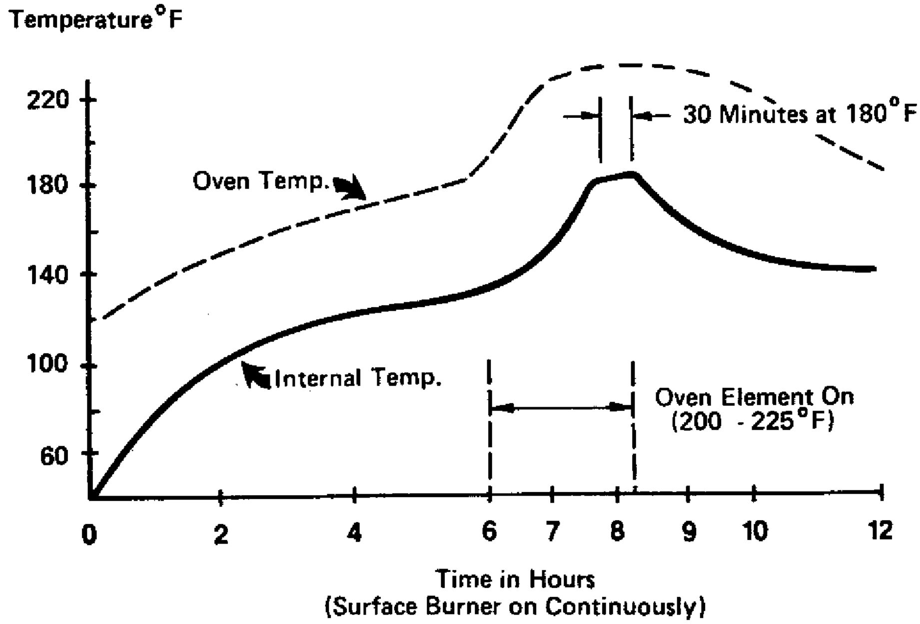


Figure 1.—*Typical internal fish temperature during smoking cycle.*

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° to 225° F (93° 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° to 130° F, 48° 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.

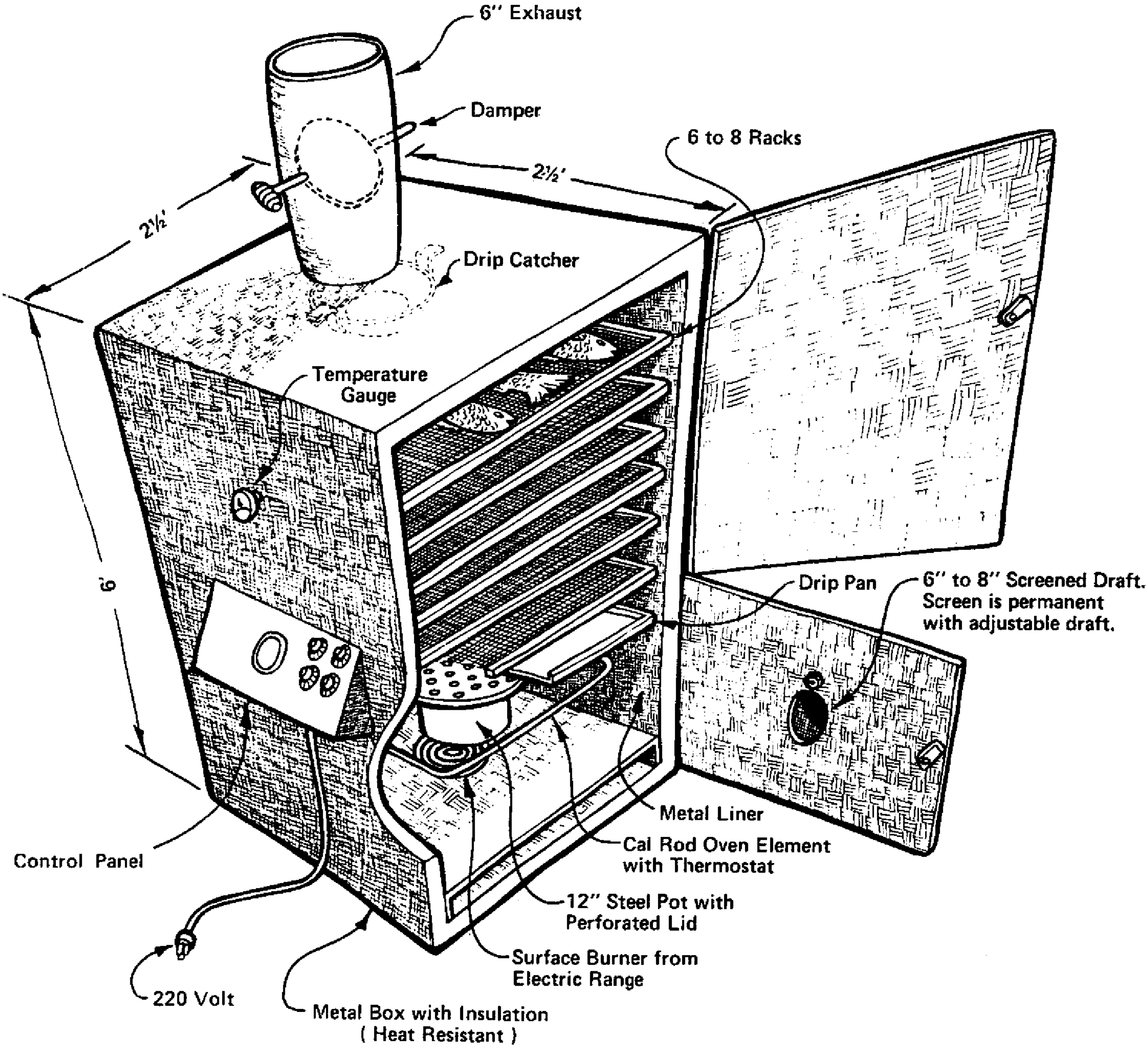


Figure 2.—*Basic components of a smokehouse.* This drawing is not intended, nor should it be used, as a blueprint for building a smokehouse. It shows the features to look for in a smokehouse and their general arrangement. The key features are: (1) an independent source of heat for the pot of wood chips 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:

Dudley, Shearon, J. T. Graikoski, H. L. Seagran, and Paul M. Earl, *Sportsman's Guide to Handling, Smoking, and Preserving Coho Salmon,* National Marine Fisheries Service, Fishery Facts-5 (Seattle, 1973). Available in some libraries. Reprint copies available (30¢ each) from: Extension Marine Education Specialist, OSU Marine Science Center, Newport, OR 97365.

Hilderbrand, Kenneth S. Jr., *Building a Small Crab Cooker for Home Use,* Oregon State University Extension Service, Sea Grant Marine Advisory Program Publication SG 70 (Corvallis, 1981).

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

Hilderbrand, Kenneth S., Jr., *Preparation of Salt Brines for the Fishing Industry,* Oregon State University Extension Service, Sea Grant Marine Advisory Program Publication SG 22 (Corvallis, reprinted 1979).

