FOOD PATHOGEN CONTROL DATA SUMMARY *

Microorganism	Contribution to Hazard Control Logic
1. ***Yersinia enterocolitica*** Temperature range for growth = 29.3° - 111°F (-1.5° - 44°C) (Hudson et al., 1994; Sutherland and Varnham, 1977) pH range for growth = 4.0 – 10.0 (Shiemann 1980) Minimal water activity (a_w) for growth = 0.945. (NZFSA 2001). G [32°F (0°C)] = 53 hours (Hanna et al., 1977a) G [41°F (5°C)] = 17 hours in raw beef (Hanna et al., 1977a) G [77°F (25°C)] = 1.3 hours in cooked beef, after 6-24 hour lag period (Hanna et al., 1977a) D [145°F (62.8°C)] = 0.24 - 0.96 minutes (Lovett et al., 1982) D [140°F (60°C)] = 0.4 - 0.55 minutes in milk (Hanna et al., 1977a) 2. ***Listeria monocytogenes*** Temperature range for growth = 29.3° to 112°F (-1.5° to 44°C) (Hudson et al., 1994; Grau and Vanderline, 1990; Khan et.al., 1972; Lovett, 1989) pH range for growth = 4.5 - 9.5 (Lovett, 1989) = 4.1 – 9.6 (Jay et al., 2005) Minimal water activity (a_w) for growth = 0.92. (NZFSA 2001). *Listeria monocytogenes* is one of the few food-borne pathogens that can grow at an a_w value below 0.93. (Faber et al. 1982). G [32°F (0°C)] = 7.5 days on fatty tissue of beef (Grau and Vanderline, 1990) G [95°F (35°C)] = 41 min. in skim, whole, chocolate milk and whipping cream (Rosenow and Marth, 1989) D [140°F (60°C)] = 2.85 minutes (USDA, FSIS. 1990)	1. & 2. *Yersinia enterocolitica* and *Listeria monocytogenes* are capable of multiplication at 29.3°F (-1.5°C). *Listeria monocytogenes* and *Yersinia enterocolitica* can multiply about 1 time every day at 41°F (5°C). This temperature is the standard for refrigerated storage. In order to prevent growth of these pathogens to a hazardous level there must be a designated time (< 7 days) for storing products at this temperature. If foods are stored in refrigeration units at 41°F (5°C) or less, they must be cooked or used within 7 days to assure that vegetative cells of pathogenic bacteria are in range that will not cause illness or disease. If 10 *Listeria monocytogenes* / gram of food (a rather high contamination level) multiply to 160 (4 generations) vegetative cells, the 5D *Salmonella* spp. pasteurization treatment is sufficient to effect inactivation of *Listeria monocytogenes* to a safe level. If raw foods (e.g. fruits and vegetables) with a moderate level of contamination are washed thoroughly prior to consumption, pathogenic bacterial populations can be reduced from 100/gram to 1/gram. This level is below the 100-1,000 *Listeria monocytogenes* per gram that seems necessary to make healthy people ill.
3. ***Clostridium botulinum*** - **Type E and other non-proteolytic strains** Temperature range for growth = 38° - 113°F (3.3° - 45°C) (Hauschild, 1989) pH range for growth = 5.0 - 9.0 (Hauschild, 1989) Minimal water activity (a_w) for growth = 0.97 (Hauschild, 1989) <u>Spores</u> D [180°F (82.2°C)] = 0.49 - 0.74 min. (Lynt et al., 1982) <u>Neurotoxin</u> D [185°F (85°C)] = 5 minutes for any botulinal toxin (Woodburn, et al., 1979)	3. The fact that non-proteolytic types of *Clostridium botulinum* begin to multiply at 38°F (3.3°C) dictates that any pasteurized, chilled food to be stored longer than 5 days must be stored at temperatures below 38°F (3.3°C) for absolute safety. In order to inactivate the spores of type E and nonproteolytic strains of *Clostridium botulinum* food must be heated to 180°F (82.2°C) for 15 minutes. The toxin is destroyed by heating food to temperatures above 180°F (82.2°C) for a few minutes. If food preparers bring all food to a boil when preparing it for consumption, this pathogen becomes less of a hazard, because any pre-formed toxin is inactivated.

