

Appendix 4: Bacterial Pathogen Growth

This appendix contains information on the growth of bacterial pathogens.

Table #A-1 contains information on: the minimum water activity (a_w), acidity (pH), and temperature; the maximum, pH, water phase salt, and temperature; and oxygen requirements that will sustain growth for the bacterial pathogens that are of greatest concern in seafood processing. Data shown are the minimum or maximum values, the extreme limits reported among the references cited. These values may not apply to your processing conditions.

Table #A-2 contains information on maximum, cumulative time/temperature combinations for exposure of fish and fishery products that, under ordinary circumstances, will be safe for the bacterial pathogens that are of greatest concern in seafood processing. These maximum, cumulative exposure times are derived from published scientific information. Because the nature of bacterial growth is logarithmic, linear interpolation using the time/temperature guidance is not appropriate.

In summary, the table indicates that:

- If the product is held at 70°F (21°C) or more during processing, exposure time should ordinarily be limited to two hours (three hours if *Staphylococcus aureus* is the only pathogen of concern);
- If the product is held at 50°F (10°C) or more, but not above 70°F (21°C), exposure time should ordinarily be limited to six hours (twelve hours if *Staphylococcus aureus* is the only pathogen of concern).

It is not possible to furnish recommendations for each pathogen, process, type of seafood, and temperature or combination of temperatures. Programmable models to predict growth rates for certain pathogens associated with various foods under differing conditions have been developed by the U.S. Department of Agriculture (“Pathogen Modeling Program” [PMP]) and the United Kingdom (“Food MicroModel” [FMM]). These programs can provide growth curves for selected pathogens. You indicate the conditions, such as pH, temperature, and salt concentration that you are interested in and the models provide pathogen growth predictions (e.g., growth curve, time of doubling, time of lag phase, generation time). FDA does not endorse or require the use of such modelling programs, but recognizes that the predictive growth information they provide may be of assistance to some processors. However, you are cautioned that significant deviations between actual microbiological data in specific products and the predictions do occur, including those for the lag phase of growth. Therefore, you should validate the time-temperature limits derived from such predictive models.

Table #A-1

Limiting Conditions for Pathogen Growth

Pathogen	min. a _w	min. pH	max. pH	max. % salt	min. temp.	max. temp.	oxygen requirement
<i>Bacillus cereus</i>	.92	4.3	9.3	18	39.2°F 4°C	131°F 55°C	aerobe
<i>Campylobacter jejuni</i>	.987	4.9	9.5	1.5	86°F 30°C	113°F 45°C	micro-aerophilic*
<i>Clostridium botulinum</i> , type A, and proteolytic B and F	.935	4.6	9	10	50°F 10°C	118.4°F 48°C	anaerobe**
<i>Clostridium botulinum</i> , type E, and nonproteolytic B and F	.97	5	9	5	37.9°F 3.3°C	113°F 45°C	anaerobe**
<i>Clostridium perfringens</i>	.93	5	9	7	50°F 10°C	125.6°F 52°C	anaerobe**
pathogenic strains of <i>Escherichia coli</i>	.95	4	9	6.5	44.6°F 7.0°C	120.9°F 49.4°C	facultative anaerobe***
<i>Listeria monocytogenes</i>	.92	4.4	9.4	10	31.3°F -0.4°C	113°F 45°C	facultative anaerobe***
<i>Salmonella</i> spp.	.94	3.7	9.5	8	41.4°F 5.2°C	115.2°F 46.2°C	facultative anaerobe***
<i>Shigella</i> spp.	.96	4.8	9.3	5.2	43°F 6.1°C	116.8°F 47.1°C	facultative anaerobe***
<i>Staphylococcus aureus</i> – growth	.83	4	10	25	44.6°F 7°C	122°F 50°C	facultative anaerobe***
<i>Staphylococcus aureus</i> – toxin	.85	4	9.8	10	50°F 10°C	118°F 48°C	facultative anaerobe***
<i>Vibrio cholerae</i>	.97	5	10	6	50°F 10°C	109.4°F 43°C	facultative anaerobe***
<i>Vibrio parahaemolyticus</i>	.94	4.8	11	10	41°F 5°C	111°F 44°C	facultative anaerobe***
<i>Vibrio vulnificus</i>	.96	5	10	5	46.4°F 8°C	109.4°F 43°C	facultative anaerobe***
<i>Yersinia enterocolitica</i>	.945	4.2	10	7	29.7°F -1.3°C	107.6°F 42°C	facultative anaerobe***

* requires limited levels of oxygen ** requires the absence of oxygen *** grows either with or without oxygen.

Table #A-2

Time/Temperature Guidance for Controlling Pathogen Growth and Toxin Formation in Seafoods

<i>Potentially Hazardous Condition</i>	<i>Product Temperature</i>	<i>Maximum Cumulative Exposure Time</i>
Growth of <i>Campylobacter jejuni</i>	86-93°F (30-34°C) Above 93°F (above 34°C)	48 hours 12 hours
Germination, growth, and toxin formation by <i>Clostridium botulinum</i> type A, and proteolytic B and F	50-70°F (10-21°C) Above 70°F (above 21°C)	12 hours* 4 hours*
Germination, growth, and toxin formation by <i>Clostridium botulinum</i> type E, and nonproteolytic B and F	37.9-50°F (3.3-10°C) 51-70°F (11-21°C) Above 70°F (above 21°C)	24 hours 12 hours 4 hours*
Growth of pathogenic strains of <i>Escherichia coli</i>	44.6-50°F (7-10°C) 51-70°F (11-21°C) Above 70°F (above 21°C)	14 days 6 hours 3 hours
Growth of <i>Listeria monocytogenes</i>	31.3-50°F (-0.4-10°C) 51-70°F (11-21°C) Above 70°F (above 21°C)	2 days 12 hours* 3 hours*
Growth of <i>Salmonella</i> species	41.4-50°F (5.2-10°C) 51-70°F (11-21°C) Above 70°F (above 21°C)	14 days 6 hours 3 hours
Growth of <i>Shigella</i> species	43-50°F (6.1-10°C) 51-70°F (11-21°C) Above 70°F (above 21°C)	14 days* 6 hours* 3 hours*
Growth and toxin formation by <i>Staphylococcus aureus</i>	44.6-50°F (7-10°C) 51-70°F (11-21°C) Above 70°F (above 21°C)	14 days 12 hours* 3 hours
Growth of <i>Vibrio cholerae</i>	50°F (10°C) 51-70°F (11-21°C) Above 70°F (above 21°C)	21 days 6 hours* 2 hours*
Growth of <i>Vibrio parahaemolyticus</i>	41-50°F (5-10°C) 51-70°F (11-21°C) Above 70°F (above 21°C)	21 days 6 hours* 2 hours*
Growth of <i>Vibrio vulnificus</i>	46.4-50°F (8-10°C) 51-70°F (11-21°C) Above 70°F (above 21°C)	21 days 6 hours 2 hours
Growth of <i>Yersinia enterocolitica</i>	29.7-50°F (-1.3-10°C) 51-70°F (11-21°C) Above 70°F (above 21°C)	1 days 6 hours 2.5 hours

* Additional data needed.

Notes: