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of the Food Safety Authority of Ireland

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An investigation of the most appropriate *z*-value to be used in calculating 'equivalent cooks' for beef burgers in food business establishments

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CONTENTS

SUMMARY

The safety of beef burgers is dependent on sufficient cooking to ensure the destruction of pathogens such as Shiga toxin-producing *Escherichia coli* (STEC) O157. It is recommended that beef burgers are cooked to a minimum core temperature of 70 °C for at least two minutes or to a core temperature of no less than 75 °C. However, in recent years, catering establishments have started offering beef burgers prepared at temperatures below a core temperature of 70 °C.

It is possible to achieve an 'equivalent cook' (equivalent to 70 °C for two minutes) at lower temperatures if the heat is applied for longer times. However, calculating an 'equivalent cook' requires the use of a mathematical formula that uses the *z*-values[1] of the target organism, which is usually *Listeria monocytogenes*, as it is one of the most thermal-resistant foodborne non-spore-forming bacterial pathogens. The *z*-value recommended for inactivation of *L. monocytogenes* is 7.5 °C. In 2007, the UK Advisory Committee on Microbiological Safety of Food (ACMSF) recommended using a *z*-value of 6.0 °C for calculating equivalent cooks when cooking burgers, based on heat inactivation data for STEC O157. These two *z*-values give different cooking time requirements at a given target temperature. Thus, the objective of this report was to determine which *z*-value was more appropriate (would offer the greatest food safety protection).

At temperatures below 70 °C, using a *z*-value of 6.0 °C resulted in longer time requirements, while at temperatures above 70 °C, the same *z*-value suggested shorter times are needed to achieve a cook equivalent to 70 °C for two minutes. However, at temperatures above 70 °C these time differences (between the time predicted using a *z*-value of 6.0 and 7.5) were small (6.6 seconds at 71 °C, 9.6 seconds at 72 °C, 10 seconds at 73 °C and 9 seconds at 74 °C, etc.) and were of no practical significance. Thus, it was concluded that a *z*-value of 6.0 °C was more appropriate, as it would require longer cooking times for temperatures below 70 °C and cooking times that were practically the same as those predicted using a *z*-value of 7.5 °C for temperatures above 70 °C.

In conclusion, based on the *z*-value of 6.0 °C, the time and temperature combinations in Table 8 are recommended. It was concluded that the *z*-value of 6.0 °C is appropriate for calculating an equivalent cook only over the range from 60 °C for 93 minutes to 75 °C for 18 seconds. **If alternative temperature-time combinations to those in Table 8 are to be employed, they must first be scientifically validated.** This recommendation of not cooking to below 60 °C is based on the following; [1] the 'equivalent cook' equation should only be used within the temperature range for which the model has been validated and [2] at temperatures below 60 °C sub-populations of pathogens such as *E. coli* O157 and *Salmonella* spp. may survive. **It is also highlighted that an effective food safety management system including good hygiene practices (GHPs) and monitoring of cooking temperature is important in assuring the safety of beef burgers**.

[1] The *z*-value is defined as 'the number of degrees by which the temperature has to change to achieve a tenfold (i.e. 1 $\log_{10}$) change in the *D*-value', with the *D*-value being 'the time required in a given medium, at a given temperature, for a tenfold (1 $\log_{10}$ or 90% of the population) reduction in the number of organisms'.

CHAPTER 1. BACKGROUND

Beef burgers are considered to be a 'high risk' product because the meat raw materials may be contaminated with harmful bacteria such as *Salmonella* spp. or Shiga toxin-producing *Escherichia coli* (STEC), also known as verocytotoxigenic *E. coli* (VTEC). Moreover, during mincing and mixing of the meat preparation, pathogens located on the surface are often relocated to the centre of the product, the point which usually receives minimum heat treatment during cooking. Nonetheless, proper cooking to the core (or thickest part of the burgers) will ensure destruction of the pathogenic bacteria of concern. However, in recent years the trend in catering establishments has been to reduce the temperatures applied, as it is considered that lower cooking temperatures result in a better flavour and texture that reflects the preference of modern consumers. In 2016, a STEC O157 outbreak in Ireland was linked to a restaurant serving undercooked beef burgers. An Ipsos MRBI (2017) survey commissioned by *safe*food found that, in the Republic of Ireland (n=504), 65% of people questioned expressed a preference for well-done burgers when dining out, 13% for medium well, 5% for medium, 3% for medium rare and 0.4% for rare (13% of respondents said that they did not eat burgers). Within the Dublin region (n=142), 57% expressed a preference for well done, 18% for medium well, 7% for medium, 6% for medium rare and 0.69% for rare. Overall (n=504), 17% of respondents thought that rare burgers were safe to eat.

Although there are several pathogens which may be transmitted to humans through bovine meat, Shiga toxin-producing *E. coli* (STEC) and *Salmonella* spp. are considered to be high risk, based on the reported human incidence and the severity of the associated disease (EFSA, 2013). Both of these organisms are non-spore-forming bacteria and sensitive to thermal destruction during cooking. It has been demonstrated that a core temperature of 70 °C for two minutes or reaching a core temperature of 75 °C (26 seconds) is sufficient to ensure their destruction in beef burgers. This is based on a *D*-value (the time required for a tenfold reduction in bacterial numbers) of 20 seconds (0.33 minutes) at 70 °C for *Listeria monocytogenes* (FSAI Guidance Note No. 20, 2006) and thus a two-minute cook at this temperature will achieve a minimum 6 $\log_{10}$ *L. monocytogenes* reduction.

Lower temperature-longer time or higher temperature-shorter time combinations would also achieve the same level of pathogen destruction and food safety assurance.

Such 'equivalent cooks' can be calculated using the formula:

$\text{Log } D_T = \log D_{ref} + (T_{ref} - T)/z$ (EFSA, 2015).

D_T = the required *D*-value (the time required for a tenfold reduction in numbers) at an alternative target temperature T (minutes)

D_{ref} = reference *D*-value (minutes)

T_{ref} = reference temperature (°C)

T = target temperature (°C)

z = *z*-value (°C), the temperature change required for a tenfold change in the *D*-value

For example, in the scenario where the alternative target cooking temperature is 75 °C, and the target log reduction is the same as that attained by cooking at 70 °C for two minutes (i.e. a minimum 6 $\log_{10}$ reduction) at a *z*-value of 6.0 °C then the D_{ref} is two minutes, T*ref* is 70 °C, T is 75 °C and D_T is the unknown, and the equation becomes:

$$\text{Log } D_T = \log (2) + (70 - 75)/6$$

$$\text{Log } D_T = -0.5323$$

It follows that D_T = 0.293 minutes or 18 seconds. This formula requires use of the *z*-value of a suitable target organism. The *z*-value is defined as 'the number of degrees by which the temperature has to change to achieve a tenfold (i.e. 1 $\log_{10}$) change in the *D*-value' with the *D*-value being 'the time required in a given medium, at a given temperature, for a tenfold (1 $\log_{10}$ or 90% of the population) reduction in the number of organisms'. In Ireland and many other countries, *Listeria monocytogenes* (with a *z*-value of 7.5 °C) has historically been taken as the target organism for cooking of beef burgers (as it is considered to be the most heat resistant of the vegetative foodborne bacteria (Mackey and Bratchell, 1989; Doyle *et al.*, 2000)) although STEC and *Salmonella* have been more associated with illness related to beef burgers. In 2007, the UK Advisory Committee on Microbiological Safety of Food (ACMSF) recommended using a *z*-value of 6.0 °C for calculating equivalent cooks when cooking burgers based on heat inactivation data for STEC O157. The *z*-values for *L. monocytogenes* and STEC O157 give different cooking time requirements at a given target temperature and there is an inconsistency in the 'equivalent' cooking times obtained at a given temperature depending on the *z*-value used. At temperatures below 70 °C, for example, using a *z*-value of 6.0 °C results in predicted longer cooking times than those obtained with 7.5 °C (Table 1).

Table 1 Equivalent heat treatments to achieve a 6 $\log_{10}$ reduction in *L. monocytogenes* based on *z*-values of 6.0 °C (for *E. coli* O157, ACMSF (2007)) and 7.5 °C (for *L. monocytogenes*, FSAI Guidance Note No. 20 (2006))

Temperature (°C)	Time	
	z-value = 6.0 °C	*z*-value = 7.5 °C
60	93 min	43.1 min
65	13.6 min	9.3 min
70	2 min	2 min
75	18 s	26 s
80	3 s	5.6 s

The objective of this work was, therefore, to advise on the most appropriate *z*-value to use when calculating equivalent heat treatments to assure the microbiological food safety of beef burgers (Annex I). This brief only covered fresh or frozen burgers prepared from minced beef (100% beef) and excluded burgers prepared using other meat species. Meatballs and other products prepared from minced beef are also excluded.

