Appendix 4: Foodborne Pathogen Supplementary Information

Microbial growth can be limited when conditions are outside of an organism's growth parameters, and certain time-temperature combinations can inactivate foodborne pathogens in foods. This appendix presents several tables with information on parameters that can be used to inhibit growth or inactivate certain microorganisms.

- Table A4-1 summarizes conditions that limit or prevent foodborne pathogen growth or toxin formation, including temperature, pH, water activity and maximum percent of water phase salt.
- Table A4-2 provides information on time-temperature combinations that, under ordinary circumstances, will prevent growth of foodborne bacterial pathogens. This includes information on maximum cumulative time and internal temperature combinations for exposure of foods that, under ordinary circumstances, will be safe for the bacterial pathogens that are of greatest concern. The exposure times are derived from published scientific information. Because bacterial growth is logarithmic, linear interpolation using the time and temperature guidance may not be appropriate. Furthermore, the food matrix effects bacterial growth (e.g., presence of competing microorganisms, available nutrients, growth restrictive agents). Consideration of such attributes is needed when using the information in Tables A4-2.
- Table A4-3 provides information on time-temperature combinations for destruction of *L. monocytogenes.* Lethal rate, as used in this table, is the relative lethality of 1 minute at the reference internal product temperature of 158°F (70°C) (i.e., z=13.5°F (7.5°C)). For example, 1 minute at 145°F (63°C) is 0.117 times as lethal as 1 minute at 158°F (70°C). The times provided are the length of time at the designated internal product temperature necessary to deliver a six logarithm (6D) process for *L. monocytogenes.* The length of time at a particular internal product temperature needed to accomplish a six logarithm reduction in the number of *L. monocytogenes* (6D) is, in part, dependent upon the food in which it is being heated. The values in the table are generally conservative and apply to all foods. You may be able to establish a shorter process time for your food by conducting scientific thermal death time studies. Additionally, lower degrees of destruction may be acceptable in your food if supported by a scientific study of the normal initial levels in the food. It is also possible that higher levels of destruction may be necessary in some foods, if especially high initial levels are anticipated.
- Table A4-4 lists properties of common bacterial foodborne pathogens. Information such as pathogenicity, primary sources, types of foods involved in transmission, contributing factors, atmosphere required for growth, whether the organism is a sporeformer, and other properties are included.

The tables are followed by an alphabetical listing of the organisms (bacteria, viruses and parasites) identified by Painter et al. (2013) as being relevant for transmission through food. More information on foodborne pathogens is available in FDA's *Bad Bug Book* (see references).

Appendix 4

Table A4-1 Limiting conditions for pathogen growth

Organism	Temperature °F (°C)			pH			Water Activity (a_w)			Max. % water phase salt
	Minimum	Optimum	Maximum	Minimum	Optimum	Maximum	Minimum	Optimum	Maximum	
Bacillus cereus	39 (4)	86-104 (30-40)	131 (55)	4.3	6.0-7.0	9.3	0.92	-	-	10
Campylobacter	86 (32)	108-109 (42-43)	113 (45)	4.9	6.5-7.5	9.5	>0.987	0.997	-	1.7
Clostridium botulinum										
• Proteolytic ABF	50 (10)	95-104 (35-40)	-118 (48)	4.6	-	9	0.935	-	-	10
• Non-proteolytic BEF	38 (3.3)	82-86 (28-30)	113 (45)	5.0	-	9	0.970	-	-	5
Clostridium perfringens	50 (10)	109-117 (43-47)	126 (50)	5	7.2	9.0	0.93	0.95-0.96	>0.99	7
Enterohemorrhagic *Escherichia coli* (EHEC)	44 (6.5)	95-104 (35-40)	121 (49.4)	4	6-7	10	0.95	0.995	-	6.5
L. monocytogenes	31 (-0.4)	99 (37)	113 (45)	4.4	7.0	9.4	0.92	-	-	10
Salmonella	41 (5.2)	95-109 (35-43)	115 (46.2)	3.7	7-7.5	9.5	0.94	0.99	>0.99	8
Shigella	43 (6.1)	-	117 (47.1)	4.8	-	9.3	0.96	-	-	5.2
Staph. aureus										
• growth (anaerobic)	45 (7)	99 (37)	122 (50)	4	6-7	10	0.83 (0.90)	0.98	>0.99	20
• toxin (anaerobic)	50 (10)	104-113 (40-45)	118 (48)	4	7-8	9.8	0.85	0.98	>0.99	10
Streptococcus group A	50 (10)	99 (37)	<113 (<45)	4.8-5.3	7	>9.3	-	-	-	6.5
Vibrio spp.	41(5)	99 (37)	114 (45.3)	4.8	7.6-8.6	11	0.94	0.91-0.99	0.998	10
Yersinia enterocolitica	30 (-1.3)	77-99 (25-37)	108 (42)	4.2	7.2	10	0.945	-	-	7

From FDA 2011. *Fish and Fishery Products Hazards and Controls Guidance.* 4th Edition and International Commission on Microbiological Specifications for Foods. 1996. *Microorganisms in Foods 5: Microbiological Specifications of Food Pathogens.* Blackie Academic and Professional, New York.

Table A4-2. Cumulative time and temperature guidance for controlling pathogen growth and toxin formation in foods[1]

Potentially Hazardous Condition	Product Temperature	Maximum Cumulative Exposure Time
Bacillus cereus growth and toxin formation	39.2-43°F (4-6°C) 44-59°F (7-15°C) 60-70°F (16-21°C) Above 70°F (21°C)	5 days 1day 6hours 3 hours
Campylobacter jejuni growth	86-93°F (30-34°C) Above 93°F (34°C)	48 hours 12 hours
Clostridium botulinum germination, growth and toxin formation Type A and proteolytic Types B and F	50-70°F (10-21°C) Above 70°F (21°C)	11 hours 2 hours
- Type E and non-proteolytic Types B and F	37.9-41°F (3.3-5°C) 42-50°F (6-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	7 days 2 days 11 hours 6 hours
Clostridium perfringens growth	50-54°F (10-12°C) 55-57°F (13-14°C) 58-70°F (15-21°C) Above 70°F (21°C)	21 days 1 day 6 hours[2] 2 hours
Escherichia coli pathogenic strains growth	43.7-50°F (6.6-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	2 days 5 hours 2 hours
Listeria monocytogenes growth	31.3-41°F (-0.4-5°C) 42-50°F (6-10°C) 51-70°F (11-21°C) 71-86°F (22-30°C) Above 86°F (30°C)	7 days 1 days 7 hours 3 hours 1 hour
Salmonella species growth	41.4-50°F (5.2-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	2 days 5 hours 2 hours
Shigella species growth	43-50°F (6.1-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	2 days 5 hours 2 hours
Staphylococcus aureus growth and toxin formation	50°F (10°C) 51-70°F (11-21°C) Above 70°F (21°C)	14 days 12 hours[2] 3 hours
Vibrio species growth	≤50°F (10°C) 51-70°F (11-21°C) 71-80°F (22-27°C) Above 80°F (27°C)	21 days 6 hours 2 hours 1 hour[3]
Yersinea enterocolitica growth	29.7-50°F (-1.3-10°C) 51-70°F (11-21°C) Above 70°F (27°C)	1 days 6 hours 2.5 hours

[1] Adapted from FDA 2011. *Fish and Fishery Products Hazards and Controls Guidance*. 4th Edition and assumes high water activity food with pH near neutrality
[2] Additional data needed
[3] Applies to cooked, ready-to-eat foods only