Food Pathogen Control Data Summary (cont.)

Microorganism	Contribution to Hazard Control Logic
4. ***Bacillus cereus*** Temperature range for growth = 39.2°- 122°F (4°- 50°C) (van Netten, et al., 1990; Kramer and Gilbert., 1989) pH range for growth = 4.3 - 9.0 (Kramer and Gilbert, 1989) Minimal water activity (a_w) for growth = 0.912 (Bryan et al., 1981) <u>Vegetative cells</u> G [86°F (30°C)] = 27 minutes in pasteurized milk (Wong et al., 1988) D [140°F (60°C)] = 1 minute (Kramer and Gilbert, 1979) <u>Spores</u> D [212°F (100°C)] = 2.7 - 3.1 minutes (Kramer and Gilbert, 1979) <u>Toxin destruction</u> Diarrheal: D [133°F (56.1°C)] = 5 min. (Kramer and Gilbert, 1979) Emetic: Stabile at [249.8°F (121°C)] (Kramer and Gilbert, 1979)	4. *Bacillus cereus* spores are found in many foods (eg. milk, corn starch, rice, dried legumes, and spices). Vegetative cells of some strains of this microorganism begin to multiply at 39.2°F (4°C). Foodborne illness produced by the growth of this pathogen in food is usually not life threatening, however its onset and duration are quite uncomfortable. Reheating leftover foods in which these bacteria may have grown and produced toxin does not ensure its safety, because the emetic toxin produced by *Bacillus cereus* is very heat stable. The rule for holding food at 41°F (5°C) for <7 days will control the *Bacillus cereus* hazard. For long term chilled food storage, pasteurized chilled food products must be stored at < 38°F (3.3°C). **Note:** Although the growth of *Bacillus cereus* was shown to occur at 131°F (55°C) in studies reported by Johnson et al. (1983), no other research has demonstrated growth at this temperature. Therefore, growth of *C. perfringens* at 125°F (51.7°C) will be used as the upper limit bench mark for pathogen growth.
5. ***Salmonella*** spp. Temperature range for growth = 41.5° - 114°F (5.5° -45.6°C) (Matches and Liston, 1968; Angelotti et al., 1961a) pH range for growth = 4.1 - 9.0 (Silliker, 1982) Minimal water activity (a_w) for growth = 0.95 (Sperber, 1983) G [98.6°F (37°C)] = 20.4 min (Fehlhaber and Kruger, 1998) G [104°F (40°C)] = 25 minutes in barbecued chicken (Pivnick et al., 1968) D[140°F (60°C)] = 1.73 minutes (9CFR 1987, 318.17)	5. Some *Salmonella* spp. can begin to multiply at 4.1 pH. If potentially hazardous egg supplies (whole shell eggs or unpasteurized liquid eggs) are used in the production dressings and sauces, the safe pH for salad dressings and pasteurized foods must be set at ph 4.1 or less. Acetic acid (vinegar) and citric acid (lemon juice) are used to cause the destruction of vegetative cells of *Salmonella* when salad dressings and mayonnaise are prepared commercially. When the product pH is less than pH 4.1, due to the addition of vinegar (acetic acid), and the dressings and mayonnaise are held at room temperature for a few days, *Salmonella* spp. are inactivated (Smittle, 1977). Other organic acids do not function as effectively as acetic acid. The outside of many fruits such as melons can become contaminated with *Salmonella* during growing and distribution. The salmonellae will not multiply on the surface because of lack of nutrients and moisture, but will survive on the surface for 7 to 14 days. When the melons are cut, the salmonellae are spread to the interior of the melon and can multiply about as fast on the flesh of the melon as on meat. If the melons and other fruits are kept at 41°F (5°C), there will be no significant multiplication of *Salmonella* spp. Because the thermal destruction *Salmonella* spp. is well defined, the $5D_{140°F}$ = 8.7 minutes and Z = 10°F values are used as the standards for pasteurization times and temperatures for many processed foods. While *Staphylococcus aureus* and *Listeria monocytogenes* are more resistant to thermal destruction, they are not used as the thermal destruction standard because people can consume larger numbers of these types of vegetative cells before becoming ill. It appears that *Salmonella* spp. must be reduced to < 1/25 grams of food in order to assure safety for immune-compromised people.

Food Pathogen Control Data Summary (cont.)

Microorganism	Contribution to Hazard Control Logic
6. ***Vibrio parahaemolyticus*** 41° - 109.4°F (5° - 43°C) (Twedt, 1989) pH range for growth = 4.5 - 11.0 (Twedt, 1989) Minimal water activity (a_w for growth = 0.937 (Twedt, 1989) G [98.6°F (37°C)] = 7.6 minutes in squid (Lee, 1973; Aiso, 1967) D [116°F (47°C)] = 0.8 - 48 minutes (Beuchat and Worthington, 1976; Beuchat, 1982)	6. *Vibrio parahaemolyticus* is a pathogenic bacterium that is commonly present in raw fish and seafood. The hazard is that this bacteria can multiply once every 7 to 8 minutes under ideal conditions [95°F (35°C)] that occur in warm kitchens and street vending operations. Hence, it can multiply to a hazardous level in 2 to 3 hours at 90°F (32.2°C). It is easily destroyed by the 7D *Salmonella* destruction standard. Storing food at 40°F (4.4°C) or below prevents the multiplication of this pathogen.
7. ***Staphylococcus aureus*** Temperature range for growth = 43.8°- 122°F (6.5°- 50°C) (Halpin-Dohnalek and Marth, 1989b) pH range for growth = 4.5 - 9.3 (Bergdoll, 1989) Minimal water activity (a_w) for growth = 0.83 (Sperber, 1989) Vegetative cells G [98.6°F (37°C)] =24.6 in steak and kidney pie (ICMSF 1996. **Microorganisms in Foods 5**) D [140°F (60°C)] = 5.2 - 7.8 minutes (Angelotti et al., 1961b) Toxin production Temp. range for toxin production = 50°F - 114°F (0° - 46°C) (Tatini, 1973) pH range for toxin production = 5.15 - 9.0 (Scheusner, et al., 1973) Minimal water activity (a_w) for toxin production = 0.86 (Tatini, 1973) Toxin destruction D [210°F (98.9°C)] = 2 hours, 14.2 minutes (Read and Bradshaw, 1966)	7. *Staphylococcus aureus* is more resistant to thermal destruction than *Listeria monocytogenes*. It is commonly found in raw foods, at levels of 10 - 100 vegetative cells per gram. The absence or complete destruction of *Staphylococcus aureus* is a good indicator of an effective pasteurization process. The presence of this pathogen can also be used to indicate post-process contamination due to poor personal hygiene and hand washing, and cross-contamination from other raw animal products. *Staphylococcus aureus* dictates cold food mixing temperatures because it does not produce toxin below 50°F (10°C). Therefore, moderately large volumes of salads can be safely mixed with ungloved, clean hands (which may still be shedding *Staphylococcus aureus*), if the ingredients are pre-cooled to 40°F (4.4°C) prior to mixing, and if the product temperature is kept below 50°F (10°C) before it is returned to the refrigeration unit to re-cool to less than 41°F (5°C). The toxin produced by the growth of *Staphylococcus aureus* in foods, like the toxin produced by *Bacillus cereus*, is heat-stabile. Reheating food to 165°F (73.9°C) can not be used as a hazard control for general food processes. The controls are correct cooking, cooling, and cold holding of food.
8. ***Clostridium botulinum*** - **Type A and proteolytic B strains** Temperature range for growth = 50° - 118°F (10° - 47.8°C) (Hauchild, 1989) G = [68°F (20°C)] = 1.2 hours in pork slurry (Type A) (Gibson et al., 1987) pH range for growth = 4.6 - 9.0 (Hauchild, 1989) Minimal water activity (a_w) for growth = 0.94 (Hauchild, 1989) Spores D [250°F (121.1°C)] = 0.3 - 0.23 min. for A, B (proteolytic) (Lynt et al., 1982) Neurotoxin D [185°F (85°C)] = 5 minutes for any botulinal toxin (Woodburn et al., 1982)	8. Type A and type B proteolytic *Clostridium botulinum* begin to grow and produce toxin at 50°F (10°C) in foods with a pH <4.6. This fact demands that no food capable of sustaining growth of this microorganism be stored or displayed in anaerobic conditions (an oxygen reduction potential of <+200 mv* above 50°F (10°C). This is particularly important for plastic wrapped vegetables which become anaerobic and where enough toxin can be formed in 2 or 3 days at 75°F (23.9°C) to kill a person. Improperly processed canned foods have also been a source of this toxin. Canned low-acid foods (<4.6 pH) must be processed for times at temperature that assure destruction of spores of type A and type B proteolytic *C. botulinum*. The toxins produced by both proteolytic and non-proteolytic strains of *Clostridium botulinum* are inactivated at boiling temperatures. When foods are brought to a boil [212°F (100°C)], the toxin is inactivated and the food becomes safe to consume. * mv = millivolt