Extension Service, Oregon State University, Corvallis, Henry A. Wadsworth, director. This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties.

Extension's Marine Advisory Program is supported in part by the Sea Grant Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

Extension invites participation in its activities and offers them equally to all people.

CANNING SMOKED FISH PRODUCTS

Al Bailey
American Can Company
400 Baker Blvd.
Seattle, WA 98188
(206)246-9000

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
Malcolm Hunter, BSC (HONS), C ENG
AFOS, Limited
Manor Estate, Anlaby
Hull
HU10 GRL
England
(144) 0482-52152

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 seafoods: 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 seafoods 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

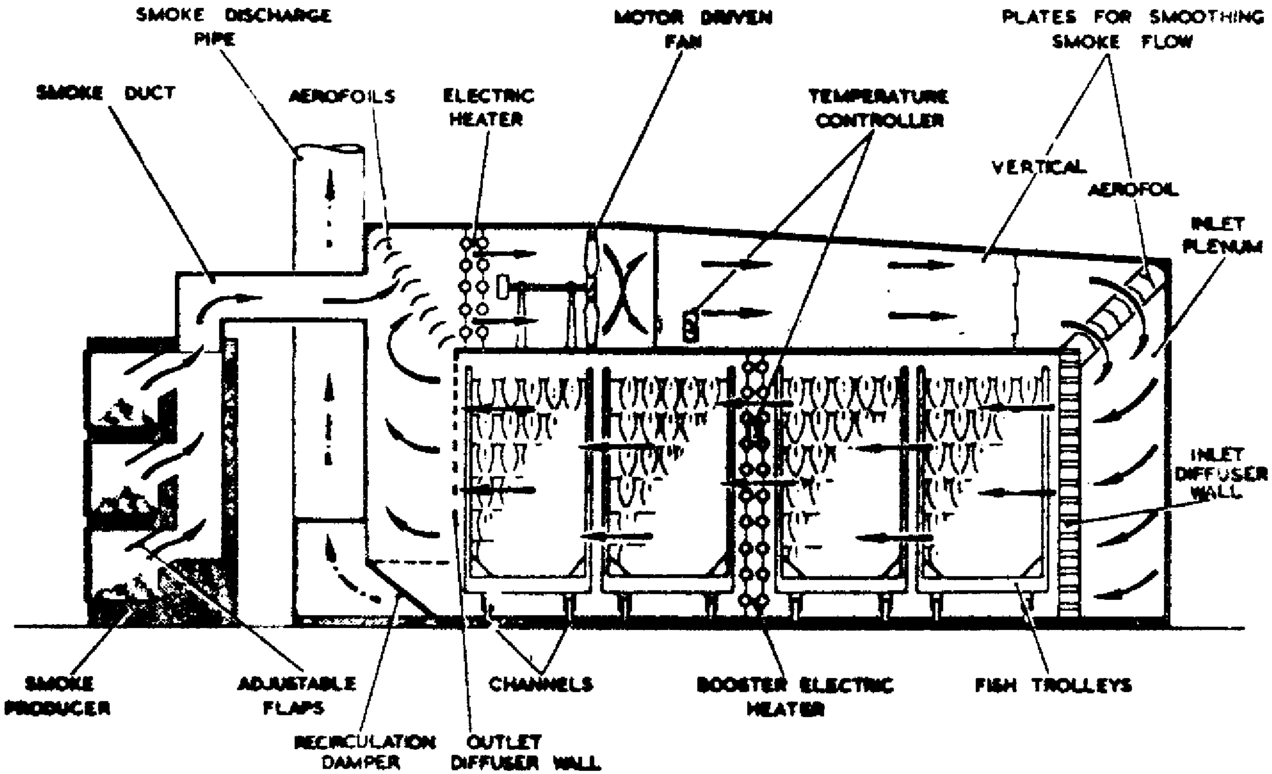
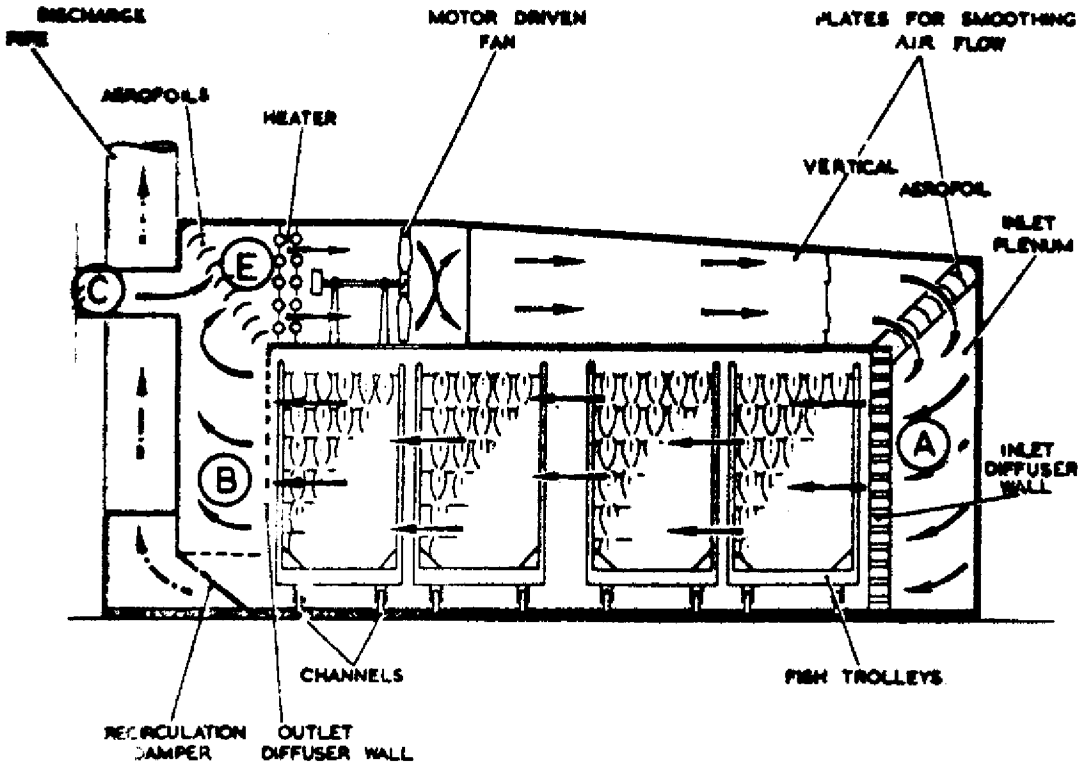


Figure 1. Sectional view of the Torry kiln and smoke producer.



N.B. LETTER IN CIRCLE REFERS TO POINTS ON PSYCHROMETRIC CHART.

Figure 2. Sectional view of ventilated drier.

