# Chapter 7: Smoked Fish and Fishery Products

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## Potential Food Safety Hazard

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*Clostridium botulinum* toxin formation can result in consumer illness and death. This chapter covers the potential for *C. botulinum* growth and toxin formation as a result of time/temperature abuse during processing, storage and distribution.

When *C. botulinum* grows it can produce a potent toxin, which can cause death by preventing breathing. It is one of the most poisonous naturally occurring substances known. The toxin can be destroyed by heat (e.g. boiling for 10 minutes), but processors cannot rely on this as a means of control.

There are two major groups of *C. botulinum*, the proteolytic group (i.e. those that break down proteins) and the nonproteolytic group (i.e. those that do not break down proteins). The proteolytic group includes *C. botulinum* type A and some of types B and F. The nonproteolytic group includes *C. botulinum* type E and some of types B and F.

The vegetative cells of all types are easily killed by heat. *C. botulinum* is able to produce spores. In this state the pathogen is very resistant to heat. The spores of the proteolytic group are much more resistant to heat than are those of the nonproteolytic group. Table A-4 provides guidance about the conditions under which the spores of the most heat resistant form of nonproteolytic *C. botulinum*, type B, are killed. However, there are some indications that substances that may be naturally present in some products, such as lysozyme, may enable nonproteolytic *C. botulinum* to

more easily recover after heat damage, resulting in the need for a considerably more aggressive process to ensure destruction.

Temperature abuse occurs when product is exposed to temperatures favorable for *C. botulinum* growth for sufficient time to result in toxin formation. Table A-1 provides guidance about the conditions under which *C. botulinum* and other pathogens are able to grow.

Packaging conditions that reduce the amount of oxygen present in the package (e.g. vacuum packaging) extend the shelf life of product by inhibiting the growth of aerobic spoilage bacteria. The safety concern with these products is the increased potential for the formation of *C. botulinum* toxin before spoilage makes the product unacceptable to consumers.

*C. botulinum* forms toxin more rapidly at higher temperatures than at lower temperatures. The minimum temperature for growth and toxin formation by *C. botulinum* type E and nonproteolytic types B and F is 38°F (3.3°C). For type A and proteolytic types B and F, the minimum temperature for growth is 50°F (10°C). As the shelf life of refrigerated foods is increased, more time is available for *C. botulinum* growth and toxin formation. As storage temperatures increase, the time required for toxin formation is significantly shortened. Processors should expect that at some point during storage, distribution, display or consumer handling of refrigerated foods, proper refrigeration temperatures will not be maintained (especially for the nonproteolytic group). Surveys of retail display cases indicate that temperatures of 45-50°F (7-10°C) are not uncommon. Surveys of home refrigerators indicate that temperatures can exceed 50°F (10°C).

In reduced oxygen packaged products in which the spores of nonproteolytic *C. botulinum* are inhibited or destroyed (e.g., smoked fish, pasteurized crabmeat, pasteurized surimi), normal refrigeration temperatures of 40°F (4.4°C) are appropriate because they will limit the growth of proteolytic *C. botulinum* and other pathogens that may be present. Even in products where nonproteolytic *C. botulinum* is the target organism for the pasteurization process and vegetative pathogens, such as *Listeria monocytogenes,* are not likely to be present (e.g. pasteurized crabmeat, pasteurized surimi), a storage temperature of 40°F (4.4°C) is still appropriate because of the potential survival through the pasteurization process and recovery of spores of nonproteolytic *C. botulinum* aided by naturally occurring substances, such as lysozyme. In this case refrigeration serves as a prudent second barrier.

In reduced oxygen packaged products in which refrigeration is the sole barrier to outgrowth of nonproteolytic *C. botulinum* and the spores have not been destroyed (e.g. vacuum packaged raw fish, unpasteurized crayfish meat), the temperature must be maintained at 38°F (3.3°C) or below from packing to consumption. Ordinarily processors can ensure that temperatures are maintained at or below 38°F (3.3°C) while the product is in their control. However, current distribution channels do not ensure the maintenance of these temperatures after the product leaves their control. The use of time temperature integrators on each consumer package may be an appropriate means of enabling temperature control throughout distribution. Alternatively, products of this type may be safely marketed frozen, with appropriate labeling. For some products, control of *C. botulinum* can be achieved by breaking the vacuum seal before the product leaves the processor's control (FDA, 2001).

### Sources of *C. botulinum*

*C. botulinum* can enter the process on raw materials. The spores of *C. botulinum* are very common in nature. They have been found in the gills and viscera of fin fish, crabs, and shellfish. *C. botulinum* type E is the most common form found in fresh water and marine environments. Types A and B are generally found on land, but may also be occasionally found in water. It should be assumed that *C. botulinum* will be present in any raw fishery product, particularly in the viscera (FDA, 2001).

#### Reduced oxygen packaging

There are a number of conditions that can result in the creation of a reduced oxygen packaging environment. They include:

- Vacuum packaging or modified or controlled atmosphere packaging. These packaging methods directly reduce the amount of oxygen in the package;
- Packaging in hermetically sealed containers (e.g. double seamed cans, glass jars with sealed lids, heat sealed plastic containers), or packing in deep containers from which the air is expressed (e.g. caviar in large containers), or packing in oil. These and similar processing/packaging techniques prevent the entry of oxygen into the container. Any oxygen present at the time of packaging may be rapidly depleted by the activity of spoilage bacteria, resulting in the formation of a reduced oxygen environment.

Packaging that provides an oxygen transmission rate of 10,000 $cc/m^2/24hrs$ (e.g. 1.5 mil polyethylene) can be regarded as an oxygen-permeable packaging material for fishery products. This can be compared to an oxygen-impermeable package which might have an oxygen transmission rate as low as or lower than 100 $cc/m^2/24hr$ (e.g. 2 mil polyester). An oxygen permeable package should provide sufficient exchange of oxygen to allow aerobic spoilage organisms to grow and spoil the product before toxin is produced under moderate abuse temperatures. However, use of an oxygen permeable package will not compensate for the restriction to oxygen exchange created by practices such as packing in oil or in deep containers from which the air is expressed (FDA, 2001).

## Control Measures

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There are at least 3 steps to control *C. botulinum* in smoked and smoke-flavored fishery products:

- Controlling the amount of salt or preservatives, such as sodium nitrite, in the finished product, in combination with other barriers, such as heat damage and competitive bacteria, sufficient to prevent the growth of *C. botulinum* type E and nonproteolytic types B and F;
- Managing the amount of time that food is exposed to temperatures that are favorable for *C. botulinum* growth and toxin formation during processing and storage ; and
- Controlling the growth of *C. botulinum* type A and proteolytic types B and F in the finished product with refrigerated storage.

Achieving the proper concentration of salt and or nitrite in the flesh of salted, smoked, and smoke-flavored fish is necessary to prevent the formation of toxin by *C. botulinum* type E and nonproteolytic types B and F during storage and distribution. In salted fish, the salt concentration alone is responsible for this inhibition. In smoked and smoke-flavored fish, salt works along with smoke and any nitrites that are added to prevent toxin formation by *C. botulinum* type E and nonproteolytic B and F (Note: nitrites may only be used in salmon, sable, shad, chubs, and tuna - 21CFR172.175 and 21 CFR 172.177).

In hot-smoked products, heat damage to the spores of *C. botulinum* type E and nonproteolytic types B and F also helps prevent toxin formation. In these products control of the heating process is critical to the safety of the finished product. It is important to note, however, that this same heating process also reduces the numbers of naturally occurring spoilage organisms. The spoilage organisms would otherwise have competed with, and inhibited the growth of, *C. botulinum*.

