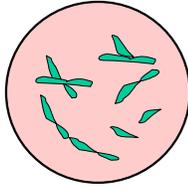


CHARACTERISTICS OF *ESCHERICHIA COLI*

- Grows with and without air.
- Grows between 45°F and 114°F.
- Survives freezing temperatures.
- Many strains are harmless.
- Source of pathogenic strains is infected animals and people.
- Found in raw milk, raw meat, non-chlorinated water, contaminated fruits and vegetables.
- Vegetative cells multiply and produce toxins in intestinal tract to cause illness.
- Can be low infective dose (*E. coli* O157:H7) = 10 to 100 cells in a portion of food for children.
- Vegetative cells killed by cooking / pasteurization.



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Escherichia coli - Characteristics

Bacterial Characteristics

Escherichia coli is a gram negative, non-spore forming rod. It may or may not be mobile. (Some rods are flagellated and some are not.) The organism is a facultative anaerobe and ferments simple sugars such as glucose to form lactic, acetic, and formic acids.

Growth Conditions

The optimal conditions for growth are a temperature of 98.6°F, with a range of 45 to 114°F. The following table indicates the generation times for *E. coli* O157:H7.

GROWTH OF *E. COLI* O157:H7 IN TRYPTICASE SOY BROTH AT DIFFERENT TEMPERATURES*

Temperature °F	Generation Time (minutes)
36	no growth
77	87.6
86	34.8
99	30.0
104	38.0
111	65.0
113	72.6
114	no growth

*Adapted from Doyle and Schoeni (1984)

The optimum pH for growth is 6.0 to 8.0. However, growth can occur as low as pH 4.3 and as high as 9 to 10 pH (Banwart, 1983; Mitscherlich and Marth, 1984).

Escherichia coli O157:H7 can survive in ground beef at -4°F for several months without change in numbers (Doyle and Schoeni, 1984).

Source

Escherichia coli is a common inhabitant of the intestinal tract of man and warm-blooded animals. Most strains of *E. coli* are harmless and are a part of the normal intestinal microflora. These strains serve a useful function in the body by suppressing the growth of harmful bacteria and by synthesizing appreciable amounts of vitamins.

However, within the species, there are 4 strains or categories that cause diarrheal illnesses or disease. These 4 categories are:

enteropathogenic *E. coli*, enteroinvasive *E. coli*, enterotoxigenic *E. coli* and enterohemorrhagic *E. coli*.

Enteropathogenic *E. coli* causes severe diarrhea in infants that can last for over 2 weeks and results in death if dehydration is severe. In adults, the illness is characterized by severe diarrhea, nausea, vomiting, abdominal cramps, headache, fever, and chills. The time for onset of the illness is 17 to 72 hours; the duration of the illness is 6 hours to 3 days. This strain has caused illness to develop in people when it was transmitted in fecally contaminated water and a coffee substitute.

Enteroinvasive *E. coli* is similar to shigellosis and is caused by bacterial penetration and destruction of intestinal mucosa. Symptoms include: chills, fever, headache, muscle pain, abdominal cramps, and profuse diarrhea. The illness occurs 8 to 24 hours after ingestion of food or water containing this organism. The ingestion of a large number of cells (10^4 to 10^5 cells) is required to cause the illness. An outbreak of this type occurred in the United States in 1981, which was traced to imported French Brie and Camembert cheese. Bacterial counts of the cheese revealed that there were 10^5 to 10^7 *E. coli*/gram. These strains are biochemically and culturally different from other strains of *E. coli*.

Enterotoxigenic *E. coli* include strains that produce enterotoxins when the organisms multiply in the intestine. These strains are commonly responsible for "traveler's diarrhea". They have been responsible for illness in India, in U.S. soldiers in Vietnam, and in travelers in Mexico. This is a problem for travelers from developed countries with good hygiene who visit countries with poor hygiene standards.

The illness is characterized by severe diarrhea, which may lead to dehydration. The diarrhea may last up to 19 days. Usually there is no fever. The onset of the illness can occur 8 to 44 hours after ingestion. Infective dose, as determined by a human study, is 10^8 to 10^{10} microorganisms.

In 1974, more than 2,000 staff members and visitors at Crater Lake National Park in Oregon developed gastrointestinal illness due to this strain of *E. coli*. The source of the microorganism was traced to the park's water supply, which had been contaminated with raw sewage. In 1980, more than 400 persons became ill with gastroenteritis after eating at a Mexican style restaurant in Wisconsin. Enterotoxigenic *E. coli* was identified as the microorganism responsible for this outbreak. A food handler, who had a diarrheal illness during the 2-week period before the outbreak was believed to be the source of the infection.

Enterohemorrhagic *E. coli* (*E. coli* O157:H7) is characterized by severe abdominal cramps usually, but not always, followed by bloody diarrhea (hemorrhagic colitis). Some individuals exhibit only watery diarrhea. Vomiting may occur but there is usually little or no fever. The incubation period is usually about 3 to 9 days.

This microorganism can also cause hemolytic uremic syndrome in children. This is the leading cause of kidney failure in children, which often requires dialysis and may ultimately lead to death.

Other manifestations of illness due to this microorganism include a central nervous system involvement in which patients develop blood clots in the brain and death frequently results.

In 1982, two outbreaks of hemorrhagic colitis occurred, one in Oregon and one in Michigan. Both outbreaks were traced to fast food restaurants of the same chain. Infected individuals had eaten hamburgers that were contaminated. Frozen ground beef patties had not been heated sufficiently to inactivate *E. coli* O157:H7.

In the fall of 1988, an incident occurred at a junior high school in Minnesota that led to illness in 30 students. Four were hospitalized. There were no fatalities. Frozen, partially cooked beef patties were incriminated in this incident. The patties had not been heated sufficiently by the processor to inactivate *E. coli* in the center. The beef patties were reheated before they were served to students, but some, again, were not reheated adequately to inactivate *E. coli* O157:H7.

From November 15, 1992 through February 28, 1993 more than 500 laboratory confirmed infections with *E. coli* O157:H7 and four associated deaths occurred in four states (Washington, Idaho, California, and Nevada). Many young children were involved. The outbreaks were traced to a fast food chain and restaurants in these states serving regular hamburgers and jumbo hamburgers. A meat traceback by the Centers for Disease Control team identified five slaughtering plants in the United States and one in Canada as the likely sources of carcasses used in the contaminated lots of meat. The animals slaughtered in these slaughtering operations were traced to cattle auctions in six western states.

Additional cases of *E. coli* O157:H7 resulted through transmission in families and in child day care settings. As a result of this outbreak, the FDA recommended that all ground meat products be cooked to 155°F for 15 seconds (FDA Food Code). The color of cooked meat is not an indication of its safety.

Other outbreaks of *E. coli* O157:H7 have been found to be associated with cider, apple juice, lettuce and alfalfa sprouts. These incidents point out that food items cannot be presumed safe unless processors or producers utilize procedures for producing safe products.

Infective Dose

Dupont et al. (1971) determined on the basis of a human study that ingestion of 10^6 to 10^8 cells of some pathogenic strains of *E. coli* were needed to cause diarrheal illness in a healthy individual.

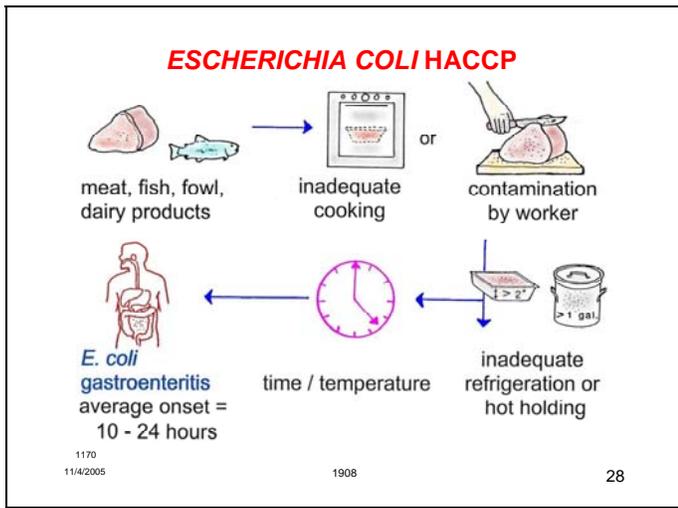
According to the FDA (1993) the infectious dose for *E. coli* O157:H7 is unknown. However, from a compilation of outbreak data, it may be as low as 10 organisms. This data indicates it takes a low number of microorganisms to cause illness in young children, the elderly and immune-compromised people.

Incidence

There is an estimated annual incidence of over 200,000 cases of enteric (intestinal) *E. coli* in the United States each year, resulting in 400 fatalities (Bennett, 1987).

References

- Adams, M.R. and Moss, M.O. 1995. Food Microbiology. The Royal Society of Chemistry. Cambridge, U.K.
- Bennett, J.V., Scott, D.H., Rogers, M.F., and Solomon, S.L. 1987. Infectious and parasitic diseases. In The Burden of Unnecessary Illness. Amler, R.W. and Dull, H.B., Eds. Oxford Univ. Press. New York, NY.
- Doyle, M.P. and Padhye, V.S. 1989. *Escherichia coli*. In Foodborne Bacterial Pathogens. Doyle, M.P., Ed. Marcel Dekker, Inc. New York, NY.
- Doyle, M.P. and Schoeni, J.L. 1984. Survival and growth characteristics of *Escherichia coli* associated with hemorrhagic colitis. Appl. Environ. Microbiol. 48(4):855-856.
- Doyle, M.P., Zhao, T., Meng, J., and Zhao, S. 1997. In Doyle, M.P., Beuchat, L.R., and Montville, T.J., Eds. Food Microbiology: Fundamentals and Frontiers. American Society of Microbiology. Washington, D.C. pp. 171-191.
- Centers for Disease Control (CDC). 1993. Multistate outbreak of *Escherichia coli* O157:H7 infections from hamburgers -- Western United States, 1992-1993. MMWR. 42(14):258-263.
- Dupont, H.L., Formal, S.B., Hornick, R.B., Snyder, M.J., Libonati, D.G., Sheahan, LaBrec, E.H., and Kalas, J.P. 1971. Pathogenesis of *Escherichia coli* diarrhea. New Eng. J. Med. 285:1-9.
- FDA. 1993. HACCP. Regulatory Food Applications in Retail Food Establishments. Dept. of Health and Human Services. Division of Human Resource Development. HFC-60. Rockville, MD.
- Jay, J.M. 1996. Modern Food Microbiology. 5th Ed. Van Nostrand-Reinhold. New York, NY.
- Mossel, D.A.A., Corry, J. E., Struijk, C.B., and Baird, R. 1995. Essentials of the Microbiology of Foods. John Wiley and Son. New York, NY.



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Escherichia coli - Process Hazard Analysis and Critical Controls

Transmission

Raw foods, particularly those of animal origin, are frequently contaminated with *Escherichia coli*. Raw milk can contain *Escherichia coli*. People are also carriers of this microorganism and can transmit the microorganism to food products through fecal contamination as a result of inadequate hand washing.

Escherichia coli is found on fish and shellfish taken from sewage-polluted waters. If a polluted water supply is used to water fresh fruits and vegetables, these foods too will become contaminated.

Carcasses are often contaminated with fecal material of infected animals or from other contaminated carcasses or equipment. It has been noted recently that young cattle are more likely to be a source of this microorganism than older cattle.

Prepared foods can become contaminated with *Escherichia coli* from equipment that has not been cleaned and sanitized after it was used to prepare raw food products and from infected food handlers.

Control

Control of enteropathogenic types of *Escherichia coli* in food can be attained by:

1. Mandating proper hand washing procedures for food handlers.
2. Purchasing food, particularly meat and poultry, from suppliers who certify the safety or microbiological quality of their products.

The FDA developed destruction standards for *Escherichia coli* O157:H7 in ground beef in 1993 based on the data of Line et al., (1991). In the following table, the D values at 125°F, 135°F, and 145°F come from this research article. The FDA used these data to extrapolate mathematically to the destruction values at 140°F, 145°F, 150°F, and 155°F. The z-value for both of these sets of data is approximately 8.3°F.

Using these data from these sources, the table indicates times needed to destroy 90% (1 decimal reduction or 1 D-value) of *Escherichia coli* O157:H7 in ground beef and the time to destroy 99.999% (5 decimal reductions or 5 D-value).

**THERMAL INACTIVATION TIMES
OF ESCHERICHIA COLI O157:H7 IN GROUND BEEF**

Temperature (°F)	5 D-values
140	8.7 minutes
145	2.7 minutes
150	52 seconds
155	15 seconds

If food products are not purchased from suppliers who certify safety:

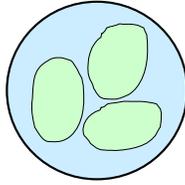
1. Food, particularly ground beef, must be cooked or heated according to thermal inactivation standards given by Table 1, or heated to 155°F for 15 seconds as recommended by the FDA. (This is a 5D *Salmonella* kill.)
2. Raw food preparation areas should be separated from cooked food preparation areas and/or good cleaning and sanitizing methods must be used to ensure that equipment and surfaces do not contaminate other products.

References

- Doyle, M.P. and Padhye, V.S. 1989. *Escherichia coli*. In Foodborne Bacterial Pathogens. Doyle, M.P., Ed. Marcel Dekker, Inc. New York, NY.
- Frank, J.F. 1988. Enteropathogenic *Escherichia coli*. Food Technol. 42(4):192-193.
- Kornacki, J.L. and Marth, E.H. 1982. Foodborne illness caused by *Escherichia coli*: A review. J. Food Protect. 45:1051-1067.
- Line, J.E., Fain, A.R., Moran, A.B., Martin, L.M., Lechowich, R.V., Carosella, J.M., and Brown, W.L. 1991. Lethality of heat to *Escherichia coli* O157:H7: D-value and z-value determinations in ground beef. J. Food Protect. 54:762-766.

CHARACTERISTICS OF *LISTERIA MONOCYTOGENES*

- Grows with and without air.
- Grows between 29.3°F and 113°F.
- Found in plant matter and soil, raw milk, raw meat, contaminated prepared foods.
- Source of contamination is infected animals and people, inadequately pasteurized food, floor drains.
- Vegetative cells multiply in intestinal tract to cause illness (severe for immune-compromised, elderly, infants, and pregnant women).
- Low infective dose = 100 to 1,000 cells in a portion of food for immune-compromised people.
- Vegetative cells killed by cooking / pasteurization.



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Listeria monocytogenes - Characteristics

Listeria monocytogenes is a gram-positive, short rod that is motile at 6 to 77°F. It is a facultative (grows with and without air), non-spore forming pathogenic bacteria.

Source

Listeria monocytogenes is commonly found in the environment and has been isolated from both cultivated and uncultivated soil. It is present in vegetables and plant matter, especially in decaying plant material. It has been found in the intestinal flora of humans, animals, fish, insects, birds and poultry. It has been recovered from both raw and treated sewage. Infected cows and sheep excrete *L. monocytogenes* in their feces and milk.

Growth

Listeria monocytogenes grows from 29.3 to 113°F and can increase in number at refrigeration temperatures (Hudson et al., 1994; Grau and Vanderline, 1990). The population will double in number in 1.5 days at 39.2°F [Rosenow et al., 1987]. The following table indicates the predicted generation times for *L. monocytogenes* in foods.

PREDICTED GENERATION TIMES FOR 1 MULTIPLICATION OF *LISTERIA MONOCYTOGENES* IN FOODS*

Temperature °F	Time
32	16 days
35	4 days
41	1.2 days
45	16.7 hours
50	9.8 hours
55	6.0 hours
60	4.5 hours
65	3.4 hours
70	2.6 hours
75	2.1 hours
80	1.7 hours
85	1.4 hours
90 to 100	1 hour

* Adapted from data of Snyder, O.P. (1998).

Foods with a pH of 5.0 to 9.0 will support its growth. The organism has been found to grow in silage as low as pH 3.6. However, the growth of this microorganism is extremely slow at

a pH less than 4.5. *L. monocytogenes* can grow in the presence of sodium chloride at levels of 5% or greater.

The organism can survive repeated freezing and thawing. Pasteurization should control *L. monocytogenes*, if the vegetative cell population is not greater than 10³/g. Any product that is not heated or pasteurized sufficiently before being chilled or frozen and consumed is a potential carrier of *L. monocytogenes*.

Symptoms

In adults there is a sudden onset of "flu-like" symptoms that include: fever, chills, headache, backache, and sometimes abdominal pain and diarrhea. These symptoms may precede more serious complications, which include septicemia, meningitis, encephalitis, and intrauterine or cervical infections in pregnant women, which may result in spontaneous abortions during the second or third trimester, or in stillbirths. Pregnant women usually suffer painful, short-term effects but their unborn fetuses are at greatest risk. Surviving infants often contract meningitis or other complications. Newborn infants, whose mothers had listeriosis, have respiratory problems, refusal to swallow, vomiting, and nodules in the throat or on the back.

The elderly and adults with underlying health problems (compromised immune systems) often die from meningitis or other complications that result from listeriosis.

Listeriosis is only positively identified by culturing the organism from blood, cerebrospinal fluid, or stool samples.