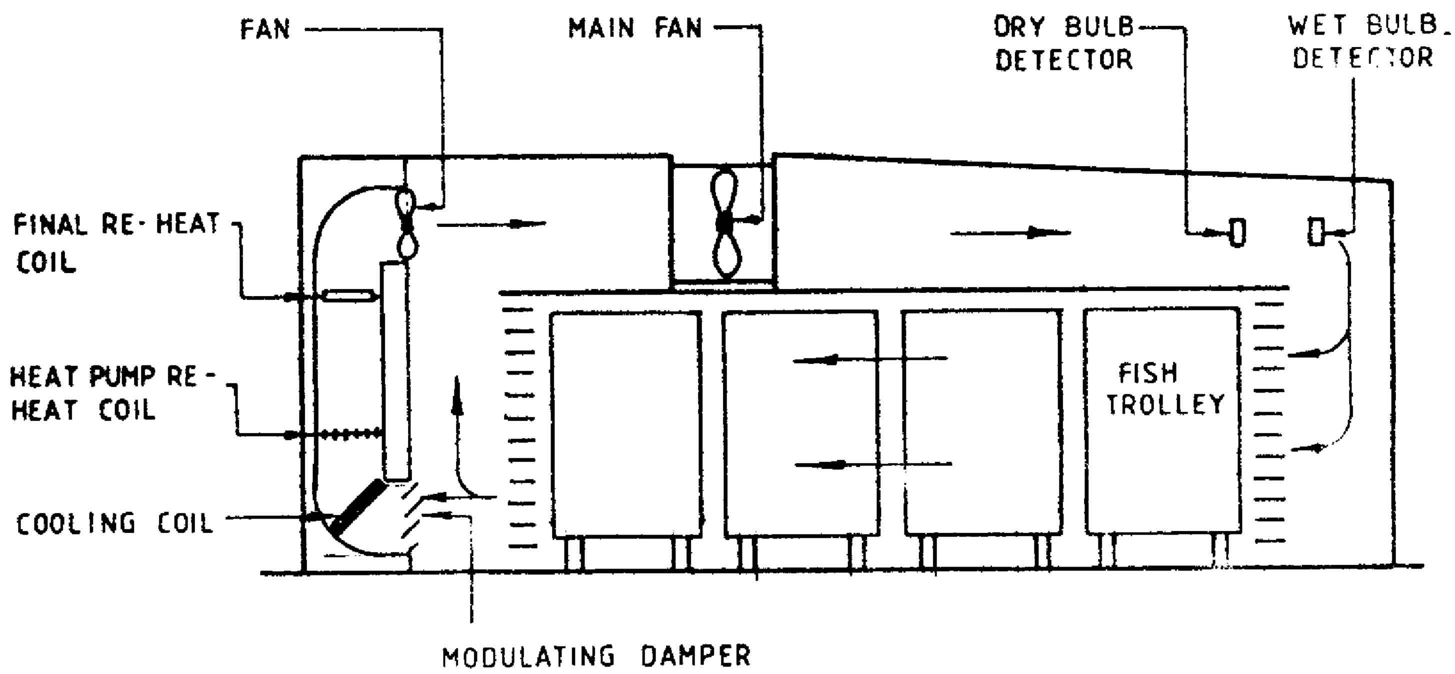


Figure 3. Sectional view of dehumidifier drier.

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 dryer, 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 dryer.

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

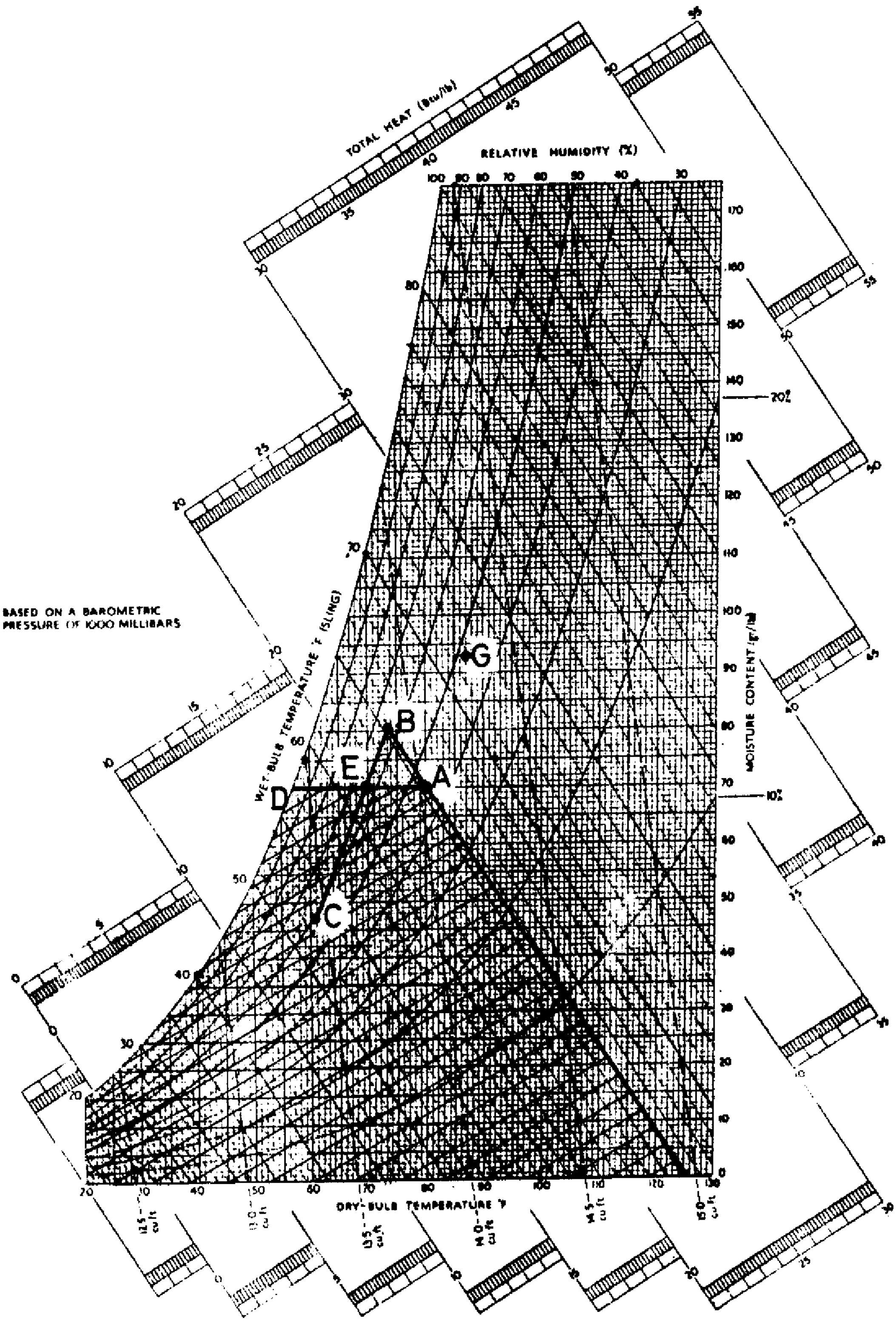


Figure 4. Psychometric chart for dry-bulb temperatures 20°F to 130°F.

