Chapter 3: Cooked Fish and Fishery Products

Updated:

- Potential Food Safety Hazard
- Control Measures
- FDA Guidelines
- State Guidelines
  - North Carolina
- Process Establishment
  - D-value
  - Z-value
  - F-value
  - Heat Exposure Calculations
- Critical Aspects of Processes
- Analytical Procedures
  - Thermometer calibration
  - Determining the adequacy of cooking processes for crawfish: Gelatin test
  - Other Analytical Procedures
  - Commercial Test Products
- Cooking Processes
- References

Potential Food Safety Hazard

Top

Pathogen survival through a cook step can cause consumer illness. Cooking is a relatively severe heat treatment, usually performed before the product is placed in the finished product container. Cooking procedures are often established to develop the desirable sensory attributes characteristic of cooked fish and fishery products, not specifically to eliminate pathogens. An important consequence of thorough cooking is the destruction of vegetative cells of pathogens (or reduction to an acceptable level) that may have been introduced in the process by the raw materials or by processing that occurs before the cook step. Cooking processes are not usually designed to eliminate spores of pathogens. (FDA, 2001; Rippen 1998).

Generally, after cooking, fishery products are referred to as cooked, ready-to-eat. Examples of cooked, ready-to-eat products are: crab meat, lobster meat, crayfish meat, cooked shrimp, surimi-based analog products, seafood salads, seafood soups and sauces and hot-smoked fish (FDA, 2001).

Undercooking may allow the survival of pathogens leading to several unintentional but potentially hazardous conditions: 1) direct contamination of a ready-to-eat product with pathogens, 2) elimination of other less heat resistant microorganisms that, if present, may suppress pathogen growth or cause spoilage prior to significant pathogen growth, and 3) thermal

conditioning of pathogens and increasing their heat resistance to any subsequent cooking or reheating step. It is also possible for a sublethal heating step to trigger bacterial spores to germinate, producing vegetative cells that are more hazardous than spores, but also far more vulnerable to subsequent reheating (Rippen, 1998).

One of the purposes of cooking products that will be aerobically packaged is to eliminate vegetative cells of pathogens (or reduce them to an acceptable level) that may have been introduced to the process by the raw materials or by processing that occurs before the cook step. Selection of the target pathogen is critical. Generally, *Listeria monocytogenes* is selected, because it is regarded as the most heat tolerant, food-borne pathogen that does not form spores. Cooking processes are not usually designed to eliminate spores of pathogens. Determining the degree of destruction of the target pathogen is also critical. Generally, a reduction of six orders of magnitude (six logarithms) in the level of contamination is suitable. This is called a "6D" process. 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 (FDA, 2001).

Table A-3 provides 6D process times for a range of cooking temperatures, with *L. monocytogenes* as the target pathogen. Lower degrees of destruction may be acceptable if supported by a scientific study of the normal innoculum 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 innoculum (FDA, 2001).

When cooking is performed immediately before reduced oxygen packaging (e.g. vacuum packaging, modified atmosphere packaging), for product that will be marketed under refrigeration, it may be necessary for the cooking process to be sufficient to eliminate the spores of *Clostridium botulinum* type E and nonproteolytic types B and F. This is the case when the product does not contain other barriers that are sufficient to prevent growth and toxin formation by this pathogen (e.g. many refrigerated, vacuum packaged hot-filled soups and sauces). Generally, a 6D process is suitable. However, lower degrees of destruction may be acceptable if supported by a scientific study of the normal innoculum 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 innoculum. 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. An example of a product that is properly cooked to eliminate nonproteolytic *C. botulinum* is a soup or sauce that is pasteurized at an internal temperature of 194°F (90°C) for at least 10 minutes. The lethal rates and process times provided in the table may not be sufficient for the destruction of nonproteolytic *C. botulinum* in soups or sauces containing dungeness crabmeat, because of the potential that naturally occuring substances, such as lysozyme, may enable the pathogen to more easily recover after damage (FDA, 2001).

Reduced oxygen packaged soups or sauces that are cooked immediately before packaging 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 (FDA, 2001).