In cold-smoked fish, it is important that the product does not receive so much heat that the number of spoilage organisms are significantly reduced. This is true because spoilage organisms must be present to inhibit the growth and toxin formation of *C. botulinum* type E and nonproteolytic types B and F. This inhibition is important in cold-smoked fish because the heat applied during this process is not adequate to weaken the *C. botulinum* spores. Control of the temperature during the cold-smoking process is, therefore, critical to the safety of the finished product.

The interplay of these inhibitory effects (salt, temperature, smoke, and nitrite) is complex. Control of the brining or dry salting process is clearly critical to ensure that there is sufficient salt in the finished product. However, preventing *C. botulinum* type E (and nonproteolytic types B and F) toxin production is made even more complex by the fact that adequate salt levels are not usually achieved during brining. Proper drying is also critical in order to achieve the finished product water phase salt level (the concentration of salt in the water portion of the fish flesh) needed to inhibit the growth and toxin formation of *C. botulinum*.

Processors should ordinarily restrict brining, dry salting, and smoking loads to single species and to fish of approximately uniform size. This minimizes the complexity of controlling the operation.

Salt levels alone in some salted products may be adequate to prevent toxin formation by *C. botulinum* type A and proteolytic types B and F. However, even the combination of inhibitory effects that are present in smoked and smoke-flavored fish are not adequate to prevent the growth of type A and proteolytic types B and F. Strict refrigeration control must be maintained to prevent the growth of *C. botulinum* type A and proteolytic types B and F in these products (FDA, 1998).

# FDA Guidelines

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### Cold-Smoked Fish (Oxygen Permeable Packaging)

- No guidelines; treat as fresh fish

### Cold-Smoked Fish (Reduced Oxygen Packaging)

- The smoker temperature must not exceed 32.2ºC (90°F) (FDA, 2001).

### Hot-Smoked Fish (Oxygen Permeable Packaging)

- No guidelines; treat as cooked ready-to-eat fish

### Hot-Smoked Fish (Reduced Oxygen Packaging

- The internal temperature of the fish must be maintained at or above 62.8ºC (145°F) throughout the fish for at least 30 min (FDA, 2001).
- Not less than 3.5% water phase salt in the loin muscle, or, where permitted, the combination of 3.0% water phase salt in the loin muscle and 100-200 ppm nitrite (FDA, 2001; 21CFR172.175; 21CFR172.177).
- The product must not be exposed to temperatures above 10ºC (50ºF) for more than 12 h nor to temperatures above 21.1ºC (70ºF) for more than 4 h, excluding time above 60ºC (140°F) (FDA, 2001).
- The product must not be exposed to storage temperatures above 10ºC (50ºF), which may be assured by:
    - A maximum cooler temperature of 10ºC (50ºF); and/or
    - The presence of sufficient cooling media (e.g., adequate ice to completely surround the product) (FDA, 2001).
- The product must not be exposed during transportation to temperatures above 10ºC (50ºF), which may be assured by:
    - A maximum refrigerated container temperature of 10ºC (50ºF) throughout transit; or
    - The presence of sufficient cooling media (e.g., adequate ice to completely surround the product) upon receipt (FDA, 2001).

## **AFDO Guidelines** (AFDO, 1991) Top

### Plants and grounds

A. The following processes must be carried out in separate rooms or in a segregated fashion so as to eliminate contamination:
    1. Receiving or shipping
    2. Storage of raw fish
    3. Presmoking operations such as thawing, dressing, and brining
    4. Drying and smoking
    5. Cooling and packing
    6. Storage of final product

B. The product must be so processed as to prevent contamination by exposure to areas, utensils, or equipment involved in earlier processing steps, refuse, or other objectionable areas.

## Sanitary operations

A. Before beginning the day's operations, all utensils and food contact surfaces of equipment to be used for the day's operations must be rinsed and sanitized to protect against the introduction of microorganisms into the fish or other ingredients. All utensils and food contact surfaces of equipment must be cleaned and sanitized after any interruption during which the food contact surfaces may have become contaminated.
B. Equipment and utensils used in the handling of raw or frozen fish and fish portions must not be used in the handling, transport, or packaging of product after it has entered the smoking chamber or used in the handling of finished product.

## Sanitary facilities and controls

A. Readily understandable signs directing employees handling unprotected food, unprotected food packaging materials, or food contact surfaces to wash and sanitize their hands before they start work, after each absence from post of duty, and when their hands have become soiled or contaminated, should be conspicuously posted in the processing room(s), finished product packing room(s), and in all other areas where conditions require.
B. Handwashing facilities shall be conveniently located to permit use by all employees in fish preparation and processing areas. Handwash facilities shall be accessible to these employees at all times.
C. Handwash facilities shall be located in or immediately adjacent to toilet rooms or their vestibules.

## Equipment and utensils

A. All plant equipment and utensils must be designed and of such material and workmanship as to be adequately cleanable, nonabsorbant, corrosion resistant, and they must be properly maintained. The design, construction, and use of equipment and utensils must preclude the adulteration of food with lubricants, fuel, metal fragments, wood fragments, contaminated water, or any other contaminants. All equipment must be installed and maintained as to facilitate the cleaning and sanitizing of the equipment and of all adjacent spaces. Food contact surfaces must be corrosion resistant when in contact with food. They must be made of nontoxic materials and designed to withstand the environment of their intended purpose (i.e., refrigerated storage, brining tank) and the action of the food, and cleaning and sanitizing agents. Food contact surfaces must be maintained to protect the food from being contaminated by any source, including unlawful indirect food additives.
B. Containers used to convey, brine, or store fish must not be nested while they contain fish or otherwise handled during processing or storage in a manner conducive to direct or indirect contamination of their contents.

C. Cleaning and sanitizing of utensils and portable equipment must be conducted in an area set aside for these purposes or in a segregated fashion so as to prevent contamination of food.
D. Each freezer and cold storage compartment used to store and hold food must be fitted with a thermometer or temperature recording device so installed as to show the temperature accurately within the compartment.
E. Instruments and controls used for measuring, regulating, or recording temperatures must be accurate and maintained on a regular schedule, and adequate in number for their designated uses.
F. Compressed air or other gases used to clean food contact surfaces or equipment must be treated in such a way that food is not contaminated with unlawful indirect food additives.
G. Each smoking chamber must be equipped with a temperature monitoring device so installed as to indicate accurately at all times the temperature of the air and of the fish within the smoking chamber, where required.
H. Thermometers or other temperature measuring devices must have an accuracy of ± 2ºF (1.1ºC) and the graduations must not exceed 2ºF (1.1ºC) within a range of 10ºF (5.5ºC) of the processing temperature. The accuracy of these devices must be maintained.
I. Equipment and utensils must be marked in some may to ensure that equipment and utensils used to handle raw fish are not used to handle product which has entered the smoking chamber or used in the handling of finished product.

## Raw materials

A. Fresh fish received shall be inspected and adequately washed before processing. Only sound, wholesome fish free from adulteration and organoleptically detectable spoilage shall be processed.
B. Frozen fish received shall be adequately inspected, and only clean wholesome fish shall be processed.
C. Fresh fish, except those to be immediately processed, shall be iced or otherwise refrigerated to an internal temperature of 38ºF (3.3ºC) or below upon receipt and shall be maintained at that temperature until the fish are to be processed.
D. All fish received in a frozen state shall be either thawed promptly and processed, or stored at a temperature that will maintain it in a frozen state.
E. The defrosting of frozen fish shall be conducted in a sanitary manner and by such methods that the wholesomeness of the fish is not adversely affected. Frozen fish shall be defrosted:
    1. In air so the temperature in any part of the fish does not exceed 45ºF (7.2ºC); or
    2. In a continuous water-overflow thaw tank or spray system in such a manner that the temperature of the water does not exceed 60ºF (15.5ºC) and the internal temperature in any of the fish does not exceed 45ºF (7.2ºC); or
    3. In a microwave tunnel in such a manner that the internal temperature in any of the fish does not exceed 45ºF (7.2ºC).
F. After thawing, fish shall be washed thoroughly with a vigorous potable water spray or a continuous water-flow system. When thawing and brining occur concurrently, the fish shall be washed in this same fashion following the thawing or brining.
G. All fish shall be free of viscera prior to processing, except:

1. Small species of fish, such as anchovies and herring sprats, provided they are processed in a safe fashion and will contain a water phase salt level of at least 10%, a water activity below 0.85, or a pH of 4.6 or less; and
2. Fermented fish, provided they are processed in a safe fashion and will contain a water phase salt level of at least 17%.