CHAPTER 2. FACTORS AFFECTING THE THERMAL RESISTANCE VALUES OBTAINED FOR *E. COLI* O157, *SALMONELLA* SPP. AND *L. MONOCYTOGENES*

2.1 *D*-values

Bacterial thermal resistance is dependent on a number of factors related to the organism (bacterial strain, vegetative cells versus spores, growth phase, culture history, previous exposure to a heat shock, etc.), the medium (fat content, a_w, pH, additives such as salt and polyphosphates, etc.) and the heating method (heating rate, maximum temperature applied, heat distribution throughout the product, etc.) (Kaur *et al*. 1998; Jackson *et al*. 1996; Stringer *et al*. 2000; Passos and Kuaye, 2002). The culture media used (non-selective versus selective recovery medium) and the method of data modelling (log-linear model versus non-log-linear models) will also affect the values reported for the thermal inactivation parameters. Hence, the reported values used to characterise the thermal resistance of a given bacteria vary considerably depending on the experimental design.

This is seen in the examples of *D*-values at different temperatures and matrices for *E. coli* O157:H7, *Salmonella* spp. and *L. monocytogenes* presented in Tables 2, 3, and 4 respectively. For example, the D_{55} values (*D*-value at 55 °C) for *E. coli* O157:H7 in different matrices range from 11.83 to 21.13 minutes (Table 2) and for *Salmonella* spp. from 3.4 to 13.07 minutes (Table 3) and for *L. monocytogenes* the $D_{62.8}$ value can range from 0.6 minutes to 2.56 minutes (Table 4).

Of concern at the lower temperatures (i.e. 60 °C and below), is that sub-populations of pathogens such as *E. coli* O157 and *Salmonella* spp. may survive. When low inactivating temperatures are used, longer treatment times are required to achieve a target microbial inactivation level. Additionally, the longer the treatment time, the larger the probability of microbial adaptation to heat during the treatment and synthesis of heat shock proteins that will provide increased thermotolerance (Prokop and Humphrey, 1970; Cerf, 1977; Gould, 1989; Whiting, 1995; Juneja and Novak, 2005). In addition, a natural distribution of heat sensitivity within a microbial population (either genetic or physiological heterogeneity) can also occur (Gould, 1989; Stringer *et al*., 2000; Juneja and Novak, 2005). Both events are reflected in the microbial survival curves (Figure 2) as the 'tailing phenomenon',[2] meaning that a small fraction of the population would have a higher resistance to heat, i.e. low numbers of cells would survive longer than the predicted *D*-values. Several examples of the tailing phenomenon in *Salmonella* spp. and *E. coli* survival curves during heat exposure have been described in the literature (Blackburn *et al*., 1997; Humpheson *et al*., 1998; Lianou and Koutsoumanis, 2013; Trevisani *et al*., 2014). For instance, Humpheson *et al*. (1998) reported that the decimal reduction time at 60 °C (D_{60}) of the tail sub-population of *Salmonella enteritidis* PT4 was more than four times that of the majority population.

[2] Deviations from linearity have been described in the survival curves of some organisms when exposed to heat. Phenomena such as tails and shoulders can occur and those are reflected as concave upwards and downwards profiles, respectively, in the survival curves (i.e. non-log-linear curves). The traditional log-linear model used to calculate the D_T value is therefore not appropriate in these cases. Other non-linear models can be used and an approximation of the D_T value can be calculated.

Table 2 Examples of reported *D*-values for *E. coli* O157:H7

Matrix/Other relevant information	Temperature (°C)	*D*-value (minutes)
Ground (minced) beef	55	21.13
	57.5	4.95
	60	3.17
	62.5	0.93
	65	0.39
Ground chicken	55	11.83
	57.5	3.79
	60	1.63
	62.5	0.82
	65	0.36

References: Juneja *et al*., 1997; Stringer *et al*., 2000; Smith *et al*., 2001; Huang, 2004; Yuk and Marshall, 2003.

