Chapter 5: Pasteurized Fish and Fishery Products

Updated:

Potential Food Safety Hazard

Survival of pathogens through the pasteurization process can cause illness to the consumer. Pasteurization is a mild or moderate heat treatment, usually performed on fishery products after the product is placed in the hermetically sealed finished product container. The purpose of pasteurization is to either: 1) make the product safe for an extended refrigerated shelf-life, which, in most cases, involves eliminating the spores of *Clostridium botulinum* type E and nonproteolytic B and F (the types of *C. botulinum* most commonly found in fish); or 2) eliminate or reduce the numbers of other target pathogens (e.g. *Listeria monocytogenes*, *Vibrio vulnificus*).

Selection of the target pathogen is critical. If a target pathogen other than *C. botulinum* type E and nonproteolytic types B and F is selected, you must consider the potential that *C. botulinum* type E or nonproteolytic types B and F will survive the pasteurization process and grow under normal storage conditions or moderate abuse conditions. Ordinarily, the potential exists if the product is reduced oxygen packaged (e.g. vacuum packaged, modified atmosphere packaged), does not contain other barriers that are sufficient to prevent growth and toxin formation by this pathogen, and is stored or distributed refrigerated (not frozen). For example, vacuum packaged lobster meat that is pasteurized to kill *L. monocytogenes* but not *C. botulinum* type E or nonproteolytic types B and F must be frozen to prevent growth and toxin formation by *C. botulinum* type E and nonproteolytic types B and F. Surveys of retail display cases and home refrigerators indicate that temperatures above the minimum growth temperature of *C. botulinum* type E and nonproteolytic types B and F (38°F [3.3°C]) are not uncommon. Therefore, refrigeration alone cannot be relied upon for control of the *C. botulinum* hazard.

For pasteurization processes that target nonproteolytic *C. botulinum*, generally a reduction of six orders of magnitude (six logarithms, e.g. from 10^3 to 10^{-3}) in the level of contamination is suitable. This is called a "6D" process. However, lower degrees of destruction may be acceptable if supported by a scientific study of the normal inoculums in the food. It is also possible that higher levels of destruction may be necessary in some foods, if there is an especially high normal inoculums. Table A-4 provides 6D process times for a range of cooking temperatures, with *C. botulinum* type B (the most heat resistant form of nonproteolytic *C. botulinum*) as the target pathogen. The lethal rates and process times provided in the table may not be sufficient for the destruction of nonproteolytic *C. botulinum* in Dungeness crabmeat, because of the potential that naturally occurring substances, such as lysozyme, may enable the pathogen to more easily recover after heat damage.

Examples of properly pasteurized products are: blue crabmeat pasteurized to a cumulative lethality of $F_{185°F}$ ($F_{85°C}$) = 31 min., z=16°F (9°C); surimi-based products pasteurized at an internal temperature of 194°F (90°C) for at least 10 minutes.

In some pasteurized surimi-based products, salt in combination with a milder pasteurization process in the finished product container work to prevent growth and toxin formation by *C. botulinum* type E and nonproteolytic types B and F. An example of a properly pasteurized surimi-based product in which 2.5% salt is present is one that has been pasteurized at an internal temperature of 185°F (85°C) for at least 15 minutes. This process may not be suitable for other types of products, because of the unique formulation and processing involved in the manufacture of surimi-based products.

Reduced oxygen packaged foods that are pasteurized to control nonproteolytic *C. botulinum*, but not proteolytic *C. botulinum,* and that do not contain barriers to its growth, must be refrigerated or frozen to control proteolytic *C. botulinum.* Control of refrigeration is critical to the safety of these products. Further information on *C. botulinum* and reduced oxygen packaging is contained in Chapter 13.

In cases where *Listeria monocytogenes* is selected, a 6D process is also generally suitable. FDA's draft *L. monocytogenes* risk assessment indicates that approximately 7% of raw fish are

contaminated with from 1 to 10^3 CFU/g, and that approximately 92% are contaminated at less than 1 CFU/g. Less than 1% of raw fish are contaminated at levels greater than 10^3 CFU/g, and none at levels greater than 10^6 CFU/g. FDA's action level for *L. monocytogenes* in ready-to-eat products, nondetectable, corresponds to a level of less than 1 CFU/25g. Table #A-3 provides 6D process times for a range of pasteurization temperatures, with *L. monocytogenes* as the target pathogen.