Cooking processes that target nonproteolytic *C. botulinum* have much in common with pasteurization processes. Like products that are pasteurized in the final container, products that are cooked and then placed in the final container also are at risk for recontamination after they are placed in the finished product container. Controls, such as container seal integrity and protection from contamination by cooling water, are critical to the safety of these products. Additionally, because these products are cooked before they are packaged, they are at risk for recontamination between cooking and packaging. The risk of this recontamination must be minimized by filling the container in a continuous filling system while the product is still hot (i.e. hot filling), another critical step for the safety of these products. This control strategy is suitable for products that are filled directly from the cooking kettle, where the risk of recontamination is minimized. It is not ordinarily suitable for products such as crabmeat, lobster meat, or crayfish meat, or other products that are handled between cooking and filling (FDA, 2001).

Control Measures

Top

Controlling pathogen survival through the cook step is accomplished by:

- Scientifically establishing a cooking process that will eliminate pathogens of public health concern or reduce their numbers to acceptable levels; and,
- Designing and operating the cooking equipment so that every unit of product receives at least the established minimum process (FDA, 2001)

A thorough hazard analysis is important when evaluating a thermal process. In some cases, a cooking or heating step will not present a potential health hazard even if it is sublethal to pathogens. Examples include a blanching step to inactivate enzymes and a par-fry operation to set the breading on products to be fully cooked by the consumer (Rippen, 1998).

FDA Guidelines

Top

FDA's recommendations for cooking fish and fishery products to destroy organisms of public health concern in food processing operations include:

- A 6-D reduction of *L. monocytogenes*, or, if necessary,
- A 6-D reduction of *C. botulinum* type B (FDA, 2001).

FDA’s recommendations for cooking fish and fishery products to destroy organisms of public health concern in food service, retail food stores, and food vending operations include:

- Raw fish and foods containing raw fish shall be cooked to heat all parts of the food to 63ºC (145ºF) or above for 15 s (FDA, 1999a).
- Comminuted fish and foods containing comminuted fish shall be cooked to heat all parts of the food to 68ºC (155ºF) for 15 s (FDA, 1999b).

- Stuffed fish or stuffing containing fish shall be cooked to heat all parts of the food to 74ºC (165ºF) for 15 s (FDA, 1999c).

FDA guidelines for cooling cooked fish and fishery products:

- Cooked products should generally be cooled from 60ºC (140°F) to 21.1ºC (70°F) or below within 2 h and to 4.4ºC (40°F) or below within another 4 h (FDA, 2001).

State Guidelines

Top

North Carolina

Top

The North Carolina Administrative Code requires the following: Cook crabs under steam pressure until the internal temperature of the center-most crab reaches 112.8ºC (235ºF). Cook other crustaceans (lobster, shrimp, or crayfish) until the internal temperature of the center-most crustacean reaches 83ºC (180ºF) and is held at this temperature for 1 min. Other cooking processes found equally effective are also allowed (North Carolina, 1997).

Process Establishment

Top

The adequacy of the cooking process should be established by a scientific study. It should be designed to ensure an appropriate reduction in the numbers of pathogens of public health concern. Selecting the target organism is critical. In most cases it will be a relatively heat tolerant vegetative pathogen, such as *Listeria monocytogenes*. However in some cases where outgrowth of spore-forming pathogens, such as *Clostridium perfringens* and *Bacillus cereus*, during the post- cook cooling step must be prevented by eliminating these pathogens during the cook (e.g., because cooling after cooking is not controlled) then they will be the target organisms. Additionally, when cooking is performed immediately before reduced oxygen packaging (e.g. vacuum packaging, modified atmosphere packaging), for product that will be marketed under refrigeration, it may be necessary for the cooking process to be sufficient to eliminate the spores of *Clostridium botulinum* type E and nonproteolytic types B and F. This is the case when the product does not contain other barriers that are sufficient to prevent growth and toxin formation by this pathogen (e.g. refrigerated, vacuum packaged hot-filled soups and sauces). Generally, a 6D process is suitable, regardless of the target pathogen. However, lower degrees of destruction may be acceptable if supported by a scientific study of the normal innoculum in the food. Tables A-3 and Table A-4 provide 6D process times for a range of internal product temperatures, with *L. monocytogenes* and *C. botulinum* type B (the most heat resistant form of nonproteolytic *C. botulinum*) as the target pathogens, respectively. The values provided in Table A-4 may not be sufficient for the destruction of nonproteolytic *C. botulinum* in products containing dungeness crabmeat, because of the potential protective effect of naturally occuring substances, such as lysozyme. Expert knowledge of thermal process calculations and the dynamics of heat transfer in processing equipment is required to establish such a cooking process. Such knowledge can be obtained by education or experience, or both. Establishing cooking processes requires access to suitable facilities and the application of recognized methods. The cooking 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 many cases, establishing the

minimum process may be simplified by repetitively determining the process needed to reach an internal product temperature that will assure the inactivation of all vegetative pathogens of public health concern under the most difficult heating conditions likely to be encountered during processing. In other instances, existing literature or federal, state or local regulations which establish minimum processes or adequacy of equipment, are available. Characteristics of the process, product and/or equipment that affect the ability of the established minimum cooking process should be taken into consideration in the establishment of the process. A record of process establishment should be maintained (FDA, 2001)

D-Value

Top

Basing the adequacy of a cooking process on product endpoint temperature is convenient for verification purposes and may be the only alternative for some cooked fish and fishery products. However, microbial lethality is a function of time and temperature, and cooking processed should be based on time and temperature.

Death of bacteria subjected to moist heat is logarithmic. A D-value (decimal reduction time) is the time required to kill 90% of the spores or vegetative cells of a given microorganism at a specific temperature in a specific medium. A 90% reduction in bacteria is equivalent to a reduction from 10,000 bacteria/g to 1,000 bacteria/g or 1 log cycle.

D-values can be determined from survivor curves when the log of population is plotted against time (Figure 3-1), or by the formula:

Where T = time of heating, a = the initial number of microbial cells, and b = the number of surviving microbial cells after heating time T (Stumbo, 1965; Rippen et al., 1993).

For example, if a suspension containing 10,000 microbial cells/ml is heated for 4 min at 140ºF (60ºC) and only 293 microbial cells survive:

Harrison and Huang (1990) determined D-values for *L. monocytogenes* (Scott A) in crabmeat (Table 3-2).

Table 3-2. D-values for *L. monocytogenes* (Scott A) in blue crabmeat.

Temperature		D-value
(ºC)	(ºF)	(min)

50	122	40.43
55	131	12
60	140	2.61

Z-Value

Top

The z-value is the number of °F or °C required for a thermal death time curve to traverse 1 log cycle. The z-value gives an indication of the relative impact of different temperatures on a microorganism, with smaller values indicating greater sensitivity to increasing heat. The z-value is obtained by plotting the logarithms of at least 2 D-values against temperature (Figure 3-2) or by the formula:

Where T_1 and T_2 are temperatures and D_1 and D_2 are D-values at temperatures T_1 and T_2 (Rippen et al., 1993).

For example, using the D values ($D_{122°F}$ = 40.43 min and $D_{140°F}$ = 2.61 min) for *L. monocytogenes*:

$$z = 15.1°F$$

Z-values are used to determine D-values at different temperatures using the formula:

Where:
D_1 = Known D-value at temperature T_1
D_2 = Unknown D-value at temperature T_2

Using the known D-values for *L. monocytogenes* (Scott A) in blue crabmeat and the z-value, D-values can be calculated for any given temperature. For example, substituting D and z values for *Listeria* in blue crabmeat (D_{140} = 2.61 min, z = 15.1°F) from the Harrison and Huang (1990) study, the equivalent D-value at 185°F is 0.16 s.

$$D_{185} = 0.0027 \text{ min or } 0.16 \text{ s}$$

D-values vary with product type and pubished D-values are rarely determined at the temperatures encountered during commercial processing.. Equivalent D-values should not be

calculated for temperatures far hotter or cooler than those used in the original laboratory studies or errors may result due to the non-linerarity of some survivor curves (Rippen, 1998).

Adequate cooking processes are generally 6-D to 7-D processes at the geometric center of the thickest product or container being processed. Table 3.3 gives 1D-, 6-D, and 7-D-values for *L. monocytogenes* (Scott A) calculated from the Harrison and Huang (1990) study with blue crabmeat.

All cooking processes are product and equipment specific and must be evaluated independently. Any changes in the critical aspects of processes will effect the adequacy of the cook.