H. The evisceration of fish shall be conducted in an area that is segregated or separate from other processing operations. The evisceration shall be performed with minimal disturbance of the intestinal tract contents. The fish, including the body cavity, shall be washed thoroughly with a vigorous spray or a continuous water flow system following evisceration.

## Operations and controls for processed fish

A. All operations involving the receiving, holding, processing, and packaging of processed fish shall be conducted utilizing clean and sanitary methods and shall be conducted as rapidly as practicable and at temperatures that will not cause any material increase in bacterial or other microscopic content or any deterioration or contamination of such processed fish.
B. All processed fish except smoked fish processed pursuant to the following sections shall be processed pursuant to a scheduled process established by a competent processing authority. A copy of said scheduled process which is utilized shall be available for examination in each processing establishment. The scheduled process must also be filed with the appropriate regulatory authority prior to the commencement of processing. Each scheduled process shall identify the name and address of the competent processing authority by whom it was established. The scheduled process shall include processing methods, procedures, and controls for each product, as well as packaging and labeling requirements. Whenever a deviation in a scheduled process occurs as discovered by records, processors check, or otherwise, the processors shall destroy all product affected by said deviation or hold it for a determination as to whether it is adulterated within the meaning of the Federal Food, Drug, and Cosmetic Act.
C. Mechanical manufacturing steps such as washing, cutting, sorting and inspecting, cooling, and drying must be performed so as to protect food against contamination including that which may drip, drain, or be drawn into the food. Protection must be provided by cleaning and sanitizing all food contact surfaces, and by using time and temperature controls at and between each manufacturing step.
D. All processed fish shall be distributed and sold at temperatures that do not exceed 38ºF (3.3ºC), except that:
    1. Processed fish that have a water phase salt level of at least 17% shall not require refrigerated storage; and
    2. Processed fish which contain a water phase salt level of at least 10% or a pH of 4.6 or below may be distributed or sold at refrigerated temperatures that do not exceed 45ºF (7.2ºC).
E. The vacuum packaging or modified atmosphere packaging of processed fish shall be conducted only within the facilities of the manufacturer.
F. Processed fish to be vacuum packaged or modified atmosphere packaged shall be chemically analyzed for water phase salt, and for nitrite and other additives when used,

with sufficient frequency to ensure conformance with finished product specification requirements.

## Brining or dry-salting

A. Brining must be carried out so that the temperature of the brine does not exceed 60ºF (15.5ºC) at the start of brining. If the brining time exceeds 4 h, the brining must take place in a refrigerated area at 38ºF 3.3ºC) or lower.
B. For dry salting, the fish must be returned to a refrigerated area of 38ºF (3.3ºC) or lower immediately after the application of the salt.
C. Different species of fish must not be mixed in the same brining tank.
D. Brines may not be reused unless there is an adequate process available to return the brine to an acceptable microbiological level.
E. Fish must be rinsed with freshwater after brining.

## Heating, cooking, or smoking operations

A. Fish must be arranged without overcrowding or touching each other within the smokehouse oven or chamber to allow for uniform smoke absorption, heat exposure, and dehydration. Fish smoked in the same batch should be of relatively uniform size and weight.
B. Liquid smoke, generated smoke, or a combination of liquid smoke and generated smoke must be applied to all surfaces of the product. Liquid smoke can be applied to the product before, at the beginning, or during the process. Generated smoke is applied to the fish during the first half of the process. If a combination of liquid smoke and generated smoke is used, the procedures for liquid smoke must be followed and the generated smoke can be applied at any stage of the process.

## Hot process smoked fish

A. Hot process smoked fish shall be produced by a controlled process that utilizes a monitoring system such as calibrated probes or recording thermometers to ensure that all products reach the required temperature. The temperature readings shall be obtained by inserting an accurate temperature indicating device into the thickest flesh portion of three or more of the largest fish in the smokehouse compartment. The coldest reading thus obtained shall be recorded in a fish smoking record as being the internal temperature of fish being smoked. The internal temperature of fish being smoked shall be obtained and recorded with the time taken at least three times during the operation of heating each load or batch of fish to assure that the required heat treatment has been accomplished. Each batch of smoked fish shall be identified as to the specific oven load, product temperature obtained, and data processed.
B. For hot process smoked fish to be air packaged, a controlled process must be used to heat fish to a continuous temperature of a least 145ºF (62.8ºC) throughout each fish for a minimum of 30 min for fish brined to contain not less than 2.5% water phase salt in the loin muscle of the finished product.

C. For hot process smoked fish to be vacuum or modified atmosphere packaged, a controlled process must be used to heat fish to a continuous temperature of at least 145ºF (62.8ºC) throughout each fish for a minimum of 30 min for fish brined to contain not less than 3.5% water phase salt in the loin muscle of the finished product or the combination of 3.0% water phase salt in the loin muscle of the finished product and not less than 100 ppm nor more than 200 ppm sodium nitrite.

## Cold process smoked fish

A. Cold process smoked fish shall be produced by a controlled process that utilizes a temperature monitoring system positioned within the smoking chamber to assure that all products do not exceed process temperatures in accordance with one of the following methods:
    1. The temperature in the smoking chamber does not exceed 90ºF (32.2ºC) during a drying and smoking period that does not exceed 20 h; or
    2. The temperature in the smoking chamber does not exceed 50ºF (10.0ºC) during a drying and smoking period that does not exceed 24 h; or
    3. The temperature in the smoking chamber does not exceed 120ºF (48.9ºC) during a drying and smoking period that does not exceed 6 h for cold process smoked sablefish.
B. For cold process smoked fish to be air packaged, only fish that have been brined to contain not less than 2.5% water phase salt in the loin muscle of the finished product may be used.
C. For cold process smoked fish to be vacuum or modified atmosphere packaged, only fish that have been brined to contain not less than 3.5% water phase salt in the loin muscle of the finished product or a combination of 3.0% water phase salt in the loin muscle of the finished product and not less than 100 ppm nor more than 200 ppm sodium nitrite may be used.

## Cooling

All finished products must be cooled to a temperature of 50ºF (10ºC) or below within 3 h after cooking and further cooled to a temperature of 38ºF (3.3ºC) or below within 12 h after cooking. The finished product must be maintained at 38ºF (3.3ºC) or lower during all subsequent storage and distribution.

## Packaging and labeling of processed fish

The finished product shall be handled only with clean, sanitized hands, gloves, or utensils. Manual manipulation of the finished product shall be kept to a minimum.

A. The finished product shall be stored and handled in a segregated area apart from unprocessed fish and equipment used for unprocessed fish.
B. Shipping containers, retail packages, and shipping records relating to processed fish shall indicate, by appropriate labeling, the perishable nature of the product. Frozen product shall clearly indicate that the product shall remain frozen until thawed at refrigerated

temperatures and shall not be refrozen. Refrigerated product shall clearly and conspicuously state "Keep Refrigerated at 38ºF (3.3ºC) or Below."

C. Each container of processed fish shall be marked with an identifying code which shall be permanently visible to the naked eye. Where the container does not permit the code to be embossed or inked, the label may be legibly perforated or otherwise marked, provided that in all instances the label shall be securely affixed to the product container. The required identification shall identify in code –the establishment where packed, the product contained therein, the year packed, the day packed, and the period during which packed. The packing period code shall be changed with sufficient frequency to enable ready identification of lots during their sale and distribution.