Table A4-3 Inactivation of *Listeria monocytogenes*

Internal Product Temperature (°F)	Internal Product Temperature (°C)	Lethal Rate	Time for 6D Process (Minutes)
145	63	0.117	17.0
147	64	0.158	12.7
149	65	0.215	9.3
151	66	0.293	6.8
153	67	0.398	5.0
154	68	0.541	3.7
156	69	0.736	2.7
158	70	1.000	2.0
160	71	1.359	1.5
162	72	1.848	1.0
163	73	2.512	0.8
165	74	3.415	0.6
167	75	4.642	0.4
169	76	6.310	0.3
171	77	8.577	0.2
172	78	11.659	0.2
174	79	15.849	0.1
176	80	21.544	0.09
178	81	29.286	0.07
180	82	39.810	0.05
182	83	54.116	0.03
183	84	73.564	0.03
185	85	100.000	0.02
Note: z = 13.5°F (7.5°C)			

From FDA 2011. *Fish and Fishery Products Hazards and Controls Guidance*. 4th Edition and assumes high water activity food with pH near neutrality

Table A4-4. Properties of common foodborne bacterial pathogens

Organism	Pathogenicity	Primary Sources	Transmitted by	Contributing Factors	Atmosphere	Spore/ non-spore	Other
Bacillus cereus	Produces two toxins – diarrheal and emetic (vomiting)	Soil	Rice, starchy foods, meats, vegetables, milk products, sauces	Temperature abuse	Facultative – grows with or without oxygen	Sporeformer	Extensive growth required for illness. Emetic toxin is heat stable
Brucella spp.	Infection causes fever, sweating, weakness, muscle aches, headache	Unpasteurized milk and undercooked meat	Uncooked/ unpasteurized milk and meat	Consumption of infected unpasteurized milk products	Aerobic	Non-sporeformer	Survives but proliferates poorly outside of the animal host
Campylobacter spp.	Infection causes diarrhea and potential nerve damage	Raw poultry, raw milk products, contaminated water	Raw poultry, raw milk products, contaminated water	Cross contamination and undercooking	3-5% oxygen optimum	Non-sporeformer	-
Clostridium botulinum	Toxin in food causes blurred or double vision, paralysis of respiratory muscles, death	Wide spread	Food with anaerobic environment	Temperature abuse	Anaerobic – requires absence of oxygen	Sporeformer	Mesophilic and psychotropic strains
Clostridium perfringens	Toxin causes diarrhea and abdominal pain	Soil and intestinal tract of healthy people and animals	Meats, stews or gravy, especially those containing spices	Inadequate hot holding and reheating	Anaerobic	Sporeformer	-
Shiga-toxin Producing *Escherichia coli* (STEC)	Infection causes bloody diarrhea and sometimes kidney failure and death	Intestinal tract of ruminant animals (e.g., cows, sheep)	Raw and undercooked beef, leafy greens, sprouts, and unpasteurized milk and juices	Poor GAP, inadequate heating, and person-to-person	Facultative - grows with or without oxygen	Non-sporeformer	-
Listeria monocytogenes	Infection causes severe illness in susceptible people – mortality 15-30%	Occurs widely in agriculture (soil, plants and water)	Refrigerated RTE foods that support growth	Environmental pathogen spread by environmental contamination, equipment, people, incoming raw ingredients	Facultative	Non-sporeformer	-