Conducting an in-plant process establishment study may result in a lower temperature process resulting in improved quality or yields. A process authority can usually identify alternative cook schedules that achieve equivalent pathogen kill (Rippen, 1998).

Table 3-3. 1-D and 7-D values for *L. monocytogenes* (Scott A) in blue crabmeat.

Temperature		**1-D**		**6-D**		**7-D**	
(ºC)	(ºF)	(Min.)	(Sec.)	(Min.)	(Sec.)	(Min.)	(Sec.)
60	140	2	37	15	40	18	16
60.56	141	2	14	13	27	15	41
61.11	142	1	55	11	33	13	28
61.67	143	1	39	9	55	11	34
62.22	144	1	25	8	31	9	56
62.78	145	1	13	7	19	8	32
63.33	146	1	3	6	17	7	20
63.89	147	-	54	5	24	6	18
64.44	148	-	46	4	38	5	24
65.00	149	-	40	3	59	4	38
65.56	150	-	34	3	25	3	59
66.11	151	-	29	2	56	3	25
66.67	152	-	25	2	31	2	56
67.22	153	-	22	2	10	2	31
67.78	154	-	19	1	51	2	10
68.33	155	-	16	1	36	1	52
68.89	156	-	14	1	22	1	36

69.44	157	-	12	1	11	1	22
70.00	158	-	10	1	1	1	11
70.56	159	-	9	-	52	1	1
71.11	160	-	7	-	45	-	52
71.67	161	-	6	-	38	-	45
72.22	162	-	5	-	33	-	38
72.78	163	-	5	-	28	-	33
73.33	164	-	4	-	24	-	28
73.89	165	-	3	-	21	-	24
74.44	166	-	3	-	18	-	21
75.00	167	-	3	-	15	-	18
75.56	168	-	2	-	13	-	15
76.11	169	-	2	-	11	-	13
76.67	170	-	2	-	10	-	11
77.22	171	-	1	-	8	-	10
77.78	172	-	1	-	7	-	8
78.33	173	-	1	-	6	-	7
78.89	174	-	<1	-	5	-	6
79.44	175	-	<1	-	5	-	5
80.00	176	-	<1	-	4	-	5
80.56	177	-	<1	-	3	-	4
81.11	178	-	<0.5	-	3	-	3
81.67	179	-	<0.5	-	2	-	3
82.22	180	-	<0.5	-	2	-	2
82.78	181	-	<0.5	-	2	-	2
83.33	182	-	<0.5	-	2	-	2
83.89	183	-	<0.5	-	1	-	2
84.44	184	-	<0.5	-	1	-	1
85.00	185	-	<0.5	-	1	-	1
85.56	186	-	<0.5	-	1	-	1

86.11	187	-	<0.5	-	1	-	1
86.67	188	-	<0.5	-	1	-	1
87.22	189	-	<0.1	-	1	-	1
87.78	190	-	<0.1	-	<0.5	-	1
88.33	191	-	<0.1	-	<0.5	-	<0.5
88.89	192	-	<0.1	-	<0.5	-	<0.5
89.44	193	-	<0.05	-	<0.5	-	<0.5
90.00	194	-	<0.05	-	<0.5	-	<0.5
90.56	195	-	<0.05	-	<0.5	-	<0.5
91.11	196	-	<0.05	-	<0.5	-	<0.5
91.67	197	-	<0.05	-	<0.5	-	<0.5
92.22	198	-	<0.05	-	<0.5	-	<0.5
92.78	199	-	<0.05	-	<0.5	-	<0.5

F-Value

Top

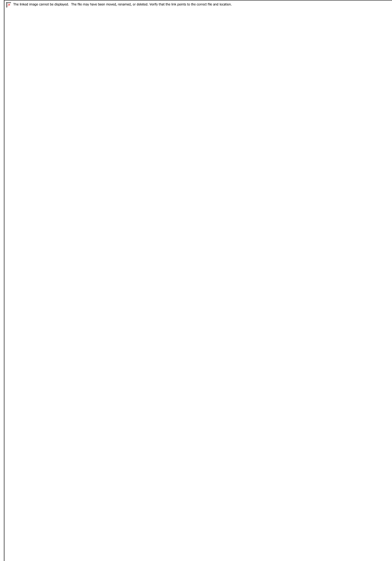
F-value is a numeric way to express the amount of heat received by bacteria at a reference temperature. Stated differently, F-value is the equivalent time spent at a given temperature in terms of microbial kill. F-values allow the direct comparison of two or more processes. For example, testing may show that the same F-value (e.g., F_{185} = 10 min) is accomplished by heating containers of product for either 1 h at 195ºF or for 2 h at 185ºF: both providing the same effective kill that would be achieved by instantly heating the product to 185ºF, holding for 10 min, then instantly cooling the product. F-values include the lethal heat the product receives during the heating and cooling portion of the process.

F-values and D-values are related in that a process F-value usually represents multiple D-values. If a research study determined that an organism's D-value was 1 min at 185ºF (D_{185} = 1 min), then a process with a F_{185} = 10 min would achieve 10 decimal reductions for the target microorganism, or a 99.99999999 % kill (Rippen, 1998).

Heat Exposure Calculations (Rippen, 2002)

Top

F-values are a numeric way to express the amount of heat that bacteria are exposed to during pasteurization. If the center of a can could be instantly heated to the reference temperature of 185° F (85° C), held there for 30 minutes and instantly cooled, the F-value would equal 30 minutes. However since heating and cooling is gradual, the accumulated bacteria killing effect is related to the slope of the heating curve, like the one in the following figure.



This curve can be divided into small sections, the F-value calculated for each, then added together. The formula for each time interval is:

where, T = the midpoint of two crabmeat temperatures over a period of time, 185 = the reference temperature and 16 = the z-value (a factor related to the sensitivity of bacteria to heat).

Using the formula, if the midpoint temperature of the crabmeat during a 5 minute period of heating was 175° F, then;

If the measured temperatures were 174° F and 5 minutes later, 176° F then the midpoint temperature for the time interval is 175° F – half way in between.)

Using data for crabmeat temperatures from a production trial;

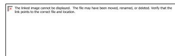
Elapsed Time	Measured Temperature	Midpoint Temperature	Calculated F-value
0	152	---	---
5	160	156	0.08
10	167	163	0.23
15	172	170	0.54
20	176	174	1.03
25	177	176	1.47
30	179	178	1.82
35	181	180	2.43
40	182	182	3.02
45	186	184	4.33
50	186	186	5.77

55	187	186	5.77
60	187	187	6.67
65	187	187	6.67
70	186	186	5.77
75	186	186	5.77
80	186	186	5.77
85	184	185	5.0
90	170	178	1.83
95	152	161	0.16
			Total F = 64.13 min

F-value may be reported as F_{185} to identify 185° F as the reference temperature.

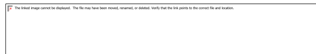
Notice in the example above that the F-value at 180° F is only half that at 185° F. In other words, crabmeat held for 10 minutes at 185° F would require more than 20 minutes at 180° F to achieve the same process.

An F-value based on one reference temperature can be converted to an equivalent F-value at another temperature by applying the formula:



Where, T_1 = reference temperature, and T_2 = another temperature for which you wish to know the equivalent process.

For example, if a process produces F_{185} = 30 minutes, the time needed at 170° F to achieve the same lethality is 260 minutes. That is:



Critical Aspects of Processes

Top

Critical aspects of cooking processes may include:

- length of the cook cycle (e.g., speed of the belt for a continuous cooker);
- temperature of the steam, water, or other medium used for cooking (or visual observation of min at a boil);
- Temperature uniformity in cooker;
- Thickness of the product;
- Initial temperature of the product;
- Accuracy of thermometers, recorder thermometer charts, high temperature alarms, maximum indicating thermometers, and/or digital data loggers;
- Accuracy of other monitoring and timing instruments (FDA, 1998).

Analytical Procedures

Top

Thermometer calibration

Top

See Chapter 2.

Determining the adequacy of cooking processes for crawfish: Gelatin test (Moody, 1999)

Top

Theory

Adequate cooking of crawfish eliminates proteolytic enzymes. Gelatin liquefaction is used to indicate the presence of proteolytic enzymes in crawfish after cooking.