# NMFS Guidelines

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### Inspection and certification of vacuum packaged hot-processed smoked or hot-processed smoke-flavored salmon

A. The processing facility must be in compliance with the requirements of 50 CFR Part 260.

B. Defrosting of eviscerated frozen fish shall be carried out in:
   1. Air at 45° F (7.2° C) or below until completely thawed and the internal temperature of any part of the fish does not exceed 45° F (7.2° C).
   2. A continuous water flow tank or spray system until thawed. Salmon shall not be mixed with other species during thawing. Fish shall not remain in the tank for over 4 h after they are completely defrosted and the temperature in any part of the fish shall not exceed 60° F (15.6° C) during this period. If longer delays and encountered, the fish shall be returned to temperatures of 38° F (3.3° C) or below until brined.

C. Both fresh and thawed fish shall be washed thoroughly with a vigorous chlorinated water spray or in a continuous water flow system prior to brining. (Chlorine concentration in water shall not exceed 50 ppm available chlorine).

D. All fish shall be dry-salted at a temperature not to exceed 38° F (3.3° C) throughout the fish, or if brined, the salmon shall not be mixed with other species of fish in the same tank and shall be brined in such a manner that the temperature of the fish and brine:
   1. Does not exceed 60° F (15.6° C) at the start of the brining, and
   2. If the brine time exceeds 4 h, the brining shall take place in a refrigerated room of 42° F (5.6° C) or lower. The product may not be held above 38° F (3.3° C) for more than 48 h.
   3. Brines may not be reused unless there is an adequate process (e.g., ultrafiltration) to return the brine to an acceptable microbiological level.

   **[Note:** Brine tanks that have been used to brine other species of fish shall be cleaned and sanitized before being used to brine salmon]

E. Hot-process smoked or hot-process smoke-flavored salmon shall be brined in such a manner that the final sodium nitrite content of the loin muscle of the finished product shall be no less than 100 ppm and no more than 200 ppm (parts per million) after

processing. These same products shall contain not less than the minimum concentrations of one of the following combinations of water phase salt (w.p. NaCl) and sodium nitrite in the deepest part of the loin:

| % w.p. NaCl | ppm sodium nitrite |
|---|---|
| 3.5 | 100 |
| 3.4 | 120 |
| 3.3 | 140 |
| 3.2 | 160 |
| 3.1 | 180 |

F. Hot-process smoked or hot-process smoke-flavored salmon shall be heated by a controlled heat process that provides a monitoring system (e.g., calibrated probes or dial thermometers) positioned in as many strategic locations in the oven as necessary to assure that all products reach the minimum internal temperature.

[Note: The temperature monitoring device shall be tested for accuracy against a known standard thermometer upon installation and at least once a year thereafter, or more frequently if necessary, to ensure their accuracy. Graduations on the temperature monitoring device shall not exceed 2° F (1.1° C) within a range of 10° F (5.6° C) of the processing temperature.]

Each fish or fish portion shall be heated to an internal temperature of 150° F (65.6° C) or higher and maintained at 150° F (65.6° C) for 30 min or longer.

G. Liquid smoke or generated smoke or a combination of liquid smoke and generated smoke shall be applied to the entire product. If only liquid smoke is used in the process it can be applied to the product prior to, at the beginning of, or during the process. Liquid smoke added during the process shall be applied before the internal temperature of the product exceeds 125° F (51.7° C). The liquid smoke shall be prepared by the aqueous process (e.g., U.S. Patent 3,106,473) and have a minimum of the following major constituents in its compositions: 1) 10% titratable acidity; 2) 9 mg phenol/g; 3) 12 g carbonyls/100 ml, and be used at concentrations of 50% or greater.

When only generated smoke is used in the process, dense smoke shall be applied to the fish for at least 90 min at the beginning of the process. If a drying cycle is used in the smoking process, the air temperature surrounding the product shall not exceed 110° F (43.3° C) and the time period shall not exceed 60 min at temperatures between 60° F (15.6° C) and 110° F (43.3° C) before the application of smoke. If lower temperatures (60° F [15.6° C] or below) are used, this time period shall not exceed 6 h. Generated

smoke shall be produced from burning hardwood. If a combination of liquid smoke and generated smoke are used, the procedures for liquid smoke shall be followed and the generated smoke can be applied at any stage of the process.

H. The finished product shall be cooled to a temperature of 50° F (10° C) or below within 5 h after cooking and further cooled to a temperature of 38° F (3.3° C) or below within 12 h after cooking. The finished product shall be maintained at 38° F (3.3° C) or lower during all subsequent storage and distribution.
I. Primary packages and master cartons shall be clearly marked with a statement to maintain the product below 38° F (3.3° C). If fish are frozen, they shall be clearly labeled to thaw at refrigerated temperatures and that the thawed product must subsequently be stored below 38° F (3.3° C).
J. The finished product shall be analyzed chemically with sufficient frequency to assure that the required water-phase salt and sodium nitrite is obtained and that other chemical additives are present at authorized levels. To reduce the possibility of post processing contamination with food poisoning bacteria, the product shall be vacuum-packaged only within the facility in which it was processed.
K. Permanently legible code marks shall be placed on the outer layer of every finished product package and master carton. Such marks shall identify at least the plant where packed and the date of packing. Records shall be maintained at the processing facility for a minimum of 6 months from the date of processing as to provide positive identification (1) of the process procedures (including process/product time, temperature, sodium nitrite and water-phase salt levels) used for the manufacture of hot-process smoked and hot-process smoke-flavored fish and (2) of the distribution of the finished product (NMFS, 1984).

# State Guidelines

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## Alaska Smoked Fish Regulations

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Article 3. Smoked or Smoke-Flavored Seafood Products Processing
Section 300. Applicability of Smoked or Smoke-Flavored Seafood Products Processing Requirements

- Section 310. Processing Requirements for Smoked or Smoke-Flavored Seafood Product
- Section 315. Native-Style Smoked or Smoke-Flavored Dried Salmon
- Section 320. Finished Product Handling

## Michigan Smoked Fish Regulations

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Regulation No. 289.7105 Processor of smoked fish; variance; waiver. The requirement that a processor of smoked fish obtain a variance under the smoked fish rules is waived if the processor demonstrates compliance with 21 C.F.R. part 123, the "seafood HACCP plan".

Regulation No. 569. Smoked Fish

## New York: Smoked Fish Air Packed (Corby, 1999) Top

All processed fish shall be produced pursuant to a scheduled process established by a competent processing authority. A copy of said scheduled process shall be available for examination in each fish processing establishment. Each scheduled process shall identify the name and address of the competent processing authority by whom it was established. The scheduled process shall include processing methods, procedures and controls for each product, as well as packaging and labeling requirements. Whenever a deviation in a scheduled process occurs, as disclosed by records, processor check or otherwise, the processor shall destroy all product affected by said deviation or hold it for a determination as to whether it is adulterated within the meaning of Section 200 of the Agriculture and Markets Law:

## New York: Vacuum Packaged or Modified Packaged (Corby, 1999) Top

Unless otherwise provided by a scheduled process, the following additional requirements shall apply to vacuum packaged or modified atmosphere packaged smoked fish.

