

Table 1. Minimum growth temperatures for selected foodborne pathogens.

	Minimum Growth Temperatures	
Salmonellae ¹	7C	44.6F
Pathogenic <i>E. coli</i>	7-8C	44.6-46.4F
<i>L. monocytogenes</i>	-0.4C	31.3F
<i>Y. enterocolitica</i>	-1.3C	29.7F
<i>Campylobacter jejuni</i>	32C	89.6F
<i>Staphylococcus aureus</i>	7C	44.6F
<i>Bacillus cereus</i> ²		
psychrotrophic strains	4C	39.2F
<i>Clostridium perfringens</i>	12C	53.6F
<i>Clostridium botulinum</i>		
nonproteolytic	3.3C	38F
proteolytic	10C	50F

- ¹One report of initial growth on bacon at 5C but then the population decreased.
- ²While growth of *B. cereus* occurs in milk at refrigeration temperatures (e.g., <7C), there is no evidence for this in meat and poultry. One study reported death of vegetative cells in ground beef at 12.5C (54.5F) and below.
- Parasites (e.g., *Trichinella spiralis*, *Taenia* spp., *Toxoplasma gondii*) and viruses do not multiply in meat or poultry products.

Source: International Commission on Microbiological Specifications for Foods. 1996.
Microorganisms in Foods: Microbiological Specifications of Food Pathogens. Blackie
Academic & Professional, New York.

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Table 2. Estimated time (hours) for a ten fold increase at 50, 60 and 70F.

	Estimated Time (hours) to increase from 10 to 100 CFU/ml		
	50F (10C)	60F (15.6C)	70F (21.1C)
Salmonellae	107	24	9
<i>E. coli</i> O157:H7			
aerobic	50	21	9
anaerobic	123	38	16
<i>L. monocytogenes</i>			
aerobic	38	16	8
anaerobic	58	27	16
<i>Y. enterocolitica</i>	68	31	16

Source: USDA ARS Pathogen Modeling Program Version 4.0.

Conditions: broth medium, pH 6.0, salt 0.5%, sodium nitrite 0.0%

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Table 3. Public health significance of meat and/or poultry held at 40-50F (4.4 to 10C) during storage and/or distribution.

Pathogen ¹	Estimated No. of cases of illness from meat/poultry ²	Estimated cost/year (billion) ³	Foods most likely to be involved ⁴	Impact of 40-50F on growth of the pathogen ⁵
<i>T. gondii</i>	2,056	2.7	raw pork	None. This parasite can not multiply in meat or poultry products.
<i>Campylobacter</i>	1,031,000-1,313,000	0.5 - 0.8	poultry	None. <i>C. jejuni/coli</i> can not multiply below about 90F.
<i>S. aureus</i>	756,000	0.6	cooked meat/poultry	None. <i>S. aureus</i> is a poor competitor and would not grow in raw meat or poultry at 50F or below. Most outbreaks involve cooked products that become contaminated and are held at 75-100F in the presence of air.
<i>L. monocytogenes</i>	808-837	0.1-0.2	ready-to-eat foods	Little, if any. Listeriosis has not been linked to raw meat or poultry . The potential for growth in some ready-to-eat foods does exist.
<i>C. perfringens</i>	50,000	0.1	cooked products	None. <i>C. perfringens</i> can not grow below about 54F

<i>E. coli</i> O157:H7	6,000 - 12,000	0.1-0.2	undercooked ground beef	Little, if any. The minimum temperature for growth is about 45F. At 50F, from 2 to 5 days would be needed for a 10 fold (1 log) increase depending on available oxygen
Salmonellae	549,000- 2,745,000	0.3-2.6	undercooked meat/poultry	Little, if any. The minimum temperature for growth is about 45F. At 50F, about 4 days may be needed for a 10 fold (1 log) increase.

Source: ^{1,2,3} Department of Agriculture, FSIS, Proposed Rule. 1995. Federal Register 60: 6881-6881. (This source was used for "the pathogens," "estimated cases", and "estimated cost/year")

^{4,5} The "foods most likely to be involved" and the "impact of 40-50F" are based upon the scientific literature.

Notes: • The Federal Register notice listed 50-75% of salmonellosis cases as being due to meat/poultry. The 75% value was used for the above estimate of cases.

• Recent estimates from the Center for Disease Control indicates the total number of cases of listeriosis is about 1100/year. Thus the number of cases from meat/poultry (50% of the total) now would be estimated at about 550/year.

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Table 4. Estimated time (hours) for a one log increase of typical spoilage bacteria at 40, 50 and 57-59F. Applicable to raw meat and poultry.