Equipment and materials

1. 12% gelatin solution (by weight, 12 parts gelatin to 88 parts water)
    a. Approximately 1 ounce (28 g) gelatin (four ¼ ounce (7 g) envelopes) to 7 ounces (7/8 cup, 207 ml) water
    b. Bring the solution to a boil to dissolve gelatin
    c. IMPORTANT: cool to about 100ºF (37.8ºC) before using; otherwise the gelatin will "cook" any active enzymes that may be present.
2. Crawfish fat removed from crawfish samples at 1 min intervals (more or less frequently according to needs) during cooking process
    a. Random sampling is important (i.e., stir crawfish before removing some for test; don't select crawfish that are all the same size).
    b. Put crawfish in/on labeled containers to avoid confusing crawfish samples removed at different times.
    c. Allow crawfish to cool and remove some fat from 3 or 4 crawfish. About ½ teaspoon (5 ml) of fat for each tablespoon (30 ml) of gelatin solution.
3. Other needed materials include containers and covers for fat-gelatin mixtures, mixing utensils, utensils for preparation of gelatin solution, etc.

Procedure

1. Put fat samples from each period into separate labeled containers. Put some raw fat in one container(time "0"); leave one container empty.
2. Add cooled liquid gelatin to all containers, including the empty one.
3. Mix well – IMPORTANT: do not cross-contaminate samples when mixing as active enzymes may be carried from a sample cooked less to one cooked more.
4. Cover containers to prevent drying.
5. Leave mixtures at room temperature for 1-2 h, and at that time…
6. Record texture of gelatin-fat mixture and of plain gelatin as follows:

    1 = thin liquid
    2 = thick liquid
    3 = soft gel
    4 = firm gel

Note: gelatin-raw fat mixture should have a texture = 1; plain gelatin should have a texture = 4, and should serve as a reference when checking for lack of enzyme activity

7. Refrigerate covered containers overnight at approximately 37-40ºF (2.8-4.4ºC). The next day (about 24 h later) check and record texture again (this is important to detect lower levels of active enzymes which will continue to act on gelatin).
8. IMPORTANT: enzyme activity is indicated in all gelatin mixtures that have texture softer than "4". These active enzymes can degrade the texture of fresh and frozen crawfish meat packed with fat, and produce a product with an unacceptable textural quality.

An adequate cook process is indicated by the first time yielding crawfish that contain fat samples which allow development of a firm ("4") gel of the fat-gelatin mixture, the texture of which is maintained for at least 24 h

For example,

Time (min.)	**Texture**
0 (raw)	1
1	1
2	1
3	2
4	2
5	3
6	3
7*	4
8	4
9	4

*Minimum cook time required to eliminate enzymes.

Other Analytical Procedures

Top

- Determination of internal cooking temperature (phosphatase) (Lind, 1965; USDA, 1993).
- Determination of internal cooking temperature (coagulation) (UDSA, 1993).

Commercial test products

Top

Table 3-4. Commercial test products for cooked fish and fishery products.

Test Kit	Analytical Technique	Approx. Total Test Time	Supplier
CHEF Test with Charm LUM-T meter [Used to identify undercooked fish]	Phosphatase measurement	5 min	Charm Sciences, Inc. 36 Franklin St. Malden, MA 02148-4120 Phone: 781/322-1523 E-mail: info@charm.com Web: www.charm.com

Cooking 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.

Cooked Dungeness crab sections I

Remove crab carapace cleanly. Cut the crabs in half. Brush off intestinal content as completely as possible. Wash and rinse the halves in running water or with spray. Cook the crab sections at 100ºC (212ºF) for at least 15 min (Lee and Hilderbrand, 1992).

Cooked Dungeness crab sections II

Butcher live crab by holding the crab by the legs on each side while bringing the belly down shapely on a knife edge. Shake to jar out viscera that cling to the body cavities. Clean off gills and remaining viscera with revolving nylon brush. Cook crab sections in unsalted boiling water for 10-12 min (Babbitt, 1981).

Cooked whole Dungeness crab

For crab planned for fresh sales, cook whole crab in salted boiling water for 20-25 min. Begin timing cook when water returns to a boil after crab have been added. Use 4-5% salt (16-20º salimeter) in the cook water. (Babbitt, 1981).