a. Brining of fish for smoking shall be carried out so that the temperature of the brine does not exceed 60 degrees Fahrenheit at the start of brining. If the brining time exceeds 4 hours, the brining shall take place in a refrigerated area of 38 degrees Fahrenheit or lower. For dry salting, the fish shall be returned to a refrigerated area of 38 degrees Fahrenheit or lower immediately after the salting step.
b. Brining tanks shall be cleaned and sanitized prior to use. Different species of fish shall not be mixed in the same tank and brines shall not be reused unless there is an adequate process available to return the brine to an acceptable microbiological level.
c. Fish to be smoked shall be arranged without overcrowding or touching each other within the smokehouse oven or chamber to allow for uniform smoke absorption, heat exposure and dehydration.
d. Liquid smoke, generated smoke or a combination of liquid smoke and generated smoke shall be applied to all surfaces of fish to be smoked. Liquid smoke may be applied to the product prior to, at the commencement of, or during the process, while generated smoke shall be applied to the fish during the first half of the process and longer if necessary. If a combination of liquid smoke and generated smoke is used, the procedures for liquid smoke shall be followed and the generated smoke may be applied at any stage of the process.
e. Vacuum packaged or modified atmosphere packaged hot process smoked fish shall be produced by a controlled process that utilizes a monitoring system such as calibrated probes or dial thermometers to assure that all products reach the required temperature. The temperature readings shall be obtained by inserting an accurate temperature indicating device into, the thickest flesh portion of three or more of the largest fish in the smokehouse compartment. The coldest reading thus obtained shall be recorded in a fish smoking record as being the internal temperature of fish being smoked. The internal temperature of fish being smoked shall be obtained and recorded with the time taken at least three times during the operation of heating each load or batch of fish to assure that the required heat treatment has been accomplished. Each batch of smoked fish shall be

identified as to the specific oven load, product temperature obtained and date processed. The temperature monitoring system shall be accurate to within 2 degrees Fahrenheit.

f. Vacuum packaged or modified atmosphere packaged hot process smoked fish shall be produced by a controlled process whereby each fish or fish portion shall be heated to an internal temperature of 145 degrees Fahrenheit or higher and maintained at 145 degrees Fahrenheit or higher for 30 minutes or longer. The smoked fish shall be brined to contain at least 3.5 percent water phase salt in the loin muscle of the finished product, except that vacuum packaged or modified atmosphere packaged hot process smoked fish which contain 100-200 parts per million sodium nitrite shall contain at least 3.0 percent water phase salt in the loin muscle of the finished product when processed in this fashion. Vacuum packaged or modified atmosphere packaged seafood processed in this fashion shall be brined to contain at least 3.5 percent water phase salt in the flesh portion of the product.

g. Vacuum packaged or modified atmosphere packaged cold process smoked fish shall be produced by one of the following processes:
    1. Vacuum packaged or modified atmosphere packaged cold process smoked fish shall be produced by a controlled process that utilizes a temperature monitoring system positioned within the smoking chamber and results in a temperature that shall not exceed 90 degrees Fahrenheit during the drying and smoking period, which period shall not exceed 20 hours. The smoked fish shall be brined to contain at least 3.5 percent water phase salt in the loin muscle of the finished product except that vacuum packaged or modified atmosphere packaged cold process smoked fish which contain 100-200 parts per million sodium nitrite shall contain at least 3.0 percent water phase salt in the loin muscle of the finished product when processed in this fashion or;
    2. Vacuum packaged or modified atmosphere packaged cold process smoked fish shall be produced by a controlled process that utilizes a temperature monitoring system positioned within the smoking chamber and results in a temperature that does not exceed 50 degrees Fahrenheit during the drying and smoking period, which period shall not exceed 24 hours. The smoked fish shall be brined to contain at least 3.5 percent water phase salt in the loin muscle of the finished product except that vacuum packaged or modified atmosphere packaged cold process smoked fish which contain 100-200 parts per million sodium nitrite shall contain at least 3.0 percent water phase salt in the loin muscle of the finished product when processed in this fashion or;
    3. Vacuum packaged or modified atmosphere packaged cold process smoked sable fish shall be produced by a controlled process that utilizes a temperature monitoring system positioned within the smoking chamber and results in a temperature that shall not exceed 120 degrees Fahrenheit during the drying and smoking period, which period shall not exceed 6 hours. The smoked fish shall be brined to contain at least 3.5 percent water phase salt in the loin muscle of the finished product except that vacuum packaged or modified atmosphere packaged cold process smoked sable fish which contain 100-200 parts per million sodium nitrite shall contain at least 3.0 percent water phase salt in the loin muscle of the finished product when processed in this fashion.

h. Vacuum packaged or modified atmosphere packaged smoked fish shall be immediately cooled after processing to 50 degrees Fahrenheit or below within 5 hours and further cooled to a temperature of 38 degrees Fahrenheit or below within 12 hours after processing.

### New York: VP/MAP Smoked Fish Processing Guidelines from NYS Agriculture and Markets Field Operations Manual (Corby, 1999)

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1. Brining Procedures: (VP/MAP)
    A. Brine not to exceed 60°F at start
    B. Brining procedures greater than 4 hours to be conducted under refrigeration of 38°F
    C. Dry salting placed under 38°F refrigeration after the salting step
    D. Brines not to be reused
    E. Mixing of fish species in brines not allowed
2. Smoking Procedures: (VP/MAP)
    A. Fish not overcrowded in smokehouse so as to promote absorption and exposure
    B. Generated smoke applied to fish during the first half of process
    C. Liquid smoke may be added before or during process
        - Hot Smoking
            1. Temperature probe of 3 or more fish with the coldest reading being recorded on process record
            2. Temperature recorded 3 times during heating
            3. Process record to include batch load temperature and date
            4. 145°F/30 minutes and 3.5% wps. 145°F/30 minutes and 3.0% wps w/100-200 ppm nitrite
        - Cold Smoking
            1. Smokehouse or chamber temperature monitored
            2. Processing parameters:
                - 90°F/20 hours and 3.5% wps
                - 90°F/20 hours and 3.0% wps w/100-200 ppm nitrite
                - 50°F/24 hours and 3.5% wps
                - 50°F/24 hours and 3.0% wps w/100-200 ppm nitrite
                - Sablefish 120°F/6 hours and 3.5% wps
                - Sablefish 120°F/6 hours and 3.0% wps w/100-200 ppm nitrite
3. Cooling Procedures: (VP/MAP)
    - 50°F within 5 hours and 38°F within 12 hours

# Process Establishment

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Except where finished product water phase salt analysis is the monitoring procedure, the adequacy of the brining/dry salting and/or drying process should be established by a scientific study. It should be designed to ensure a water phase salt level in the loin muscle of: 2.5% for air packaged smoked or smoke-flavored fish; 3.5% or 3.0% with 100-200 ppm nitrite for vacuum or

modified atmosphere packaged smoked fish or smoke-flavored fish; or 10% for salted fish. Expert knowledge of salting and/or drying processes is required to establish such a process. Education or experience or both can provide such knowledge. Establishment of brining/dry salting and drying processes requires access to adequate facilities and the application of recognized methods. The drying equipment must be designed, operated, and maintained to deliver the established drying process to every unit of product. In some instances, brining/dry salting and/or drying studies will be required to establish minimum processes. In other instances, existing literature establishes minimum processes or adequacy of equipment. Characteristics of the process, product, and/or equipment that affect the ability of the established minimum salting and/or drying process should be taken into consideration in the process establishment. A record of the process establishment should be maintained (FDA, 1998; 21CFR172.175; 21CFR172.177).

# Critical Aspects of Processes

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Critical aspects of reduced oxygen packaged smoking processes may include:

- brine strength;
- brine to fish ratio;
- brining time;
- brining temperature;
- thickness,
- texture,
- fat content,
- quality, and species of fish;
- drying time;
- input/output air temperature, humidity, and velocity;
- smoke density;
- drier loading;
- accuracy of thermometers, recorder thermometer charts, high temperature alarms, maximum indicating thermometers, and/or digital data loggers; and
- accuracy of other monitoring and timing instruments (FDA, 1998).

# Analytical Procedures

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### Moisture analysis

See Chapter 1.

### Salt analysis

See Chapter 1.

### Water activity

See Chapter 1.

### Water phase salt calculation

See Chapter 1.

## Smoking Processes Top

Examples of seafood processes are provided for information only. The National Seafood HACCP Alliance does not endorse or recommend specific seafood processes. Some of the referenced processes are of historical interest and may not reflect current best management practices. Processes should not be followed as written without validation.

### Cold-smoked roe

Clean lobes of roe of all slime, blood, bits of gall bag and other extraneous material. Wash in seawater and drain for a few min. Salt roe using about 10 pounds (4.5 kg) of salt per 100 pounds (45.4 kg) of roe. Cure until desired color is obtained. Wash several times in seawater and hang in the shade for about 24 h. Cold smoke on wire mesh trays for 2-3 d. Split and remove membrane on each roe sac. Pack roe in barrels and store in a cool (about 12.8-15.6ºC [55-60° F]) place for 1 month to 6 weeks. As soon as fermentation begins, mix enough salt (about 15 pounds (6.8 kg) per 100 pounds (45.4 kg) roe) with the roe to arrest fermentation. Pack in metal containers or glass jars and hermetically seal (Jarvis, 1987).

### Cold-smoked croaker

Remove croaker (*Micropogon undulatus*) head, retaining the collarbones. Cut the fish down the belly to the vent. Remove viscera and clean the belly cavity thoroughly. Split fish down the belly side to within 1 inch (2.5 cm) of the tail, without cutting all the way through the fish. Wash the fish and brine in strong brine for 30 min to 1 h. Fasten the fish to rods so the fish lay out flat. Air-dry using a fan. Smoke at less than 32.2ºC (90ºF) using light smoke for 2-4 h and heavy smoke for an additional 2 h (Jarvis, 1987).

### Cold-smoked eel

Remove surface slime by scraping or rubbing with fine salt. Split eel down the belly from the head past the vent and eviscerate. Remove head and tail. Split lengthwise into 2 fillets, removing the backbone. Cure in a 90º salinometer brine for 6 h. Wipe dry and coat the fillets with the following preparation which has been pounded into a paste: 1 large anchovy, 1 ounce (28 g) fine salt, 8 ounces (227 g) powdered sugar, 1 ounce (28 g) saltpeter, and sufficient butter to make it a smooth paste. Roll fillets into tight cylinders beginning with the tail portion. Tie cylinders with cord to hold them together. Cover the outside of the fillet rolls with a cloth, leaving the ends of the cylinders uncovered. Hang cylinders in the smoker and smoke, using a cool, dense smoke, for 5-6 d (Jarvis, 1987).

### Cold-smoked flounder

Use small flounder weighing about ½ pound (0.2 kg) . Gut the fish, wash, and brine for 2 h in a 90º salinometer brine. String the fish on rods, drain and air-dry for a few h. Cold-smoke for 8-10 h (Jarvis, 1987).

## Cold-smoked haddock (finnan haddie)

Remove heads from dressed fish and wash thoroughly. Split fish down the belly side to within 1-2 inches (2.5-5.1 cm) of the tail, without cutting entirely through the flesh. Soak fish in at least a 90º salinometer brine for 30 min to 2 h. Hang fish so that the split fish is open and flat. Air-dry for a few h, using a fan. Smoke lightly for 8-12 h and then under dense smoke for 6-7 h. The temperature of the smoker should average 26.7ºC (80ºF) (Jarvis, 1987).

## Cold-smoked haddock fillets

Fillet fish and skin and wash fillets. Drain and brine in a 90º salinometer brine for 20 min to 2 h. Drain and dye, if desired. Hang fillets over rods or arrange on wire-mesh trays. Air-dry for about 2 h until a pellicle forms on the flesh. Smoke at no higher than 32.2ºC (90ºF) for about 4 h using light smoke, then turn the fillets over and smoke for an additional 4 h. Smoke in dense smoke for 4-6 h, turning the fish once during the process (Jarvis, 1987).

## Cold-smoked herring

Dry-salt gutted and eviscerated fish with 12-20% salt by weight, and pressed with a weight, for about 1 week.. The fish can also be brined in saturated brine with an additional 5% salt by weight of fish added for about 40 h. Rinse in freshwater. Pierce heads with a bar and dry fish for 1 d. Smoke for 3-4 weeks at about 18ºC (64.4ºF) for the first week, about 22ºC (71.6ºF) for the second week, and about 25ºC (77.0ºF) for the final stage (Tanikawa et al., 1985).

## Cold-smoked herring (bloaters I)

Brine round or eviscerated herring in a 90-95º salinometer brine for about 48 h. Rinse. Hang fish on rods by inserting the rod through the gill cover and out the mouth. Drain for a few min. Smoke at 18.3ºC (65ºF) for 48 h and then at about 15.6ºC (60ºF) for 2-5 d (Jarvis, 1987).

## Cold-smoked herring (bloaters II)

Wash herring and dry-salt, using about 25 pounds (11.3 kg) of salt to 100 pounds (45.4 kg) of fish. Cure for 12-14 h. Rinse herring free of salt. Hang fish on rods by inserting the rod through the gill cover and out the mouth. Smoke 8-12 h at about 29.4ºC (85ºF) (Jarvis, 1987).

## Cold-smoked herring (hard-smoked herring)

For 4,800 pounds (2,177 kg) of fish, fill the brining tank partially full with 40º salinometer brine. Add a layer of fish on the bottom and scatter about 30 pounds (13.6 kg) of salt over the fish Add a second layer of fish and cover with 60-90 pounds (27.2-40.8 kg) of salt. Add the third and top layer of fish and cover with 180-300 pounds (81.6-136.1 kg) of salt. Salt for 24-36 h for small

fish and 48 h or longer for large or very fat fish. Rinse off excess salt in the brine and freshen in sea water for 12-15 h. Rinse in clean sea water. Hang fish on rods by inserting the rod through the gill cover and out the mouth. Hang rods in smoker and dry for 1-5 h without smoke. Smoke with heavy smoke for 12-15 h or until the herring are colored by the smoke. Continue smoking for about 3 weeks until the fish are completely cured. The smoker temperature should not exceed 21.1ºC (70ºF). For boneless smoked herring, clip off the heads, bellies and tails with scissors, and remove skin and bones with a knife (Jarvis, 1987).

## Cold-smoked herring (kippered herring)

Wash herring to remove slime, blood, scales and other debris. Split the fish down the left side of the backbone from the head almost to the tail. Open fish to lie flat and remove gills, viscera, blood and membranes. Wash well in freshwater and drain a few min. Brine in a 90-95º salinometer brine for 20-30 min. Dip in dye solution (1 g dye to 2 L water) for about 30 s. Drain and hang on smoke sticks. Drain and dry in smoker. Smoke lightly for 6-8 h (Jarvis, 1987).

## Cold-smoked herring (red herring)

Mix whole herring with about 30 pounds (13.6 kg) of salt to 100 pounds (45.4 kg) of fish. Cure for at least 10 d. Hang fish on rods by inserting the rod through the gill cover and out the mouth. Dry in smoker for 12-25 h. Smoke at 14-19ºC (57.2-66.2ºF) on alternate d for 3-6 weeks (Jarvis, 1987).

## Cold-smoked kingfish

Fillet the kingfish (*Scomberomorus cavella*) and remove the backbone. Wash sides thoroughly and drain. Soak for about 1 h in a 40º salinometer brine chilled with ice. Drain for a few min and then dredge in fine salt and lay in a box for 1-2 h. Rinse with freshwater, attach to hangers and air-dry until a pellicle has formed. Place the fish in the smoker and dry for 24-36 h without much smoke. Smoke for an additional 6-12 h with dense smoke. Keep the smoker temperature below 32.2ºC (90ºF) (Jarvis, 1987).

## Cold-smoked mackerel

Split mackerel (*Scomber scombrus*) down the left side of the backbone from the tip of the head almost to the tail and open to lay flat in 1 piece. Clean out gills, viscera and blood. Wash and soak in fresh warm water for 15-30 min to remove blood. Drain and soak in a 80º salinometer brine for about 1 h. Fix fish on rods so that fish remain flat and not touching each other. Air-dry for several h. Smoke for 8 h in a light cool smoke (Jarvis, 1987).