Food Pathogen Control Data Summary (cont.)

Microorganism	Contribution to Hazard Control Logic
9. ***Clostridium perfringens*** Temperature range for growth = 59° - 125°F (15° - 51.7°C) (Labbe, 1989; Shoemaker and Pierson, 1976) pH range for growth = 5.0 - 9.0 (Fuchs and Bonde, 1957) Minimal water activity (a_w) for growth = 0.93-97 depending on solute (NZFSA 2001). <u>Vegetative cells</u> G [105.8°F (41°C)] = 7.0 minutes (Willardson, et al., 1978) D [138°F (59°C)] = 7.2 minutes (Roy, et al., 1981) <u>Spores</u> D [210°F (98.9°C)] = 26-31 minutes (Bradshaw, et al., 1977)	9. *Clostridium perfringens* is important in determining hazard control standards for 3 reasons: • It is the fastest multiplying pathogen to consider during heating of food products. Therefore it dictates the maximum slow rate of heating foods from 40°F to >130°F (4.4°C to >54.4°C) in < 6 hours. • *Clostridium perfringens* sets the high temperature growth control standard at 125°F (51.7°C). • Because the spores of *C. perfringens* are not inactivated by most cooking/pasteurization temperatures [The FDA Food Code recommends a cooling time of 6 hours for cooling food to 41°F (5°C) *[from 140°F to 70°F (60°C to 21°C) in 2 hours and 70°F to 41°F (21°C to 5°C) in 4 hours]* or according to USDA-FSIS cooling recommendation of cooling from 120 to 55°F (48.9 to 12.8°C) in 6 hours followed by continued cooling to 40-41°F (4.4-5.0°C).
10. ***Campylobacter jejuni*** Temperature range for growth = 90°- 113°F (30°- 45°C) (Doyle and Roman, 1981) Minimal water activity (a_w) for growth = 0.987 (NZFSA 2001). pH range for growth = 4.9 - 8.0 (Doyle and Roman, 1981) G [107.6°F (42°C)] = 50 minutes in egg yolk (Clark and Bueschkins, 1986) D [137°F (58.3°C)] = 12 - 21 seconds (Koidis and Doyle, 1983)	10. *Campylobacter jejuni* is easily inactivated by heating and it is doubtful that it will multiply in food. Yet, indications are that this microorganism is the leading cause of foodborne bacterial illness. The hazard is that a dose of < 500 vegetative cells can cause illness in a healthy person. This pathogen is often found to be present in poultry, frequently at levels of >10,000 /g. The incidence of this pathogen dictates the cleaning and sanitizing standard for food contact surfaces. Food contact surfaces are safe when the surfaces are cleaned and sanitized, reducing a population of 1,000,000 *Campylobacter jejuni* per 8 inches^2 to < 100 per 8 inches^2.

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