Cooked whole Dungeness crab

Live male Dungeness crabs, weighing about 2 pounds (907 g) each, were cooked using either a minimal input of steam (less than 212ºF [100ºC]) or an excess input of steam. After a 23 min cooking period, crabs processes with a minimal input of steam had an internal temperature of

60ºC (140ºF); crabs processed with an excess input of steam had an internal temperature of 77.8ºC (172ºF). All parts of crabs cooked with excess steam input were cooked adequately (Barnett and Nelson, 1966).

Cooked lobster I

Heat lobster for a period of time such that the thermal center of the product reaches a temperature adequate to coagulate the protein (FAO, 1978a).

Cooked lobster II

Place lobsters in 1 layer on racks immersed in fresh boiling water. For whole lobster that will be frozen up to 1 month, cook 1 pound (454 g) lobsters 1-2 min and 1½ pound (680 g) lobsters 2-3 min. For lobsters that will be kept in frozen storage for 3 months or longer, cook 1 pound (454 g) lobsters 8-10 min and 1½ pound (680 g) lobsters 12-14 min. After cooking, cool lobsters in clean cold water for about 10 min, drain 5-10 min, and commence freezing within 1 h (Wojtowicz, 1974).

Cooked lobster III

Lobsters (about 1¼ pounds [567 g]) were cooked in boiling water. With lobster 1, temperature changes were monitored from the time the lobster was placed in the boiling water. For lobsters, 2-4, temperature changes were monitored when the pot began to boil a second time (Table 3-1). Thermocouples were inserted into the lobster's crusher claw by punching a small hole in the top of the claw, and inserted into the lobster's tail through the first joint in the carapace. The researchers concluded that 12-15 min cooking time was sufficient to kill disease-causing bacteria (Bushway and Bayer, 1996).

Table 3-1. Temperature changes in lobster claw and tail muscle during cooking in boiling water.

Time	Tail temp.		Claw temp.	
(min.)	ºC	ºF	ºC	ºF
Lobster #1				
0	11.9	53	12.7	55
2	54.9	131	55.4	132
4	86.4	188	81.7	179
6	94.2	202	97.4	207
8	95.9	205	100.5	213

10	97	207	103.7	219
12	98.2	209	105.1	221
14	98.8	210	105.6	222
15	99.3	211	105.7	222
Lobster #2				
0	14.7	59	16.7	68
2	52.1	126	67.2	153
4	67.7	154	79.4	175
6	84.2	184	88.2	191
8	91.2	196	93.6	201
10	94.6	202	98.1	209
12	95.5	204	100.5	213
14	96.7	206	101.4	215
15	98.1	209	101.7	215
Lobster #3				
0	17.1	63	19.5	67
2	61.5	143	60.3	141
4	78.6	174	84.3	184
6	90.3	194.5	94.9	203
8	95.5	204	100.0	212
10	97.4	207	102.2	216
12	99.6	211	103.1	218
14	100.4	213	103.4	218
15	100.8	213	103.4	218
Lobster #4				
0	16.6	62	17.1	63
2	53.3	128	69.1	156
4	62.9	145	79.9	176
6	70.5	159	97.4	207

8	88.7	192	101.5	215
10	94.4	202	104.4	220
12	96.7	206	105.7	222
14	97.8	208	106.1	223
15	98.5	209	106.2	223

Cooked Pacific shrimp

Controlled experiments with a pilot scale mechanical peeler gave 23.5% yields for untreated shrimp and 28.6% yields for shrimp treated with 1.5% condensed phosphate for 5 min prior to steam precooking. The shrimp were fed onto a steam pre-cooker no more than 1 body layer thick and cooked for 90 s in steam at 101ºC (213.8ºF) (Crawford, 1980).

Cooked shrimp

Boil shrimp in potable water, clean sea water, or brine or heat in steam for a period of time sufficient for the thermal center of the shrimp to reach a temperature adequate to coagulate the protein (FAO, 1976; FAO, 1978b).

Inactivation of *C. botulinum* toxin

Cooking to an internal temperature of 79ºC (174.2ºF) for 20 min or to an internal temperature of 85ºC (185ºF) for 5 min inactivates any *C. botulinum* toxin at concentrations up to 10^5 LD_{50}/g in foods (Woodburn et al., 1979).

Note: LD_{50} is an abbreviation for the dose (expressed in milligrams per kilogram of body weight of the test animal) that is lethal to 50 per cent of the group of test animals (Ali, 1995).

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Top

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