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 lloligo 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

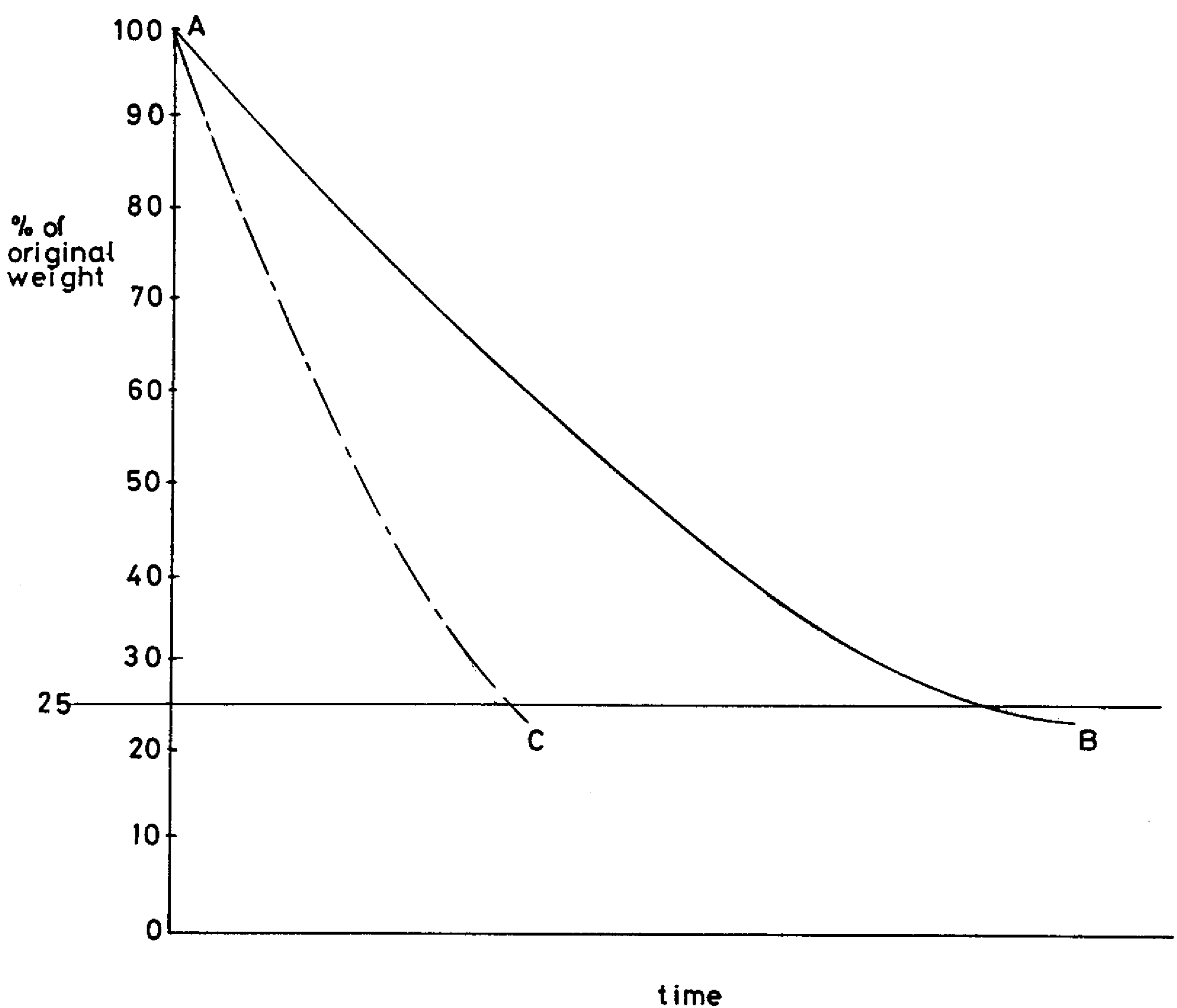


Figure 5. Comparison of drying times between standard drying equipment (A-B) and accelerated drier developed by AFOS Ltd. and Torry Kiln (A-C).

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.

APPENDIX

Additional references are provided here for those seeking more information on fish smoking or other related processes. A list of publishers follows this bibliography. Those entries marked with an asterisk are available from the publisher. Many of these publication are also available to Alaskans and residents of other participating states through inter-library loan.

SMOKING PROCESSES

*Alaska Fisheries Development Foundation. 1981. Saltfish workshop proceedings. Anchorage, AK. ($8.00 per copy)

*Bannerman, A. McK. 1977. Kippers. Torry advisory note no. 48. Aberdeen, Scotland: Torry Research Station.

*Bannerman, A. McK. and J. Horne. 1980. Recommendations for the preparation of smoked salmon. Torry advisory note no. 5 (revised). Aberdeen, Scotland: Torry Research Station.

*Berg, I.I. 1969. Smokehouses and the smoke curing of fish. Olympia, WA: Washington State Department of Fisheries.

*Burgess, G.H.O. and A. McK. Bannerman. 1979. Fish smoking: A Torry kiln operator's handbook. Aberdeen, Scotland: Torry Research Station.

*Cutting, C.L. 1951. The general principles of smoke-curing of fish. Food investigation leaflet no. 13. Aberdeen, Scotland: Torry Research Station.

*Dudley, S. et al. 1973. Sportsman's guide to handling, smoking, and preserving coho salmon. Fisheries facts no. 5. Seattle, WA: National Marine Fisheries Service: Northwest and Alaska Fisheries Center.

Food and Agricultural Organization. 1976. The production of dried fish. New York, NY: United Nations. Available from:
UNIPUB
Box 433
Murray Hill Station
New York, NY 10016

Food and Agricultural Organization. 1970. Smoke curing of fish. New York, NY: United Nations. Available from:
UNIPUB
Box 433
Murray Hill Station
New York, NY 10016

*Hilderbrand, K.S. 1979. Preparation of salt brines for the fishing industry. Oregon State University Sea Grant College Program publication no. 22. Newport, OR.

Jarvis, N.D. 1944. Mild curing, dry salting, and smoking salmon. U.S. Fish and Wildlife Service fishery leaflet no. 60. Washington, DC.

Jarvis, N.D. 1950. Curing fishery products. U.S. Fish and Wildlife Service research report no. 18. Washington, DC.

Jarvis, N.D. 1964. Home preservation of fishery products: Salting, smoking, and other methods of curing fish at home. U.S. Fish and Wildlife Service fishery leaflet no. 18. Washington, DC.

Kosak, P.H. and R.T. Toledo. 1981. Brining procedures to produce uniform salt content in fish. In. Food Science (not yet published). Available from:
Romeo Toledo
Food Science Department
University of Georgia
Athens, GA 30602

Kosak, P.H. and R.T. Toledo. 1980. Product quality and energy use in high temperature smoking of fish. Jn. Food Science 45(1980):1481-1486. Also available from:
Romeo Toledo
Food Science Department
University of Georgia
Athens, GA 30602

Seagran, H.L., J.T. Graikoski and J.A. Emerson. 1970. Guidelines for the processing of hot-smoked chub. U.S. Bureau of Commercial Fisheries circular no. 331. Washington, DC.

Stansby, M.E. and F.P. Griffiths. 1943. Preparation and keeping quality of lightly smoked mackerel. U.S. Fish and Wildlife Service research report no. 6. Washington, DC.

*Torry Research Station. 1977. Smoked white fish: Recommended practice for producers. Torry advisory note no. 9. Aberdeen, Scotland.

*Torry Research Station. 1978. Smoked fish: Recommended practice for retailers. Torry Advisory note no. 14 (revised). Aberdeen, Scotland.

*Waterman, J.J. 1980. Fish smoking: A dictionary. Torry advisory note no. 83. Aberdeen, Scotland: Torry Research Station.

COMMERCIAL PROCESSES CLOSELY RELATED TO FISH SMOKING

*Charm, S.E. 1978. Fundamentals of food engineering. 3rd ed. Westport, CT: AVI Publishing Co.

*Edward E. Judge & Sons, Inc. thru 1941. The almanac of the canning, freezing and preserving industries. (After 1941, "Canning Trade Almanac Yearbook.") Westminister, MD.

Farrall, A.W., ed. 1976. Food engineering systems, Vol I: Operators; Vol. II: Utilities. Westport, CT: AVI Publishing Co.

*Food Processors Institute. 1980. Canned foods: Principles of thermal process control, acidification, and container closure evaluation. 3rd ed. (revised). Washington, DC.

Gillies, M.T. 1975. Fish and shellfish processing. Park Ridge, NJ: Noyes Data Corp.

*Jackson, J.M. and B.M. Shinn. 1979. Fundamentals of food canning technology. Westport, CN: AVI Publishing Co.

Jarvis, N.D. 1943. Principles and methods in the canning of fishery products. U.S. Fish and Wildlife Service research report no. 7. Washington, DC.

*Joslyn, M.A. and J.L. Heid. 1963. Food processing and operations: Their management, machines, materials, and methods. Westport, CT: AVI Publishing Co.

*Lopez, A. 1981. Basic information on canning. Baltimore, MD: The Canning Trade, Inc. Also available from:
Dixie Canner Equipment Co.
P.O. Box 1348
Athens, GA 30603

*Lopez, A. 1981. Processing procedures for canned food products. Baltimore, MD: The Canning Trade, Inc. Also available from:
Dixie Canner Equipment Co.
P.O. Box 1348
Athens, GA 30603

*Lopez, A. 1981. A complete course in canning, Vol. I: Basic information: Vol. II: Processing procedures. Baltimore, MD: The Canning Trade, Inc.

*Sarachow, S. and R.C. Griffin. 1970. Food packaging. Westport, CN: AVI Publishing Co.

*Stansby, M.E. 1963. Industrial fishery technology. Huntington, NY: R.E. Krieger Publishing Co.

QUALITY CONTROL CONSIDERATIONS

Chichester, C.O. and H.D. Graham, eds. Microbial safety of fishery products. New York, NY: Academic Press.

Dougherty, J.B., and H.L. Seagran. 1966. Steps to effective sanitation in smoked fish plants. U.S. Fish and Wildlife Service circular no. 259. Washington, DC.

Food and Agricultural Organization. 1977. Freezing in fisheries. FAO technical paper no. 167. New York, NY: United Nations. Available from:
UNIPUB
Box 433
Murray Hill Station
New York, NY 10016

Food and Agricultural Organization. 1975. Ice in fisheries. FAO fisheries report no. 59 (revision no. 1). New York, NY: United Nations. Available from:
UNIPUB
Box 433
Murray Hill Station
New York, NY 10016

*Graham, H.D., ed. 1980. The safety of foods, 2nd ed. Westport, CT: AVI Publishing Co.

*Guthrie, R.K., ed. 1972. Food sanitation. 2nd ed. Westport, CT: AVI Publishing Co.

*Jowitt, R., ed. 1980. Hygenic design and operation of food plants. Westport, CT: AVI Publishing Company.

*Katsuyama, A.M. 1980. Principles of food processing sanitation. Edited by Allen M. Katsuyama and Jill P. Strachan. Washington, DC: The Food Processor's Institute.

*Kramer, A. and B.A. Twigg. 1973. Quality control for the food industry, Vol. I: Fundmentals; Vol. II: Applications. 3rd ed. Westport, CT: AVI Publishing Company.

*Lee, J.S. 1977. Hazard analysis and critical point applications to the seafood industry. Oregon State Sea Grant College Program publication no. H-77-001. Corvallis, OR.

National Academy of Sciences. 1975. Prevention of microbial and parasitic hazards associated with processed foods: A guide for the food processor. Washington, DC.

*U.S. Fish and Wildlife Service. 1967. Sanitation standards for smoked-fish processing, Part I: Fish smoking establishment (1967 recommendations). Washington, DC.

LIST OF PUBLISHERS

Alaska Fisheries Development Foundation
805 W. 3rd Avenue
Anchorage, AK 99501

Academic Press, Inc.
111 Fifth Avenue
New York, NY 10003

AVI Publishing Company
P.O. Box 831
Westport, CT 06881

Food Processors Institute
1133 20th Street N.W.
Washington, DC 20036

National Academy of Science
National Academy Press
2101 Constitution Avenue
Washington, DC 20418

Northwest and Alaska Fisheries Center
2725 Montlake Blvd. E.
Seattle, WA 98112

Noyes Data Corp.
Park Ridge, NJ 07656

R.E. Krieger Publishing Co.
P.O. Box 542
Huntington, NY 11743

Oregon State University
Sea Grant College Program
Ads A418, Oregon State University
Corvallis, OR 97331

Torry Research Station
P.O. Box 31
Aberdeen AB9 80G
Scotland, UNITED KINGDOM

Washington State Department of Fisheries
115 General Admn. Bldg.
Olympia, WA 98504

U.S. Fish and Wildlife Service
Interior Bldg.
18th and C Sts.
Washington, DC 20240

Kathy Abarr
P.O. Box 1558
Wrangell, AK 99929

Jerry Adams
142 Willoughby Ave.
Juneau, AK 99801

Don Albright
Egegik, AK 99579

Alfred Alsaker
President
Norse Marine Enterprises, Inc.
17020 Talbot Road
Edmonds, WA 98020

Tom Amabisca
Koch Supplies
927 W. Evans
Visialia, CA 93277

Peter Apokedak
Levelock Natives, Ltd.
Levelock, AK 99625

Donald Arndt
Box 2338
Kodiak, AK 99615

Lloyd W. Arnold
Nantucket Seafood Co.
Straight Wharf
Nantucket, MA 02554

Steve Augdahl
Kawerak, Inc.
P.O. Box 505
Nome, AK 99762

Basil Backford
Box 10008
Dillingham, AK 99576

Al Bailey
American Can Company
400 Baker Blvd.
Seattle, WA 98188

Alex McK. Bannerman
MBE A.I.F.S.T.
(Independent Consultant)
Swanland, North Ferriby, Yorkshire
ENGLAND HU14 3QT

Tibor Bathony
STR 1687-R
Anchorage, AK 99501

Terrill Beck
Universal Seafoods, Ltd.
P.O. Box 94
Redmond, WA 98052

Bonita Rae Bequet
Network Fish Co.
503 Sterling St.
Uniondale, NY 11553

Richard D. Bishop
Silver Lining
Box 761
Ward Cove, AK 99928

John Blackwell
P.O. Box 1541
Seward, AK 99664

Wilburt H. Blatter
Hegg and Hegg, Inc.
801 Marine Drive
Port Angeles, WA 98362

Charles T. Borbridge
603 West 10th Street
Juneau, AK 99801

John E. Borbridge
603 West 10th Street
Juneau, AK 99801

Jim Bourquin
Stikine River Song
Telegraph Creek, British Columbia
CANADA VOJ 2WO

John Boyd
Dept. of Fisheries and Oceans
5788 Crown Street
Vancouver, British Columbia
CANADA V6N 2B7

Richard Boyden
Seattle Knife Supply
1920 Pike Place
Seattle, WA 98101

Robin Briant
P.O. Box 1197
Elma, WA 98541

Gene Broadbent
Broadfire Intl., Inc.
P.O. Box 702
Cape Coral, FL 33904

Neil Brophy
P.O. Box 1197
Elma, WA 98541

Bill N. Brown
Bristol Red Seafood
Star Rt. 2, Box 3A
Clallam Bay, WA 98326

Jim Bulldis
National Fish and Oyster
5028 N.E. Meridian
Olympia, WA 98506

Gary and Ann Carlson
338 Main Street
Ketchikan, AK 99901

Murray L. Clayton
Box 188
Haines, AK 99827

Marvin E. Carlson
Carlson Associations
Washington Dept. of Agriculture
222 W. 18th Avenue
Olympia, WA 98501

Lori Coulter
Fishermen Direct Seafood
4157 49th S.W.
Seattle, WA 98116

Douglas B. Carr
681 Sudden Valley
Bellingham, WA 98225

J. B. Crow
J.B. Crow & Sons, Inc.
Box 567
Bethel, AK 99559

Miguel Cayrisse
University of Washington
Food Science Fisheries
Seattle, WA 98195

Lucy Crow
J.B. Crow & Sons, Inc.
Box 567
Bethel, AK 99559

Fred Chukwak
Levelock Natives, Ltd.
Levelock, AK 99625

D. Cruickshank
Seafood Products Company
8575 Lund Street
Port Hardy, British Columbia
CANADA V0N 2P0

Graciela Cisneros
1006 N.W. 70th
Seattle, WA 98117

Luis A. Davidovich
University of Washington
College of Fisheries
9123 25th N.E.
Seattle, WA 98115

Walt Clark
AISD
Box 7
Metlakatla, AK 99926

Dion Davis-Kapp
1639 Sapphire TR #2
Bellingham, WA 98225

John DeGroot
Island Fresh Seafoods
Lopez, WA 98261

John N. Dong
4123 Baker Ave., N.W.
Seattle, WA 98107

Elsa Demeksa
1724 Evergreen Avenue
Juneau, AK 99801

John Duckett
Farallon Fisheries
159 South Blvd.
San Mateo, CA 94401

Mr. and Mrs. Frank Demmert
2800 3rd
Ketchikan, AK 99901

Sharon Dwyer
SRA #30
Anchor Point, AK 99556

Larry Demmert, Jr.
1275 E. Bakerview
Bellingham, WA 98225

William E. Eberhardt
P.O. Box 1114
Juneau, AK 99802

Dwayne DesLongchamps
Nova, S.A.
Los Azafranes
Lima,
PERU

Alvin Eden-Shaw
Box 41
Hydaburg, AK 99922

Albert Dick
Huna Totem Corp.
P.O. Box 198
Hoonah, AK 99829

Claire E. Egtredt
Castle-Cooke, Inc.
5904 96th St., S.W.
Mukilteo, WA 98275

Walt R. Dickenson
Fin Foods Seafood Co.
5739 S.E. Division St.
Portland, OR 97206

Mel Eklund
National Marine Fisheries Service
2725 Montlake Blvd., E.
Seattle, WA 98112

Robert Emel
Port Chatham Packing Co.
632 N.W. 46th Street
Seattle, WA 98107

Carol Fisher
795 E. Cordova Street
Vancouver, British Columbia
CANADA V6A 1M2

John Farleigh
F/V Billy J.
17550 Pt. Lena Lp. Rd.
Juneau, AK 99801

Joy A. Fleenor
Edgewater Marine
P.O. Box 929
Shelton, WA 98584

Duncan A. Fenton
Annette Island Packing Co.
P.O. Box 70547
Seattle, WA 98107

Hank Fletcher
P.O. Box 6031
Ketchikan, AK 99901

John H. Ferguson
Bay Fish Co., Inc.
4333 1st, N.E.
Seattle, WA 98105

James Fox
Fox Seafood, Inc.
22 Cedar Street
Narragansett, RI 02882

Joe Ferluga
Diamond E Fisheries, Inc.
3618 Oas Dr., W.
Tacoma, WA 98466

Bruce Friend
Favco, Inc.
P.O. Box 2323
Anchorage, AK 99510

Carmen C. Fernandez
University of Washington
951 McMahon Hall
Seattle, WA 98195

Percy Frisby
Haida Corporation
P.O. Box 89
Hydaburg, AK 99922

Andy Fernando
Upper Skagit Indian Tribe
725 Fairhaven Avenue
Burlington, WA 98233

Sean Gallagher
Salmon Shack, Inc.
1525 Lowe Avenue
Bellingham, AK 98225

Carol R. Garcia
Fresh Fish Co.
4549 Latona, N.E.
Seattle, WA 98105

Glen Gibbard
Dept. of Fisheries and Oceans
6640 N.W. Marine Drive
Vancouver, British Columbia
CANADA V5E 1W4

Jerry Goldschmidt
AFP - Sitka
Box 4472
Mt. Edgecumbe, AK 99835

Durwood Gray
Cooperative Extension Service
Federal Building
Machias, ME 04654

Dick Griffin
Kake Student Co-op
P.O. Box 302
Kake, AK 99830

Hal H. Gunnarssen
Northern Sea, Inc.
4131 Brooklyn Ave., N.E.
Seattle, WA 98105

Lynne Zeitlin Hale
Alaska Native Foundation
411 W. 4th, Suite 314
Anchorage, AK 99501

Vicki Handyside
Commercial Fisheries
515 Van Buren
Port Townsend, WA 98368

Chris Hanson
Box 218
Petersburg, AK 99833

Alan Harriman
Harriman Trout Co.
Box 173
St. Ignatius, MT 59865

William Henderson
Guilford Packing Co.
1005 Quincy Street
Port Townsend, WA 98368