Table A4-4. Properties of common foodborne bacterial pathogens (*continued)*

Organism	Pathogenicity	Primary Sources	Transmitted by	Contributing Factors	Atmosphere	Spore/ non-spore	Other
Mycobacterium bovis	Infection causes respiratory symptoms and tuberculosis	Cattle and raw milk	Raw milk products	Lack of milk pasteurization and exposure to aerosols from infected animals	Grows very slowly and under reduced oxygen	Non-sporeformer	-
Salmonella spp.	Infection causes nausea, vomiting, diarrhea, fever, headache	Intestinal tract of people and animals	Meat, poultry, eggs, raw milk and many other foods (nuts, spices, produce, chocolate, flour)	Cross-contamination, undercooked food, poor agricultural practices, environmental contamination	Facultative	Non-sporeformer	-
Shigella spp.	Infection causes diarrhea, which may be watery to bloody. The infection is called dysentery	Human intestinal tract	Fecal contamination from contaminated water or infected food workers	-	Facultative	Non-sporeformer	-
Staphylococcus aureus	Produces heat stable toxins after extensive growth	Boils, nasal passages and skin	Recontaminated cooked foods, and foods with high salt or high sugar	Recontamination and temperature abuse	Facultative	Non-sporeformer	Poor competitor
Streptococcus spp. group A	Infection causes sore throat, tonsillitis and fever	Infected sites of humans and animals, raw milk	Infected workers handling food and consumption of raw milk or meat products	-	Facultative	Non-sporeformer	-
Vibrio spp.	Infection symptoms vary depending on strain, ranging from diarrhea to high fever	Salt water environment and seafood	Marine seafood products	-	Facultative	Non-sporeformer	Requires salt to reproduce
Yersinia enterocolitica	Infection causes abdominal pain, fever and diarrhea. May mimic appendicitis.	Raw pork, raw milk	Cross contamination between raw pork products and RTE foods	-	Facultative	Non-sporeformer	-

Descriptions of Common Foodborne Pathogens

Bacillus cereus causes either vomiting with short onset (30 minutes to 6 hours), or diarrhea and cramps in 6-15 hours. Different strains produce two different toxins – the one responsible for short-onset vomiting is heat resistant. The toxin that causes diarrhea is produced in the intestines. Symptoms mimic those of either *S. aureus* (vomiting type) or *C. perfringens* (diarrheal type). Many foods are associated with the diarrheal type of illness, while rice and other grains and starchy foods are associated with the vomiting type. Transmission of illness is caused by consumption of food containing preformed toxin for the vomiting type of illness, or high levels of vegetative cells produced during growth under temperature abuse for the diarrheal disease. *B. cereus* spores are resistant to normal cooking processes and the vegetative cells grow with or without oxygen ("facultative"). Refrigeration and freezing inhibit *B. cereus* growth but do not kill the bacteria.

Brucella spp. rarely cause illness in the United States because of pasteurized milk. It may be an issue with raw milk products if stringent controls are not in place.

Campylobacter causes diarrhea 2-7 days after eating contaminated food and may cause nerve damage 1-6 weeks after infection. The live bacteria invade the cells lining the intestine. The primary source is fecal contamination of raw poultry and meat and transmission is associated with cross contamination from raw meat or poultry drippings or consumption of undercooked animal products. *Campylobacter* is sensitive to heat and drying, grows in reduced oxygen environments, grows best above body temperature, and survives but does not grow during refrigeration and freezing.

Clostridium botulinum produces several types of toxins. Types A, B, E and F toxins are concerns in food and cause the severe disease called botulism. Blurred or double vision, dry mouth, difficulty swallowing, paralysis of respiratory muscles, vomiting and diarrhea may be present. Symptoms develop 18-36 hours (sometimes days) after eating contaminated food and death can occur unless treatment is received. Recovery may be slow (months, rarely years). *C. botulinum* spores may be present in soil and the intestinal tract of animals and are wide spread in nature. The spores are heat resistant and, under the right conditions in the absence of oxygen, can come out of dormancy and produce toxin.

Some *C. botulinum* strains (type E and some strains of B and F) can grow at refrigeration temperatures, but most cannot. The spores of strains that grow under refrigeration are not as heat resistant as other spores. The toxin is destroyed by high heat (boiling for 5 min); however, the disease is so severe that heating to destroy toxin is not an appropriate control method. *C. botulinum* can grow in many foods under strict anaerobic (low oxygen) conditions. A pH $\leq$4.6 prevents toxin production by *C. botulinum,* and toxin production for those strains that grow under refrigeration is inhibited at pH<5.0. Sodium nitrite used in cured foods slows toxin production.