Isolate and strain #	Estimated time (hours) to increase from 10 to 100 CFU/ml		
	39.2-41F (4-5C)	50F (10C)	57-59F (14-15C)
<i>Pseudomonas</i> (92)	39	18	8
<i>Pseudomonas</i> (69)	49	22	9
<i>Ps. fluorescens</i>	27	12	7
<i>Ps. fluorescens</i> (P-200)	-	13	7
<i>Ps. fluorescens</i>	22	-	-
<i>Ps. fragi</i>	17	9	-
<i>Pseudomonas</i> (21-3c)	24	11	7
<i>Pseudomonas</i> (1-3b)	23	9	8
<i>Enterobacter aerogenes</i> (Ps48)	40	14	7
<i>Gram negative rod</i>			
<i>aerobic</i>	14	-	-
<i>anaerobic</i>	32	-	-
<i>Gram negative rod</i>	25 ¹	-	-
<i>Achromobacter</i> (7)	18	8	5
<i>Achromobacter</i> (438)	20	8	4
<i>Achromobacter</i> (5)	24	10	5
<i>Pseudomonas</i> (451)	32	13	4

¹ Data obtained at 6C.

Source: Adapted from Tompkin. 1973. Food Technol. 27(12):54-58.

Table 5. Effect of temperature on time of spoilage for pork and poultry.

	Temperature (F)	Days to spoilage
A. Chicken	32	18
	37	11
	42	8
	47	6
	68	2
B. Pork	31	14
	36	9
	41	5

Source: A. Adapted from Shannon and Stadelman. 1957. *J. Poultry Sci.* 36:121-123.
B. Unpublished data from Swift and Company (before 1977).

Table 6. Combined effect of temperature and bacterial content on time of spoilage of poultry and beef.

	Temperature (F)	Days to spoilage	
		Initial level of 100 CFU/cm ²	Initial level of 100,000 CFU/cm ²
A. Chicken	40	14	1 - 2
	50	6	1 - 2
B. Beef	32	22	11
	41	13	6
	50	8	4
	68	3	2

Source: A. Adapted from Ogilvy and Ayres. 1951. Food Technol. 5:97-102.
 B. Adapted from Ayres. 1960. Food res. 25:1-18.

Table 7. Factors influencing the microbial content of ready-to-eat meat and poultry products from production through distribution/storage.

Factor	Measurement (s)
Ingredients	Types and levels of microorganisms in ingredients which can multiply and/or survive during subsequent processing, distribution and storage.
Formulating	The conditions of formulating and holding that may lead to microorganisms in finished product
Heating	The conditions of heating (e.g., time, temperature, humidity).
Cooling	The conditions of cooling and potential for recontamination.
Further processing	The conditions of holding and further processing before packaging
Product composition	Brine content / water activity Type and amount of fermentable carbohydrate Product pH; type and level of acidulant Level of smoke, liquid or natural Phosphate content Level of residual nitrite Hot oil dipping or flaming to brown the surface Spices, condiments applied to the surface after heating Sodium lactate content Metal ion content
Packaging	Product temperature during packaging and palletizing Degree of vacuumization and leaker formation Rate of oxygen transmission through packaging materials Addition of oxygen scavengers Modified atmosphere content
Contamination after heating	Types and levels of microorganisms contaminating the product between heating and packaging.
Distribution/storage	Time-temperature history after packaging. Damage to packaging permitting contamination

Source: Adapted from Tompkin, 1995. The use of HACCP for producing and distributing processed meat and poultry products. pp. 72-108. In A.M. Pearson and T.R. Dutson (eds.), HACCP in Meat, Poultry and Fish Processing. Blackie Academic & Professional, New York.

Options for arriving at time, temperature criteria for chilling, storage and distribution of meat and poultry.

I. Chilling Rate

A. Carcasses, head meat, variety meats

1. Specify time and temperature requirements based upon:
 - a. predictive modeling and published research
 - b. data submitted by industry through conferences such as this and other means
 - c. survey of current commercial practice for rates of chilling carcasses
 - d. microbial sampling of carcasses before and after chilling
 - e. review requirements from other countries
2. Arbitrarily establish a performance standard
 - a. for example, <2 log increase in salmonellae and *E. coli* O157:H7
3. Conduct a risk assessment (This is highly recommended)

B. Cooked meat and poultry products

1. Provide time and temperature guidance such as in the current guideline (FSIS Directive 7110.3 Rev. 1; 1-24-89)
2. Establish a performance standard
 - a. for example, <1.5 log increase in *C. perfringens*

II. Distribution/Storage

A. All perishable meat and poultry that requires refrigeration for food safety

1. a. Establish an action level in the range of 40 to 50F because a critical limit based solely upon temperature does not exist in this range. A valid critical limit would have to specify time and temperature.
- b. A temperature of 45 or 46F (7 or 8C) is suggested.

2. Establish performance standards

- a. for example, <1.5 log increase in *C. perfringens*
- b. for example, <1.5 log increase in salmonellae and *E. coli* O157:H7

III. If the action level or other criteria are exceeded:

- A. place product on hold
- B. collect information (e.g., time-temperature history)
- C. review information
- D. collect more information, if needed (e.g., sample and test)
- E. consider the food, its intended use and consumers of the product
- F. decide disposition:
 - options; destroy, reprocess, freeze, divert to other safe use etc.
- G. implement decision
- H. follow through with corrective action to prevent future occurrences