## Cold-smoked mullet

Split mullet (*Mugil cephalus*) along the back just above the backbone, almost to the tail, so they will lay flat in 1 piece. Leave the belly portion solid and the backbone in. Remove all traces of viscera and black membrane. Remove the head, if desired. Soak in 40º salinometer brine for 30 min to soak out blood. Drain, dredge in salt, and pack in a tub. Salt for 1-3 h. Rinse in brine and

place on wire-mesh trays. Air-dry for about 3 h. Hang on rods and cold-smoke for 8-12 h using light smoke. Increase the smoke and smoke for a total of 20-24 h, if they are to be kept for about 10 d, or 3-5 d if they are to be kept for some time (Jarvis, 1987).

## Cold-smoked salmon I

Gut, eviscerate, wash and dry-salt salmon. Cure with 20-30% salt by weight for 10-30 d. Rinse with freshwater for 1-3 d to remove salt. Hang by the tail and dry until the surface skin is dried up. Smoke during the night time and open smoker during the day to cool and dry the fish. Smoke at about 18ºC (64.4ºF) for the first week, about 22ºC (71.6ºF) for the second week, and about 25ºC (77.0ºF) for the final stage (Tanikawa et al., 1985).

## Cold-smoked salmon II

Soak mild-cured salmon sides overnight (12-16 h) in freshwater, changing the water 2-3 times. Drain and trim salmon, removing any ragged edges. Hang sides on wire hangers and dry for 24-48 h, using mechanical fans, until a thin shiny skin has formed on the surface. Smoke for 48-72 h at 23.9-32.2ºC (75-90ºF) (Jarvis, 1987).

## Cold-smoked salmon (German smoked salmon)

Freshen mild-cured salmon sides in running water for 5-10 h. Hang and dry sides for several h. Smoke at 20-25ºC (68-77ºF) for 3-5 d (Jarvis, 1987).

## Cold-smoked salmon (hard-smoke or Indian-cure salmon)

Split salmon into 2 sides and remove backbone. Cut each side longitudinally into several strips. Soak strips in 90º salinometer brine, adding the thickest strips first, the medium sized strips an h later and the smaller pieces after another h. Cure for 16-20 h and drain. Hand strips and air-dry for 24 h. Smoke slowly at 21.1-26.7ºC (70-80ºF) for about 2 weeks (Jarvis, 1987).

## Cold-smoked salmon (Scotch smoked salmon I)

Wash salmon thoroughly and split down the back. Clean belly cavity of viscera and blood. Rinse fish and drain. Rub fish with a mixture of salt and brown sugar and pack in a tub. Cure for 48 h. Rinse and insert 3 double pointed sticks in the belly cavity to hold it open. Hang and smoke lightly for 10-14 h (Jarvis, 1987).

## Cold-smoked salmon (Scotch smoked salmon II)

Wash fish thoroughly and score skin at 2 inch (5.1 cm) intervals longitudinally. Split salmon into 2 sides and remove viscera. Rinse to remove blood and press remaining blood out of veins in belly cavity. Wash thoroughly in ice water and soak in ice water for about 30 min. Drain and trim. Dredge salmon sides in a ground mixture of 6 pounds (2.7 kg) salt, 4 pounds (1.8 kg) brown sugar, 1 ounce (28 g) saltpeter, and ½ ounce (14 g) each of bay leaves, black peppers, cloves, coriander seed, and allspice. Pack sides into a tub and cure for 48 h. Scrub sides and soak

in cold water for 1 h. Lay sides in a small pile, skin side down, with weights on top for several h to press out moisture. Hang sides on smoke sticks and dry in the air until a thin skin or pellicle forms on the surface. Smoke lightly for 16-24 h and in dense smoke for an additional 8 h. Maintain the smoker temperature at no more than 26.7ºC (80ºF) (Jarvis, 1987).

## Cold-smoked shrimp (peeled shrimp)

Peel and wash shrimp. Drain and blanch for 5-8 min in boiling 50º salinometer brine. Air-dry and spread on oiled wire-mesh trays. Smoke for 90 min in a dense cool smoke at not higher than 26.7ºC (80ºF) (Jarvis, 1987).

## Cold-smoked shrimp (shell-on shrimp)

Remove heads, wash, and drain. Either soak for 30-60 min in 50º salinometer brine and steam or boil shrimp until they turn pink, or boil in 50º salinometer brine. Spread on wire-mesh trays and air-dry. Smoke at 21.1-32.2ºC (70-90ºF) for 60-90 min using a dense cool smoke (Jarvis, 1987).

## Cold-smoked yellowtail

Fillet fish, bleed, and remove bones in belly portion. Cure trimmed fillets in brine containing 25-30% salt, 5% sugar and 2% spice. Cure wild fish for 8-15 d and cultured fish for 4-5 d. Rinse fillets in freshwater for 2-3 d for wild fish and 1 d for cultured fish. Hang fillets to dry for 1 d. Smoke wild yellowtail at 20-25ºC (68-77ºF) for the first 4-5 d with the shutter fully open. Smoke at 25-86ºC for the next 3 d with the shutter half-closed. Smoke at 30-35ºC (86-95ºF) for the last 3 d with the shutter closed. Smoke cultured fish a few d less (Tanikawa et al., 1985).

## Hot-smoked butterfish

Wash butterfish (*Poronotus triacanthus*). Brine for 2-6 h in 90º salinometer brine. String fish on rods by running the rod through the eye sockets. Drain and air-dry for a few h. Cold-smoke for 4-5 h until the fish have the desired color, and then hot-smoke at 93.3ºC (200ºF) for about 1 h (Jarvis, 1987).

## Hot-smoked carp

Head and gut carp (*Cyprinus carpio*), and clean thoroughly. Cut into ½-1 pound (0.2-0.5 kg) chunks. Brine for 10-12 h in 60-70º salinometer brine. Hang the fish on rods or place on wire-mesh trays. Sprinkle spices on the fish, if desired. Smoke for 3 h at 107.2ºC (225ºF) using very little smoke, and for 1 h at 32.2-43.3ºC (90-110ºF) using dense smoke (Jarvis, 1987).

## Hot-smoked catfish

Gut and remove catfish heads. Skin the fish and cut into 1-1½ pound (0.5-0.7 kg) chunks. Wash the pieces and brine in 90º salinometer brine for 6-8 h. Rinse pieces, string on rods or place on wire-mesh trays. Air-dry for 2 h. Smoke for 8-9 h, using light smoke and low temperatures

during the first part of the smoking and raising the temperature to 79.4ºC (175ºF) during the last 1-2 h (Jarvis, 1987).

## Hot-smoked eel

Remove surface slime by scraping or rubbing with fine salt. Split eel down the belly from the head past the vent and eviscerate. Cut large eels into 1-2 inch (2.5-5.1 cm) cross sections. Cure in 100º salinometer brine for 2-24 h, or rub with salt and allow brine to form naturally. Rinse and string on rods with the rods passing through the head, or through the throat cartilage and out of the mouth. Place eel sections on wire-mesh trays. Smoke at a low temperature for 4-5 h until they have acquired the proper color, and then at 115.6ºC (240ºF) for 30 min (Jarvis, 1987).

## Hot-smoked goosefish

Head and eviscerate the goosefish (*Lophius piscatorius*). Wash thoroughly to remove slime. Skin the fish and remove fillets by cutting along both sides of the backbone from head to tail. Cut fillets into about 1 pound (0.5 kg) portions (after smoking). Soak in 50º salinometer brine for 16-20 h. After brining, freshen in cold running water for 30-60 min. Spread pieces on a wire-mesh tray and brush with edible oil. Sprinkle with pepper, garlic salt or other spices, if desired. Air-dry at about 21.1ºC (70ºF) until a pellicle forms. Place in smoker and gradually raise temperature to 76.7ºC (170ºF) over a 4 h period. Smoke for an additional 1½ h using heavy smoke (Jarvis, 1987).