Clostridium perfringens causes diarrhea and abdominal pain 6 -24 (typically 8-12) hours after eating food contaminated with large numbers of vegetative cells (>10^6/g), which requires growth in the food. When these viable cells are consumed, they form spores and release toxin in the intestines. *C. perfringens* is found in soil and the intestinal tract of healthy people and animals. Spores survive normal cooking processes, including boiling. Spices are a potential source for *C. perfringens* as the spores can persist on spices for long periods of time. Inadequate hot holding or cooling of cooked food, particularly meats, pot pies, stew or gravies, allows bacteria to multiply because the spores can survive the cooking process. *C. perfringens* has one of the most rapid growth rates for foodborne pathogens, and can double in less than 10 minutes at optimum temperature. This pathogen grows best without oxygen.

Cryptosporidium parvum is a rarely reported parasite but is notable for its resistance to chemical agents, including standard levels of chlorine. It is sensitive to drying and ultraviolet light. *Cryptosporidium* causes diarrhea, and infection can be fatal for immunocompromised people. Foodborne outbreaks have involved apple cider and unpasteurized milk, as well as contaminated water.

Cyclospora cayetanensis is a rarely reported parasite that causes prolonged diarrhea. Death rarely occurs. Outbreaks are frequently associated with fruits (berries), leafy green and other salads, and herbs like basil.

Escherichia coli is a bacterium that is normally present in the intestinal tract of humans and other animals and most strains of *E. coli* are not associated with disease. However, certain strains, like *E. coli* O157:H7, produce a toxin called Shiga-toxin in human intestines, causing severe disease. These disease-causing strains are called enterohemorrhagic, Shiga-toxin producing *E. coli* or STECs. They cause diarrhea, which may be bloody, and occasionally fever, generally 2-3 days after ingestion of food (range 1-5 days). Kidney failure and death, especially in children, may result. Very low numbers of some STECs can cause illness. The primary source of STECs is fecal contamination from ruminants, including sheep and deer. These animals typically show no sign of illness. Consumption of raw or undercooked hamburger, contaminated produce, sprouts, and unpasteurized milk and juices have been linked to illness. *E. coli* O157:H7 and other STECs are killed by mild heat treatments. They can grow with or without oxygen. The optimum temperature for growth is around human body temperature, and the organism grows in some moist foods with a pH as low as 4.4.

STECs, or Shiga-toxin producing *E. coli,* as a group includes some stains that cause illness and some that do not. Those that cause illness are sometimes called enterohemorrhagic *E. coli*, or EHEC. The O157:H7 strain currently predominates in the US, causing ~75% of the EHEC infections worldwide. Other non-O157 EHEC serotypes also cause of foodborne illnesses. In the United States O111, O26, O121, O103, O145, and O45 are the most common non-O157:H7 serotypes isolated from clinical infections. However, other EHEC serotypes, such as O113, O91, and others, also can cause severe illness. Thus, public health concerns related to EHEC can change rapidly.

***Giardia intestinalis* (or *lamblia*),** like other parasites, causes diarrhea and is the most common parasitic cause of diarrhea in the U.S. Contaminated water is the primary source for outbreaks, but food and people spread the disease, and only one cyst may be enough to cause illness. Illness occurs about 2 weeks after eating contaminated food, so tracing the source of illness can be very difficult. Foodborne outbreaks with identified vehicles include ice, lettuce-based salads, chicken salad and unspecified vegetables.

Hepatitis A virus is causes the severe disease hepatitis. The health department will be notified if a food worker contracts hepatitis A. Symptoms of hepatitis A include weakness, fever and abdominal pain. As the illness progresses, the individual usually becomes jaundiced (skin turns yellow). The severity of the illness ranges from very mild (young children often experience no symptoms) to severe, requiring hospitalization. The fatality rate is low and deaths primarily occur among the elderly and individuals with underlying diseases. Illness occurs about 2 weeks after eating contaminated food (but can be much longer), so tracing the source of illness can be very difficult. Hepatitis A transmission can be prevented by practicing good personal hygiene and exclusion of ill workers, vaccination of food handlers, thorough cooking of food and preventing cross-contamination. Hepatitis A appears to be more heat resistant than other viruses. A laboratory study showed that hepatitis A viruses in infected oysters were inactivated after heating at 140°F (60°C) for 19 minutes.