Infective Dose

The infective dose is not known at this time, but is probably less than 1,000 total microorganisms in susceptible persons (FDA, 1993).

Incidence

Healthy children and adults are usually not made ill by these microorganisms. However, an outbreak of listeriosis in Switzerland involving cheese suggests that healthy uncompromised individuals may develop the disease if the food product is heavily contaminated. Taking antacids may even make seemingly healthy individuals more susceptible (FDA, 1993).

Listeria monocytogenes is a great risk to the elderly, infants, and pregnant women and their unborn children. Immune-compromised people with cancer, AIDS, cirrhosis, and kidney disease, or those who have undergone organ transplant are also at risk for contracting listeriosis.

In 1981, 41 cases of listeriosis were reported in Nova Scotia. There were 34 cases of perinatal listeriosis in this outbreak. As a result of this illness in these pregnant women, there were 5 spontaneous abortions, 4 stillbirths, 23 cases of live births of seriously ill infants and only 2 live births of well infants. The outbreak was due to the consumption of coleslaw made from cabbage fertilized with sheep manure. It was determined that the sheep had died previously of listeriosis.

In 1983, 49 individuals in Massachusetts acquired listeriosis and 14 people died. This outbreak was traced to "pasteurized" milk. The incident was thought to be due to raw milk, which was highly contaminated, and inadequately pasteurized, or contaminated dairy processing equipment.

In 1985, 86 cases of *L. monocytogenes* infection were identified in California. More than 1/2 of the patients were pregnant women. Forty-two of the infants delivered from these women had listeriosis within 24 hours of birth. The source of the infection was a soft Mexican cheese manufactured at a plant in southern California.

In 1988, a woman with cancer was hospitalized in Oklahoma with sepsis caused by *L. monocytogenes*. *L. monocytogenes* was isolated from an open package of turkey franks from the patient's refrigerator. The patient had eaten one turkey frank daily, heated in the microwave oven. *Listeria monocytogenes* was isolated from packages of turkey franks at a local retail store and was traced to a processing plant. Cultures of other foods in the patients' refrigerator were also positive for *Listeria monocytogenes*. This finding indicates that other opened packages of food can become cross-contaminated if *L. monocytogenes* is present in the surrounding environment.

In 1989, the estimated annual incidence of this illness in the United States was 25,000, resulting in as many as 1,000 fatalities (Todd, 1989).

In the winter of 1998-1999, an outbreak of listeriosis occurred when it was discovered that processed cold meat products were contaminated with *L. monocytogenes*. Product recalls were extensive. Poor sanitation measures at a meat processing facility is suspected as a contributing factor to this illness outbreak.

Food Analysis

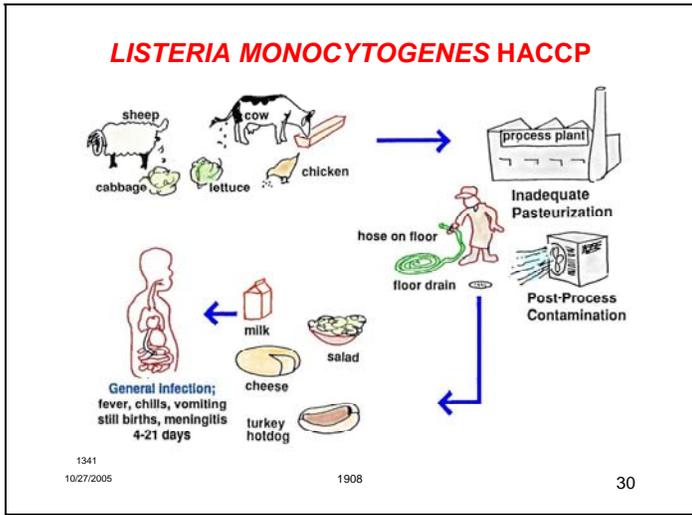
Present methods of analyzing foods for this organism are time consuming and complex. The total time for identification requires 5 to 7 days. Newer methods of analysis are expected to shorten this time.