C. J. Hendricksen
Hendricksen Supplies, Ltd.
4151 Cypress
Vancouver, British Columbia
CANADA V6J 3P7

Charlotte Henry
Washington Sea Grant
7039½ 6th, N.W.
Seattle, WA 98107

Pamela Herman
Nana Development Corp.
P.O. Box 49
Kotzebue, AK 99752

Adelheid Herrmann
Bering Sea Fisherman's Assoc.
P.O. Box 63
Naknek, AK 99633

Malcolm Hunter
BFC(HONS), C ENG
AFOS Limited
Manor Estate
Anlaby, Hull
ENGLAND HU10 6RL

Ken Hilderbrand
223 S.W. 12th
Newport, OR 97365

James Huntington
Box 71
Galena, AK 99741

Min Huang
ALKAR/DEC International
105 Spring Street
Lodi, WI 53555

Sidney Huntington
Alaska Native Foundation
Box 49
Galena, AK 99741

Warren and Glenda Huff
Warren Huff, Inc.
F/V Urania
15717 Crescent Valley
Gig Harbor, WA 98335

Wayne T. Iwaoka
University of Washington
College of Fisheries
Seattle, WA 98195

Dick Hughes
Troys Seafood Markets
11130 S.E. Powell Blvd.
Portland, OR 97266

Charles M. Jacobson
Sea Smoke N.W., Inc.
10111 129th St., N.E.
Arlington, WA 98223

Monte Hughes
Island Fresh Seafoods
Lopez, WA 98261

Aage Jensen
21323 Virginia, N.E.
Kingston, WA 98346

Doug Humes
Frank Orth and Associates
225 108th Ave., N.E., Suite 311
Bellevue, WA 98004

Bruce A. Johnson
Squaxin Island Tribe
Rt. 1, Box 257
Shelton, WA 98584

Mary E. Jones
Box A-27
Ward Cove, AK 99928

Willie Kasayulie
Akiachak, Ltd.
General Delivery
Akiachak, AK 99551

Tod Jones
Alaska Aquaculture Foundation, Inc.
Box 1288
Wrangell, AK 99929

Ole Kie
Peter Pan Seafoods
3221 74th, S.E.
Mercer Island, WA 98040

Willard L. Jones
Box A-27
Ward Cove, AK 99928

Richard Kimball
1600 Kentucky Street
Bellingham, WA 98225

Xavier Joseph
Alakanuk Native Corporation
P.O. Box 8
Alakanuk, AK 99554

Kirkland Custom Cannery, Inc.
640 8th Avenue
Kirkland, WA 98033

Steve Jovanovich
W.C.P.F.U.
615 Walnut Street
Edmonds, WA 98020

Archie Klang
2395 Delaware, #74
Santa Cruz, CA 95060

Andrew Kalinowski
Sea/Pro
3025 W. Galer Street
Seattle, WA 98199

Thelma Kostegian
Gweduc, Inc.
P.O. Box 206
Seattle, WA 98160

Loren J. Kapp
1639 Saphire Trail, #2
Bellingham, WA 98225

John A. Kroburger
University of Florida
Room 449, Food Science Bldg.
Gainesville, FL 32611

Cheryl Krone
University of Washington
Food Science, WH-10
Seattle, WA 98195

Arne Lindstrom
Port Chatham Packing Co.
632 N.W. 46th
Seattle, WA 98107

John Lacy
Longline Seafoods, Ltd.
Rt. 3, Box 119
Port Townsend, WA 98368

Keith Loan
Trinity Seafoods, Inc.
852 W. 73rd
Anchorage, AK 99502

Elwood Latta
5659 42nd Ave., W.
Seattle, WA 98199

Todd Loges
Kake Student Co-op
Box 273
Kake, AK 99830

Gordon Lee
Alaska Sea Venture
P.O. Box 2677
Home, AK 99603

Kristine Long
University of Alaska
Cooperative Extension Service
Box 6963
Ketchikan, AK 99901

Rich Lee
University of Alaska
11120 Glacier Highway
Juneau, AK 99802

Laura Lopez-Gavito
University of Washington
7455 5th Ave., N.E., 301
Seattle, WA 98115

Ruth Levy
Network Fish Co.
Elm Avenue
East Quogue, NY 11942

Jack C. Lyons
Box 527
Petersburg, AK 99833

Meredith Lind
All Alaska Services, Inc.
P.O. Box 640
Kodiak, AK 99615

Pat Malloy
Ebb Tide
1917 8th
Anacortes, WA 98221

J. N. Manson
Seafood Products Co.
2727 Commissioner Street
Vancouver, British Columbia
CANADA V5K 1A2

Loren Martinson
P.O. Box 6778
Ketchikan, AK 99901

Sharon McCauley
Alaska Seafood Marketing
526 Main Street
Juneau, AK 99801

M. J. Melone
5920 Libby Road, N.E.
Olympia, WA 98506

Denis Meslans
18415 Olympic View Drive
Edmonds, WA 98020

Tom Meyer
229 5th
Juneau, AK 99801

Pamela J. Mills
Kake Public Schools
P.O. Box 197
Kake, AK 99830

Raymond Mlecko
U.S. Food and Drug Administration
Federal Office Building
Seattle, WA 98104

Michael Monahan
Monahan's Seafood, Inc.
407 N. Fifth
Ann Arbor, MI 48104

Mel Monsen
Bering Sea Fishermen's Association
805 W. 3rd Avenue
Anchorage, AK 99501

E. J. Moore
211 N.E. 185th
Seattle, WA 98155

Janice E. Moore
1000 Union, #413
Seattle, WA 98101

M. A. Moshofsky
Bellwether Seafood Co.
Box 2
Lincoln City, OR 97367

Donald Mulivrana
Sea Smoke N.W., Inc.
3912 234th St., N.E.
Marysville, WA 98270

John W. Munsey
Crow's Nest Restaurant
225 Riverside Avenue
Ben Lomond, CA 95005

Jeni Olson
Box 1199
Wrangell, AK 99929

Craig Nelson
Birkenwald, Inc.
7543 13th Ave., N.W.
Seattle, WA 98117

Anecia Olympic
Iguigig Native Corporation
Iguigig via
King Salmon, AK 99613

Lavonda Newman
Kodiak Area Native Association
P.O. Box 172
Kodiak, AK 99615

Mary Ann Olympic
Iguigig Native Corporation
Iguigig via
King Salmon, AK 99613

Jim Norris
F/V Sea Angel
P.O. Box 334
Chinacum, WA 98325

Bill Osborne
Box 1248
Kodiak, AK 99615

John Oaksmith
Alaska Commercial Fishing and
Agriculture Bank
P.O. Box 7018
Ketchikan, AK 99901

Patricia A. Overmiller
Swinomish Indian Fish Co.
1834 Hickox Road
Mt. Vernon, WA 98273

John F. O'Connor
Seafoods of Alaska, Inc.
Box 307
Sterling, AK 99672

Joe Oyler
W.I.S.E.
1409 S.E. 17th
Portland, OR 97214

Virginia Olney
905 Argyle Avenue
Friday Harbor, WA 98250

Mildred Palmer
University of Washington
Washington Sea Grant Program
3716 Brooklyn Ave., N.E.
Seattle, WA 98105

John Pappenheimer
Alaska Fisherman's Journal
1115 N.W. 46th Street
Seattle, WA 98107

Ernest J. Peterkin
Peterkin Fisheries
4034 Mt. View Drive
Anchorage, AK 99504

Larry Patson
Patson Fisheries
Box 445
Bethel, AK 99559

John B. Peters
University of Washington
213 Fisheries Center
Seattle, WA 98195

Starlette Patterson
S.R. Box 10351
Fairbanks, AK 99701

Frank R. Peterson
KANA
Box 35
Larsen Bay, AK 99624

Mark J. Pellitier
Harbor View Way
Nantucket, MA 02554

Robert Peterson
Puget Sound Association of
Cooperating Tribes
P.O. Box 498
Suquamish, WA 98392

Gretchen Pelroy
National Marine Fisheries Service
U.R. Division
2725 Montlake Blvd., E.
Seattle, WA 98112

Vincent Petrich
Tony's Fish Market
14th and Washington Sts.
Oregon City, OR 97045

David B. Perrs
P.O. Box 3110
Ketchikan, AK 99901

Darrell Phare
Lummi Tribe
P.O. Box 309
Marietta, WA 98268

Don Peter
University of Alaska
Alaska Native Human Resources
Development Program
108 Stewart Street
Anchorage, AK 99504

George M. Pigott
University of Washington
College of Fisheries WH-10
Seattle, WA 98195

James Polley
626 N.W. 182nd
Seattle, WA 98177

Richard C. Prill
Schnaubett Fisheries
32200 Pudding Ck. Rd.
Fort Bragg, CA 95437

Mary Pruitt
Bristol Red Seafood
St. Rt. 2, Box 3A
Clallam Bay, WA 98326

Dave Reamer
Universal Seafoods, Ltd.
P.O. Box 94
Redmond, WA 98052

Ron Redman
Box 1282
Ketchikan, AK 99901

Nicholas Reft
Kodiak Area Native Association
Karluk, AK 99608

John Regitano
S.R. 10351
Fairbanks, AK 99701

Richard Rekdac
135 E. Vista del Mar
Camano Island, WA 98273

Dick Reynolds
State of Alaska
1567 Evergreen Ave.
Juneau, AK 99801

F. Bruce Ricks
CH2M Hill
200 S.W. Market Street
Portland, OR 97201

John Robben
SITE Seafoods
Rt. 5, Box 432
Shelton, WA 98584

Sy Robin
National Fish and Oyster
861 S. 137 St.
Tacoma, WA 98444

Martin Rogers
Alaska Fisheries Development Foundation
805 W. 3rd
Anchorage, AK 99501

Paul Saginaw
Monahan's Seafood Market
407 N. Fifth Avenue
Ann Arbor, MI 48104

Vernon H. Schumacher
Northern Lights Haven
Yakutat, AK 99689

Hjalmar (Jolly) Steel
Peter Pan Seafoods
1220 Dexter Horton Bldg.
Seattle, WA 98104

Mike Shadbolt
857 S.E. Watson
Roseburg, OR 97477

George Steelhammer
Steelhammer Salmon Farm
10425 188th, S.W.
Rochester, WA 98579

Eric Silberstein
International Trade Administration
U.S. Department of Commerce
1700 Westlake Avenue, North
Seattle, WA 98109

Paul Strayer
Sushi Seafoods
215 Helena Street
Santa Barbara, CA 93101

Beckye Simpson
P.O. Box 828
Anchorage, AK 99510

Dan Strombom
Community Enterprise Development
Corporation
1011 E. Tudor Road, Suite 210
Anchorage, AK 99503

John Sinclair
National Marine Fisheries Service
6509 42nd Avenue, N.E.
Seattle, WA 98115

John W. Sullivan
618 Fernside Drive, N.
Tacoma, WA 98401

Don Skaw
Kodiak Area Native Association
Box 172
Kodiak, AK 99615

John Sund
Silver Lining
1706 Willow Drive
Juneau, AK 99801

Charlie Sours
Bering Sea Fisherman's Association
Box 230
Kotzebue, AK 99752

Kathleen M. Sund
Silver Lining
1706 Willow Drive
Juneau, AK 99801

Dan Swain
1928 S.W. Laurel
Portland, OR 97201

Nancy Torhorst
DFS North America, Ltd.
3220 Sleeping Lady Lane
Anchorage, AK 99502

Vern P. Swanes
Northern Fish Products
3911 South 56th Street
Tacoma, WA 98409

James Turman
Near-Perfect Seafoods
Box 1853
Kodiak, AK 99615

Daniel P. Swecker
Swecker Salmon Farm, Inc.
10420 173rd Avenue, S.W.
Rochester, WA 98579

Roger H. Tyler
TYCO Fish
10460 S.E. 174th, #101
Renton, WA 98055

Lonnie Thomas
Shan-Seet, Inc.
S.R. 6012
Eagle River, AK 99577

Jan R. Visscher
Fisher's Continental, Ltd.
3065 Butternut
Coquitlam, British Columbia
CANADA V3C 3M7

Yako Tinker, Sr.
Box 191
Bethel, AK 99559

Jody V. M. Visscher
Fisher's Continental, Ltd.
3065 Butternut
Coquitlam, British Columbia
CANADA V3C 3M7

Don Tipwell
19700 S.E. 21st
Issaquah, WA 98027

Bela Von Tolmacsy
Cape Yakataga Salmon Co.
Box 346
Yakutat, AK 99689

Bill Tondre
Universal Seafoods, Ltd.
P.O. Box 94
Redmond, WA 98052

Neil Wagner
W.C. Foods
P.O. Box 40
Indianola, WA 98342

Andy Wahry
1304 Early View Drive
Anchorage, AK 99507

Robert A. Whorley
Halibut Producers Co-op
P.O. Box 1235
Bellingham, WA 98225

Bob Waldrop
Box 837
Ketchum, ID 83340

Darrell Willers
906 N. 76th
Seattle, WA 98103

Martin Warp
Aquaculture N.W.
91303 Coburg Road
Eugene, OR 97401

Elizabeth Williams
NFPA
1600 So. Jackson
Seattle, WA 98144

William Wason
Solar Salmon Schools
3936 S. Brandon
Seattle, WA 98118

June Williams
Pacific Fish Trading, Inc.
11426 26th Drive, SE
Everett, WA 98204

Erwin Waters
S&F Sheet Metal and Welding Works
649-57 Whittier Street
Bronx, NY 10474

Howard E. Winn
R.R. 2, Box 591C
Narragansett, RI 02882

Greg S. Wenbourne
Circle-Sea Seafoods
13001 N.E. 177th Pl.
Woodinville, WA 98072

Kenneth W. Wong
Castle and Cooke Food
9317 Valhalla Way
Bochell, WA 98011

Terry A. Whitbeck
Alaska Department of Education
Pouch F, ASOB
Juneau, AK 99811