Listeria monocytogenes can cause meningitis, a severe infection with symptoms including sudden fever, intense headache, nausea, vomiting, delirium and coma in people with suppressed immune systems. Up to one third of those who are hospitalized die. In a healthy person, infection with *L. monocytogenes* may cause no symptoms or a flu-like illness and diarrhea. This organism is a particular problem for pregnant women (causing miscarriage) and the elderly. Illness occurs about 2 weeks after eating contaminated food (but can be much longer) so tracing the source of illness can be very difficult. Refrigerated ready-to-eat foods are associated with listeriosis and five key factors influence risk of contracting listeriosis from such foods: 1) the amount and frequency of consumption of the food, 2) the frequency and extent of contamination, 3) the ability of the food to support *L. monocytogenes* growth, 4) the temperature of refrigerated storage and 5) the duration of refrigerated storage. Ready-to-eat meat products, unpasteurized dairy products and other low-acid ready-to-eat foods have been associated with listeriosis outbreaks. *L. monocytogenes* is an environmental pathogen, thus post-heat-processing contamination from the plant environment, including plant personnel, equipment, floors, walls, drains and condensation from coolers is a primary source of contamination. This non-sporeforming bacterium is killed by pasteurization temperatures, grows with or without air, and can grow at refrigeration temperatures and in higher salt concentrations than some other pathogens. Acid conditions slow growth but may allow survival. *L. monocytogenes* is extremely hardy compared to most bacteria, withstands repeated freezing and thawing, and survives for prolonged periods in dry conditions.

Mycobacterium bovis is another foodborne bacterial pathogen that rarely causes foodborne illness in the U.S. because of implementation of milk pasteurization requirements and removal of infected cattle. The primary source is cattle and raw milk. The hazard can be easily avoided by using pasteurized milk. Consumption of raw or undercooked meat, such as venison, of infected animals can also be a source of illness.

Norovirus is highly infectious and can cause illness when as few as 10-100 virus particles are consumed. People are the primary source of norovirus and when someone is ill they can shed millions of viral particles through vomit and feces. Because of this, people with norovirus must be excluded from handling food. If a food worker is diagnosed with norovirus, it is important to clean and disinfect surfaces that they may have contaminated. This is likely to require higher concentrations of sanitizers than those used for food contact sanitizing. Norovirus causes nausea, vomiting, diarrhea, abdominal cramps and occasionally fever 24-48 hours after initial contact. Norovirus outbreaks can be prevented by excluding ill workers, by proper personal hygiene, by properly cooking food and by preventing cross-contamination and by cleaning and disinfecting surfaces that were contaminated by an infected individual.

Salmonella is among the most common causes of bacterial foodborne illness and can be an environmental pathogen. The infection causes diarrhea, fever, abdominal cramps and vomiting. Occasionally, *Salmonella* may cause bloodstream infections and death. Severe cases may also result in reactive arthritis. Foodborne illness symptoms generally appear 12 to 72 hours after eating contaminated food. The intestinal tract of animals is the primary source of *Salmonella*, thus raw animal products (meat, poultry, eggs, milk products) are frequently associated with outbreaks. Because *Salmonella* survives well in many environments, many other foods have been associated with outbreaks, such as yeast, coconut, sauces, cake mixes, cream-filled desserts, gelatin, peanut products, chocolate and cocoa, and soy ingredients. Fresh fruits, vegetables and nuts can be contaminated during growing if Good Agricultural Practices are not applied.