Lower degrees of destruction may be acceptable if supported by a scientific study of the normal inoculums in the food. It is also possible that higher levels of destruction may be necessary in some foods, if there is an especially high normal inoculums.

Products that are pasteurized in the finished product container are at risk for recontamination after pasteurization. Controls, such as container seal integrity and protection from contamination by cooling water, are critical to the safety of these products (FDA, 2001).

Note: D-values and F-values are discussed in chapter 3.

Control Measures   Top

There are three primary causes of recontamination after pasteurization and after cooking that is performed immediately before reduced oxygen packaging. They are:

- Defective container closures;
- Contaminated container cooling water;
- Recontamination between cooking and reduced oxygen packaging.

Poorly formed or defective container closures can increase the risk of pathogens entering the container, especially during container cooling performed in a water bath. Contaminated cooling water can enter through the container closure, especially when the closure is defective. Container closure can be controlled by adherence to seal guidelines that are provided by the container or sealing machine manufacturer. Control is accomplished through periodic seal inspection.

Contamination of cooling water can be controlled by ensuring that a measurable residual of chlorine, or other approved water treatment chemical, is present in the cooling water, or by ensuring that ultraviolet (UV) treatment systems are operating properly.

Recontamination between cooking and reduced oxygen packaging in continuous filling systems where the product is packaged directly from the kettle can be controlled by hot filling at temperatures at or above 185°F (85°C). FDA is interested in information on the value of adding a time component (e.g. 3 minutes) to this hot filling temperature recommendation, to provide limited lethality for any nonproteolytic *C. botulinum* spores present on the packaging material.

It may also be prudent to use packaging that has been manufactured or treated to inactivate spores of *C. botulinum* type E and nonproteolytic types B and F (e.g. gamma irradiation, hot extrusion). FDA is interested in comment on the utility of such measures (FDA, 2001)

Guidelines

FDA Guidelines

FDA to assess on a case by case basis.

State Guidelines

South Carolina: Blue crab (*Callinectes sapidus*)

Cook fresh crabs under steam pressure until the internal temperature of the centermost crab reaches 112.8ºC (235ºF). Air cool the cooked crabs to room temperature and then refrigerate at 7.2ºC (45ºF) or less. Pick crabmeat from crabs and place under refrigeration within 2 h after picking. Pack into containers and tightly seal the containers as quickly as possible after the meat is picked. Pasteurize within 24 h of the time the meat is picked. Pasteurize containers of crab in a water bath until the geometric center of the containers reach at least 85ºC (185ºF) for at least 1 min. Cool to 100ºF or less within 50 min. Refrigerate at 0-2.2ºC (32-36ºF) within 1 h after processing (South Carolina, 1976).

Texas: Blue crab (*Callinectes sapidus*)

Cook crabs thoroughly enough to produce a sterile cooked crab. Move hot cooked crabs to a cooling room. Back and wash crabs immediately after cooking, or cool to room temperature and place under mechanical refrigeration at 7.2ºC (45ºF) or less within 1 h of removal from the cooker. Place backed and washed crabs under mechanical refrigeration at 7.2ºC (45ºF) or less until picked. Pick crab meat directly into the final container. Close containers of crabmeat promptly after filling and store at 1.1-4.4ºC (34-40ºF). Pasteurize the containers within 24 h of the time it is picked. Pasteurize containers of crab until the geometric center of the containers reach at least 85ºC (185ºF) for at least 1 min. Cool to 37.8ºC (100ºF) or less within 50 min. Refrigerate at 0-4.4ºC (32-40ºF) within 1 h after processing (Texas, 1993).

ECFF Guidelines

The safety, with respect to *Clostridium botulinum*, of chilled foods that have been mildly heated in hermetically sealed packages or heated and packed without recontamination can be assured:

- by a minimum heat process and strict limitation of chill shelf life or, for longer life products, by storage below 3°C,
- by heat treatment sufficient to deliver a 6 log reduction in numbers of spores of psychrotrophic strains of *C. botulinum* and storage below 10°C, or
- by intrinsic preservation factors shown to be effective in modeling or inoculated pack/challenge tests.

(Gould, 1999) **Appendix C**
Lethal rates for psychrotrophic *Clostridium botulinum* Type B

These data are supplied as an example of the necessary process to produce a 10^6 reduction of psychrotrophic *Clostridium botulinum* Type B.

Temperature (°C)	Lethal Rate	Time (Mins)
80	0.037	270.3
81	0.052	192.3
82	0.072	138.9
83	0.100	100.0
84	0.139	71.9
85	0.193	51.8
86	0.270	37.0
87	0.370	27.0
88	0.520	19.2
89	0.720	13.9
90	1.000	10.0
91	1.260	7.9
92	1.600	6.3
93	2.000	5.0
94	2.510	4.0
95	3.160	3.2
96	3.980	2.5
97	5.010	2.0
98	6.310	1.6
99	7.940	1.3
100	10.000	1.0

Note: These data have been calculated for temperatures less than 90°C using a *z*-value of 7°C, and for temperatures greater than 90°C a *z*-value of 10°C. The reference temperature is 90°C (ECFF, 1999).

Process Establishment

The adequacy of the pasteurization process should be established by a scientific study. It should be designed to ensure an appropriate reduction in the numbers of the target pathogen. Expert knowledge of thermal process calculations and the dynamics of heat transfer in processing equipment is required to determine the target pathogen and to establish such a pasteurization process. Education or experience, or both can provide such knowledge. Establishing pasteurization processes requires access to suitable facilities and the application of recognized methods. The pasteurization equipment should be designed, operated, and maintained to deliver the established process to every unit of product. In some cases, thermal death time, heat penetration, temperature distribution, and inoculated pack studies will be required to establish the

minimum process. In other instances, existing literature or federal, state, or local regulations establish minimum processes or adequacy of equipment. Characteristics of the process, product, and/or equipment that affect the adequacy of the established minimum pasteurization process should be taken into consideration in the establishment of the process. A record of process establishment should be maintained (FDA, 1998b).

Because of the variability inherent in water bath pasteurization systems, process establishment studies are usually performed initially for each container size and shape, and when equipment or procedures are modified. Generally, a process authority will compare these results to published heat sensitivity values for *C. botulinum* and other relevant pathogens when setting minimum process schedules. If conditions change in the design or operation of the equipment, or if another product container is selected, verification studies must be performed.

Process authorities commonly establish minimum pasteurization processes by generating heating profiles at the slowest heating point (cold point) of the product. Monitored containers are positioned throughout the pasteurization tank/chamber. Specialized instrumentation is required for this. These heating profiles are then used to determine process lethality, or the calculated effect of all heat exposure on a target microorganism. Commonly, this is achieved by determining an F-value for the slowest heating container in the system (Hackney et al., 1991; Rippen, 1998).

Note: Heat Exposure Calculations are discussed in Chapter 3.

Critical Aspects of Processes

Critical aspects of pasteurization processes may include:

- Length of the pasteurization cycle (speed of the belt for a continuous pasteurizer);
- Temperature of the water bath;
- Water bath circulation;
- Product initial temperature (I.T.);
- Container size (e.g., can dimensions, pouch thickness);
- Product formulation;
- Container integrity;
- Microbial quality of cooling water;
- 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, 1998a; FDA, 1998b; FDA, 1998c; Rippen et al., 1993).

Analytical Procedures

Thermometer calibration See Chapter 2.

Other analytical procedures

- Evaluating can double seams (FPI, 1989)
- Flexible package integrity (NFPA, 1989)
- Container evaluation (Gavin and Weddig, 1995)
- Performance of food cans (Hotchner, 1995)
- Guidelines for evaluation and disposition of damaged canned food containers (NFPA, 1998)

Pasteurizing Processes

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.

Blue Crab

Blue Crab (*Callinectes sapidus*) I

Cook crabs for 10 min at 121.1ºC (250ºF) (15 psi, 103.4 kPa) Cool in the retort basket using air circulation or mechanical refrigeration. Refrigerate crab at temperatures below 4.4ºC (40ºF) if delays between cooking and picking occur. Pick crabmeat into 401 flat cans and seal the containers. The crabmeat should be about 26.7-18.3ºC (60-65ºF) when the containers are sealed. Pasteurize within 24 h following picking. Pasteurize containers of crab in a water bath until the geometric center of the containers reach at least 85ºC (185ºF) for at least 1 min. Process 401 flat cans in an 87.8-88.9ºC (190-192ºF) water bath for 110-115 min to give a ☐ min. Cool containers in an ice bath at a temperature below 7.2ºC (45ºF) until the temperature of the containers reaches 37.8ºC (100ºF) (about 45 min). Transfer containers to dry storage at 0-2.2ºC (32-36ºF) (Tatro, 1970; Rippen and Hackney, 1992).

Blue crab (*Callinectes sapidus*) II

Cook crabs as soon as possible after they are delivered to the plant. Refrigerate crabs not cooked within about 2-4 h after delivery at 4.4-10ºC (40-50ºF). Cool crabs in the same container in which they were cooked. If crabs are not picked within about 8 h after cooking, refrigerate them at 4.4ºC (40ºF) or below. Pasteurize within 36 h after picking. Pasteurize to achieve a thermal process of ▯ of at least 31 min (Table 5-14). Chill containers to about 12.8ºC (55ºF) or below within 180 min after pasteurization. Cool the containers further to reach 3.3ºC (38ºF) or colder within about 18 h (Rippen et al., 1993).

Table 5-14. F-values achieved for pasteurized blue crab[1].

Heating Time (min)	(min)	Heating Time (min)	(min)
90	5.0	125	35.6
95	6.8	127.5	40.7
100	9.7	130	43.6
105	13.4	132.5	46.5
110	17.3	135	49.4
112.5	21.0	137.5	52.0
115	23.4	140	55.1
117.5	26.8	142.5	58.0
120	30.2	145	60.9
122.5	32.7		

[1]86.1-87.8ºC (187-190ºF) water bath, 401 × 301 cans, crabmeat initial temperature of 15.6-18.3ºC (60-65ºF) (For illustrative purposes only--each pasteurization system must be evaluated independently!) (Rippen et al., 1993).

Blue crab (*Callinectes sapidus*) III

Cook crabs within 1-2 h after receipt or refrigerate at 7.2-10ºC (45-50ºF). Cook crabs under steam pressure of 15 psig (103.4 kPa) (121.1ºC [250ºF]) for 10 min until the internal temperature of the centermost crab reaches 115.6ºC (240ºF). Air cool crabs to room temperature in the same container in which they were cooked. If not picked within 12 h, refrigerate crabs at 1.7-4.4ºC (35-40ºF). Pick crabmeat into 401 flat cans and seal within 1 h after picking. Pasteurize in a water bath at 87.8-88.9ºC (190-192ºF) for 110-115 min (an internal temperature of 85ºC (185ºF) for 3 min). Cool containers in ice water to an internal can temperature of 32.2ºC (90ºF) (45 min). Transfer to dry storage at 3.3ºC (38ºF) or below (Duersch et al., 1981).

Caviar
Caviar

Remove sturgeon roe by splitting the belly. Rub roe carefully through a 4-mesh screen over a tub. After collecting all eggs, sift about 1 pound (454 g) of Luneberg salt (or ½ pound (227 g) American dairy salt) over each 12 pounds (5.4 kg) of roe. Mix for 5-8 min and then let stand for about 10 min. Pour roe into sieves with a capacity of 8-10 pounds (3.6-4.5 kg) of caviar and drain for about 1 h. Pack into jars, seal and pasteurize in a hot-water bath at 68.3-71.1ºC (155-160° F) for 30, 45, or 60 min for 1, 2, and 4 ounce (30, 59, and 118 ml) containers (Long et al., 1982).

