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Tompkin, R.B. 1996. The Significance of time-temperature to growth of foodborne pathogens during refrigeration at 40-50°F. Presented during the Joint FSIS/FDA Conference on Time/Temperature. November 18, Washington, DC.

Attribution on page 11 of this document. From the author: 12/31/2015- This 2007 version of the document includes information about the date, where, and why the document was made available to the public. It was never published in the literature but FSIS recognizes it since it was presented at a public hearing on a proposed regulation. FSIS inserted a link on page 20 of its recent, "FSIS Compliance Guideline HACCP Systems Validation April 2015".

Table 1. Minimum growth temperatures for selected foodborne pathogens.

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

• [1]One report of initial growth on bacon at 5C but then the population decreased.

• [2]While 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.

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
E. coli O157:H7			
aerobic	50	21	9
anaerobic	123	38	16
L. monocytogenes			
aerobic	38	16	8
anaerobic	58	27	16
Y. enterocolitica	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%

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]
T. gondii	2,056	2.7	raw pork	None. This parasite can not multiply in meat or poultry products.
Campylobacter	1,031,000-1,313,000	0.5 - 0.8	poultry	None. *C. jejuni*/*coli* can not multiply below about 90F.
S. aureus	756,000	0.6	cooked meat/poultry	None. *S. aureus* 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.
L. monocytogenes	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.
C. perfringens	50,000	0.1	cooked products	None. *C. perfringens* can not grow below about 54F

E. coli 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.

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.

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

		Days to spoilage	
	Temperature (F)	Initial level of 100 CFU/cm²	Initial level of 100,000 CFU/cm²
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

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Time-temperature document

The foregoing is an electronic version of the material I used for a presentation at the USDA-FDA public meeting on time-temperature controls in 1996. The public meeting was in relation to a proposed federal regulation that would address food safety concerns during storage and distribution. The regulation was proposed but not finalized.

The material was made available as a handout for all in attendance.

The document also became a matter of public record along with my oral comments and the following discussion. Thus, it can be considered published, if that is important.

The material has since been made available to anyone who requests it. For example, the FSIS Technical Center requested a copy along with permission to distribute it among its staff.

The material also has been distributed to establishments through several trade associations.

Most establishments have found the material useful as supporting documentation for their HACCP plans.

In addition, the material provides guidance on what should be considered in the event of a problem (e.g., loss of refrigeration in a cooler or truck). It makes evident that both time and temperature should be considered when making a decision.

With few exceptions, the basis for the guidance is available in the literature.

Update on December 31, 2015:
The "Tompkin Paper" was available on the FSIS website as a resource for HACCP plan development until about 2014 after which it was removed. On page 20 of "FSIS Compliance Guideline HACCP Systems Validation April 2015", however, a link is provided to the document.
This is the preferred version because it provides information about when and where the document was made available to the public.

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