Salmonella is easily killed at traditional cooking temperatures, grows with or without air, grows best at human body temperature, grows very poorly at refrigeration temperatures and does not

grow above 115°F (46°C). Unlike most other pathogens, *Salmonella* can grow at a pH as low as 3.7 under otherwise optimum conditions. It survives well in frozen and dry foods, as well as in dry processing environments. Attempts to wet-clean dry processing environments have been shown to spread contamination and increase the risk of product contamination because of growth in environmental niches like cracks and crevices that cannot be reached by sanitizers. It is best to keep dry environments dry when *Salmonella* is a potential concern.

Shigella causes diarrhea (often bloody), fever and stomach cramps 1-2 days after consuming contaminated food or beverages, with symptoms usually lasting 5-7 days. *Shigella* is transmitted primarily by people who are infected, thus it is essential for people with diarrhea to be restricted from handling food. *Shigella* is a relatively fragile bacterium that does not survive cooking or in dry environments. It can be transmitted by foods such as fresh fruits and vegetables, especially if washed in contaminated water.

Staphylococcus aureus *c*auses a relatively mild illness with vomiting, nausea, abdominal cramps and diarrhea 1-6 hours after eating food contaminated with toxin. The toxin is produced after extensive growth in the product and is very heat stable, even withstanding processing times and temperatures used in canning foods. While the toxin is heat stable, the bacterium is killed by mild heat. Toxin production is favored by the presence of oxygen. The limits for toxin production are more restricted than those for growth. *S. aureus* is a poor competitor; thus, toxin formation may not occur in foods that have many competitive microorganisms, such as raw foods and foods that undergo a controlled fermentation.

From 25 – 50% of healthy people and animals can carry *S. aureus* on their skin and in their noses; thus food may be easily re-contaminated, especially if handled extensively. If this occurs along with temperature abuse, rapid growth and subsequent toxin formation is likely in foods with few competing organisms, such as cooked foods or foods with lower water activities that inhibit competing organisms but permit *S. aureus* growth.

Streptococcus group A infections are rare causes of foodborne illness. Transmission through food can be easily avoided by exclusion of ill workers and milk pasteurization.

Toxoplasma gondii is a parasite and a leading cause of death from foodborne illness in the United States, particularly for babies infected in the womb and people with suppressed immune systems. People infected with *Toxoplasma* may be asymptomatic, but it can spread to a variety of organs including the brain, eyes, heart and other muscles. Raw meat products and cat feces are the primary source of this parasite. Freezing food to ≤9°F (-13°C) for 24 hours or more usually prevents infectivity. Cooking meats to recommended temperatures also is an effective control measure.

Trichinella spp. is the parasite that causes trichinosis, which is associated with consumption of raw meat products. In the past, pork was the primary type of meat involved; however, transmission through commercially raised pork is now rare. Trichinellosis is more commonly associated with game meat. As with other parasites, *Trichinella* is susceptible to freezing and cooking.

Vibrio species of concern for food include *V. cholera, V. parahaemolyticus and V. vulnificus*. Because vibrios are a concern for seafood products and generally not other foods, they are not addressed in this training program. Refer to the *Fish and Fishery Products Hazards and Controls Guidance* or Seafood HACCP curriculum for more information on vibrios, as well as other regulatory requirements.

Yersinia enterocolitica foodborne illness is primarily associated with cross contamination from raw pork products. It is a relatively uncommon foodborne illness for other foods.

Additional Reading

FDA. 2012. The *Bad Bug Book Foodborne Pathogenic Microorganisms and Natural Toxins,* 2nd Edition.
FDA 2011. *Fish and Fishery Products Hazards and Controls Guidance*. 4th Edition.
.Painter, JA, RM Hoekstra, T Ayers et al. 2013. Attribution of foodborne illness, hospitalizations, and deaths to food commodities by using outbreak data, United States, 1998-2008. *Emerg. Infect. Dis.* 19(3):407-415.
International Commission on Microbiological Specifications for Foods. 1996. *Microorganisms in Foods 5: Microbiological Specifications of Food Pathogens.* Blackie Academic and Professional, New York.