Grain caviar (Russia)

Split open sturgeon belly and remove roe. Rub roe through a metal sieve that has a mesh large enough to permit the eggs to pass through without breaking, but will retain membranes. Mix eggs with salt and place in a sieve as soon as the salt is dissolved. Pack immediately into 9 ounce (255 ml) enameled cans. Process cans for 90 min at 60-65 °C (140-149 °F). Cool for 5 min to 20-30 °C (68-86 °F) with a water spray. Hold for 24 h at 24 °C (73 °F). Repeat pasteurization for a second and third time. Wash and dry cans. Store at 10 °C (50 °F) or less (Jarvis, 1987).

Dungeness crab (*Cancer magister*)

Dungeness crabmeat pasteurization processes (Table 5-15) are based on an initial crabmeat temperature of 1.1ºC (34ºF) and do not include the "come-up" time for product to reach process temperature. The processes are 7-D pasteurization processes (Peterson et al., 1997).

Table 5-15. Pasteurization time-temperature intervals and F values for the destruction of nonproteolytic *C. botulinum* type B spores in Dungeness crabmeat (Peterson et al., 1997).

Process Temp. (ºF)	(ºC)	Process Time (min)	D value	(min)
192	88.9	90	12.9	247
193	89.4	77.6	11.1	
194	90.0	66.8	9.5	
195	90.6	57.6	8.2	243
196	91.1	49.6	7.1	
197	91.7	42.8	6.1	
198	92.2	36.9	5.3	240
199	92.8	31.8	4.5	
200	93.3	27.4	3.9	
201	93.9	23.6	3.4	
202	94.4	20.3	2.9	235

Smoked salmon

Frozen and eviscerated chum salmon (*Oncorhynchus keta*) were cut into 1 inch (2.5 cm) thick steaks with an average weight of 180-220 g. The steaks were thawed in plastic bags in cold running water at less than 15.5ºC (60ºF). Steaks were brined 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), rinsed with cold water, and then stored at 3.3ºC (38ºF) in plastic bags for 2 d before smoking. Salmon steaks were smoked at an initial temperature of 60ºC (140ºF) which was increased in 5.6ºC (10ºF) at 30 min intervals. When the steaks reached an internal temperature of 63ºC (145ºF), the smoker temperature was adjusted to maintain the steaks at a constant temperature for at least 30 min. Smoked steaks were cooled and refrigerated overnight, inoculated with 106 spores of *C. botulinum* types B and E, and vacuum packaged under 23-25 inches (58.4-63.5 cm) vacuum in polyester film bags (O_2 transmission rate of 108 cm^3 per M^2 during 24 h at 22.8ºC (73ºF); CO_2 transmission rate of 526 cm^3 per M^2 during 24 h at 22.8ºC [73ºF])

Packages of smoked salmon were precooled to a uniform internal temperature of 1.1ºC (34ºF) in slush ice. Products were pasteurized in water baths. Pasteurization processes include "come-up" time and are given in Table 5-16. All processes prevented toxin formation by types B and E.

During cooling in slush ice following pasteurization, product internal temperatures dropped below 71.1ºC (160ºF) within 3 min and below 25ºC (77ºF) within 11 min (Eklund, et al., 1988; Pelroy et al., 1982).

Table 5-16. Pasteurization processes for vacuum packaged smoked salmon (Eklund et al., 1988).

Processing Temperature		Process Time (min)
(ºF)	(ºC)	
185	85	175
192	88.9	85
198	92.2	65

Surimi-based imitation crabmeat

Surimi-based imitation flaked crabmeat

Flaked artificial crab was vacuum-packed into 907 g (2 pound) packages and pasteurized for 25 min in a 91ºC (195.8ºF) water bath to achieve an internal temperature of 81-85ºC (177.8-185ºF) for at least 5 min (Hollingworth et al., 1990).

Surimi-based imitation crab meat

The heat resistance of *Listeria monocytogenes* in surimi-based imitation crab meat was examined after growth to stationary phase or adaption to 15% NaCl. An in-package pasteurization treatment at the cold spot of 71.1°C for 15 s was calculated as adequate to inactivate 5 logs of *L. monocytogenes* (*z*-value of 5.8°C). The heat resistance of *L. monocytogenes* in surimi did not increase after adaption to salt (Mazzotta, 2001).

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