## Hot-smoked haddock (smokies)

Head and gut small fish. Wash thoroughly and drain. Brine fish in 90-95º salinometer brine for 30-45 min. Tie each 2 fish together by a loop of string around their tails and hang over rods. Drain for about 2 h. Hot-smoke using dense smoke for 25-45 min (Jarvis, 1987).

## Hot-smoked herring (buckling)

Cover herring with ¾ ground salt, using about 1 part salt to 4 parts fish. Cure for 2-3 h. Rinse with freshwater and drain. Dry for 2-2½ h at 15.6-21.1ºC (60-70ºF). String herring on rods and smoke for 45-60 min at 82.2ºC (180ºF) (Jarvis, 1987).

## Hot-smoked herring

Cut herring at the back portion, eviscerate, wash with dilute brine, and cure with 10-15% brine for 40-90 min. Drain fish and dry. Smoke for 4-6 h, starting at 20ºC (68ºF) and gradually increasing the smoker temperature to 85ºC (185ºF) (Tanikawa et al., 1985).

## Hot-smoked lake herring and whitefish

Split fish down the belly to the vent and eviscerate. Wash the fish thoroughly to remove all traces of blood. Drain for a few min. Cure in 90º salinometer brine for 3-10 h. Drain for a few min and hang on rods. Air-dry until no moisture is apparent on the flesh. Smoke using light smoke at

26.7-32.2ºC (80-90ºF) for 5-6 h. Smoke an additional 1-2 h in dense smoke at 76.7-82.2ºC (170-180ºF) (Jarvis, 1987).

## Hot-smoked mackerel

Wash fresh mackerel (*Scomber scombrus*) and brine for 12-14 h in 90º salinometer brine. Make a cut at the vent to drain out brine from the belly cavity. Insert smoke sticks through the left gill cavity and out the mouth. Air-dry for 2-3 h. Cold-smoke for 4-5 h until they reach the desired color. Hot-smoke at 65.6-93.3ºC (150-200ºF) for 1-2 h (Jarvis, 1987).

## Hot-smoked mullet

Split mullet (*Mugil cephalus*) along the back just above the backbone, almost to the tail, so they will lay flat in 1 piece. Leave the belly portion solid and the backbone in. Remove all traces of viscera and black membrane. Remove the head, if desired. Soak in 40º salinometer brine for 30 min to soak out blood. Drain, dredge in salt, and pack in a tub. Salt for 1-3 h. Rinse in brine and place on wire-mesh trays. Air-dry for about 3 h. Hang on rods and cold-smoke for 8-12 h using light smoke. Increase to dense smoke and raise temperature to 93.3-115.6ºC (200-240ºF) for 30-60 min (Jarvis, 1987).

## Hot-smoked sablefish (kippered black cod)

Clean and dress sablefish (*Anaplopoma fimbria*). Split the fish into sides, remove the backbone, and trim off the thin belly flaps. Cut sides into chunks, weighing about 1 pound (0.5 kg) after smoking. Cure in 90º salinometer brine for 2½ -3 h. Drain for 5-10 min. Dip in dye, if desired. Place chunks skin-side down on wire-mesh trays coated with vegetable oil. Drain for a few h. Smoke at 21.1-37.8ºC (70-100ºF) for 8-16 h, then at 65.6-121.1ºC (150-250ºF) for 25 min to 2 h (Jarvis, 1987).

## Hot-smoked salmon I

Cut frozen and eviscerated chum salmon (*Oncorhynchus keta*) into 1 inch (2.5 cm) thick steaks with an average weight of 180-220 g. Thaw steaks in plastic bags in cold running water at less than 15.6ºC (60ºF). Brine steaks in 1.0 to 3.0% salt at 3.3ºC (38ºF) for 3 d with a fish-to-brine ratio of 1 to 7 (weight/volume). Rinse with cold water and store at 3.3ºC (38ºF) in plastic bags for 2 d before smoking. Smoke at an initial temperature of 60ºC (140ºF), increased in 5.6ºC (10ºF) at 30 min intervals. When the steaks reach an internal temperature of 62.8-76.7ºC (145-170ºF), adjust the smoker temperature to maintain the steaks at a constant temperature for at least 30 min. Cool smoked steaks and refrigerate. (Eklund, et al., 1988).

## Hot-smoked salmon II

Thaw frozen fish, and head, eviscerate and fillet. Cure fillets for several h in 15-18% brine. Rinse in freshwater and dry. Smoke for 7 h at 50ºC (122ºF), and then for 2-3 h at 80ºC (176ºF) (Tanikawa et al., 1985).

### Hot-smoked salmon (kippered salmon)

Thaw frozen salmon in cold water. Split fish into sides, remove backbone, and cut each side into pieces of about 1 pound (0.5 kg). Soak pieces in 90-95º salinometer brine for ½-2½ h depending on size and thickness. Drain and dip in a red or orange dye (1 part dye to 3,000 parts water) for 15-30 s, if desired. Drain and place pieces on an oiled wire-mesh tray. Air-dry for 1-2 h at about 21.1ºC (70ºF), using a strong current of air. Smoke for 7-13 h at about 26.7ºC (80ºF) and

then at 76.7-82.2ºC (170-180ºF) for an h (Jarvis, 1987).

### Hot-smoked Spanish mackerel

Split mackerel into 2 sides and remove the backbone from larger fish. Wash the fish and soak in 40º salinometer brine to remove blood. Cure fish for 2-4 h in brine made from 2 pounds (0.9 kg) salt, 1 pound (0.5 kg) sugar, ½ ounce (14 g) saltpeter, 1 ounce (28 g) crushed whole black peppers, 1 ounce (28 g) cardamom seeds, and ½ ounce (14 g) crushed bay leaves. The finished brine should be about 90º salinometer. Rinse fish and place on hangers or on wire-mesh trays. Air-dry for about 3 h. Smoke the fish in dense smoke at less than 32.2ºC (90ºF) for the first 8 h. Reduce the smoke and raise the temperature to 54.4-65.6ºC (130-150ºF) for about 2 h (Jarvis, 1987).

### Hot-smoked squid (seasoned-smoked squid meat)

Remove head, viscera, and tendons from body. Cut off fins. Wash with freshwater. Soak squid for 10-20 min in hot water (50-55ºC [122-131ºF]), with agitation, to remove skin. Wash and boil at 80-90ºC (176-194ºF) for 2-3 min. For 3.75 kg boiled squid, mix 200-250 g salt, 750-940 g sugar, 37 g sodium glutamate, and 3.7 g sodium 5-ribonucleotide. Season by sprinkling with seasoning materials, pile in 2-3 layers on a table, and apply light pressure on the squid. Hang the squid in smoker and smoke at 20-25ºC (68-77ºF) for the first 1-2 h, at 50-50ºC (122-140ºF) for 4 h, and at 60-70ºC (140-158ºF) for the final 2-3 h. Cut smoked squid into rings, 1-2 mm wide. Mix 357 g sugar, 100-110 g salt, 3.7 g sodium glutamate, 0.4 g sodium 5-ribonucleotide, and 500 ml water and sprinkle on the smoked squid. Dry the surfaces in a dryer (Tanikawa et al., 1985).

### Hot-smoked sturgeon

Cut fresh sturgeon into about 2 pound (0.9 kg) chunks. Cure in 90-95º salinometer brine for 10-12 h. Rinse in freshwater to remove excess salt, slime and debris. Place chunks on oiled wire-mesh trays and air-dry. Continue drying over low heat in the smoker for about 4 h. Increase smoke and raise temperature to 79.4ºC (175ºF) for an additional 1-2 h (Jarvis, 1987).

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