References

- Anon. 1985 Listeriosis transmitted by contaminated Jalisco-brand cheese. California Morbidity. 46.
- Centers for Disease Control. 1989. Listeriosis associated with consumption of turkey franks. MMWR. 38(15):267-268.
- Centers for Disease Control and Prevention. 1999. Update: Multistate outbreak of listeriosis - United States. MMWR. 47(51 & 52):1117-1118.
- FDA. 1993. HACCP. Regulatory Food Applications in Retail Food Establishments. Dept. of Health and Human Services. Division of Human Resource Development. HFC-60. Rockville, MD.
- Grau, F.H. and Vanderline, P.B. 1990. Growth of *Listeria monocytogenes* on vacuum-packages beef. J. Food Protect. 53(9):739-741.
- Hudson, J.A., Mott, S.J., and Penney, N. 1994. Growth of *Listeria monocytogenes*, *Aeromonas hydrophila*, *Yersinia enterocolitica* on vacuum and saturated carbon dioxide controlled atmosphere-packaged sliced roast beef. J. Food Protect. 57(3):204-208/
- Lovett, J. 1989. *Listeria monocytogenes*. In Foodborne Bacterial Pathogens. Doyle, M.P., Ed. Marcel Dekker, Inc. New York, NY.
- Mossel, D.A.A., Corry, J. E., Struijk, C. B., and Baird, R. 1995. Essentials of the Microbiology of Foods. John Wiley and Sons, New York, NY. p.140.
- Rosenow, E.M., and Marth, E.H. 1987. Growth of *Listeria monocytogenes* in skim, whole and chocolate milk, and in whipping cream during incubation at 4°C, 8°C, 13°C, 21°C, and 35°C. J. Food Protect. 50:452-459.
- Schlegel, W.F., Lavigne, P.M., Bortolussi, R.A., Allen, A.C., Hladane, E.VV., Wort, A.J., Hightower, A.W., Johnson, S.E., King, S.H., Nicholls, E.S., and Broome, C.V. 1989. Epidemic listeriosis

Evidence for transmission by food. New Eng. J. Med. 308(4):203:206.

- Snyder, O. P. 1998. Updated guidelines for use of time and temperature specifications for holding and storing food in retail food operations. Dairy Food Environ. Sanit. 18 (9):574-579.
- Todd, E.C.D. 1989. Preliminary estimates of costs of foodborne disease in the United States. J. Food Protect. 52(8):595-601.
- USDA Food Safety and Inspection Service. 1989. FSIS Facts - Preventable foodborne illness. FSIS. 34.



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Listeria monocytogenes - Process Hazard Analysis and Critical Controls

Transmission

Listeria monocytogenes is an animal pathogen. The first documented human cases of listeriosis traced directly to food occurred in 1981, although human cases had been reported since 1930.

The major problem with this organism is contamination after heating. Outbreaks have been traced to raw products (e.g., cole slaw) as well as post-pasteurized milk products (e.g., ice cream, soft cheese) and cured meat products (frankfurters). When the presence of *L. monocytogenes* is discovered in food products or on surfaces, the population is so large that its elimination is a major challenge.

Control

In order to prevent listeriosis:

1. Only pasteurized milk and dairy products should be consumed.
2. Products stored at 41°F or less should be consumed within 7 days after receipt, or according to correct holding times.
3. Refrigerated or frozen products should be reheated until all parts of the food reach 165°F for 15 seconds.
4. People at risk should not consume uncooked vegetables and salads.
5. Food must be heated adequately. The following D values are recommended for the destruction of *L. monocytogenes*.

Temperature °F	Time (1D) (minutes)	Time (4D) (minutes)
130	21.95	87.80
140	2.85	11.40
150	0.37	1.48
160	0.047	0.19

These times and temperatures are based on a strain of *L. monocytogenes* called Scott A. The values were based on the average of heat resistance of this strain in ground beef of high fat content (fat increases heat resistance) and lean ground beef.

References

Lovett, J. 1989. *Listeria monocytogenes*. In Foodborne Bacterial Pathogens. Doyle, M.P., Ed. Marcel Dekker, Inc. New York, NY.

Schlegel, W.F., Lavigne, P.M., Bortolussi, R.A., Allen, A.C., Haldane, E.V., Wort, A.J., Hightower, A.W., Johnson, S.E., King, S.H., Nicholls, E.S., and Broome, C.V. 1989. Epidemic listeriosis - Evidence for transmission by food. *New Eng. J. Med.* 308(4):203-206.

Snyder, O.P. 1994. HACCP-Based Safety and Quality Assured Pasteurized-Chilled Food Systems. Hospitality Institute of Technology and Management. St. Paul, MN.

USDA Food Safety and Inspection Service. 1989. FSIS Facts - Preventable Foodborne Illness. FSIS. 34.