Table 3 Examples of reported *D*-values for *Salmonella* spp.

	Matrix	*D*-value (minutes)			
		D_{55}	D_{60}	D_{65}	D_{70}
S. Montevideo	BPW	3.80	0.43	0.08	0.02
S. Typhimurium		3.40	0.22	0.10	0.02
S. Anatum		3.72	0.32	0.10	0.03
S. Muenster		3.60	0.40	0.10	0.02
S. Newport		4.48	0.28	0.08	0.02
S. Mbandaka		4.20	0.42	0.08	0.02
S. Dublin		3.93	0.48	0.08	0.02
S. Reading		3.98	0.27	0.08	0.02
S. Agona		13.07	2.47	0.33	0.13
S. Give		4.43	0.27	0.08	0.03
		D_{58}	D_{60}	$D_{62.5}$	D_{65}
8 strain cocktail	Beef	8.65–8.85	5.26–5.48	1.47–1.50	0.53–0.67
	Pork	6.37–6.68	6.6–6.65	1.57–1.62	0.73–0.87
	Turkey	7.19–7.42	4.82	1.51	0.73–0.80
	Chicken	7.07–7.08	5.19–5.20	1.35–1.36	0.45–0.59
S. Montevideo	Chicken	1.75–2.16	–	–	–
S. Typhimurium		1.41–1.54	–	–	–
S. Kentucky		1.62–1.82	–	–	–
S. Saint-Paul		1.67–1.94	–	–	–

References: Juneja *et al.*, 2001; Smith *et al.*, 2001; Huang, 2004; Stopforth *et al.*, 2008. BPW: Buffered Peptone Water.

Table 4 Examples of reported *D*-values for *Listeria monocytogenes*

Matrix	Strain	Temperature (°C)	*D*-value (minutes)
Ground beef – 34% fat	6 strain cocktail	57.5	11.28
Ground beef – 34% fat	6 strain cocktail	60	3.91
Ground beef – 34% fat	6 strain cocktail	62.5	2.40
Ground beef – 34% fat	6 strain cocktail	65	1.41
Ground beef – 34% fat	6 strain cocktail	70	0.063
Lean ground beef	Scott A	57.2	2.6
Lean ground beef	Scott A	62.8	0.6
Fatty ground beef	Scott A	62.8	1.2
Ground beef – 10% fat	5 strain cocktail	62.8	2.56
Physiological saline	SLU 10	62	0.42
Ground beef – 75% lean + 2.4% sodium lactate	5 strain cocktail	65	1.78
Ground beef – 75% lean + 4.8% sodium lactate	5 strain cocktail	65	2.23
TSBYE	Scott A – Log phase of growth	56	1.0
TSBYE	Scott A – Stationary phase of growth	56	8.6
TSBYE	Scott A – Starved cells	56	13.6

References: Fain *et al.*, 1991; Sörqvist *et al.*, 1993; Lou and Yousef, 1996; Juneja, 2003; Murphy *et al.*, 2004. TSBYE: Tryptone Soya Broth plus Yeast Extract.

2.2 *z*-values

The *z*-values for *E. coli* O157, *Salmonella* spp. and *L. monocytogenes* in different matrices from a selection of peer-reviewed publications are listed in Tables 5, 6 and 7, respectively. These range from 3.6 to 6.79 °C for *E. coli* O157 (Juneja *et al.*, 1997; Stringer *et al.*, 2000; Smith *et al.*, 2001; Huang, 2004) and from 3.9 to 7.4 °C for *Salmonella* spp. (Juneja *et al.*, 2001; Smith *et al.*, 2001; Huang, 2004; Stopforth *et al.*, 2008) and from 3.9 to 13.2 °C for *L. monocytogenes* in tryptone soya broth and fatty ground (minced) beef, respectively (Golden *et al.*, 1988; Fain *et al.*, 1991). The *z*-values reported for *L. monocytogenes* range from 3.9 to 13.2 °C.

In Ireland and many other countries, the *z*-value of 7.5 °C has been used for calculating different pasteurisation process times/temperature combinations based on the target organism *L. monocytogenes*. In 2007, the UK ACMSF recommended using a *z*-value of 6.0 °C for calculating equivalent cooks when cooking burgers. This was based on modelling of heat inactivation data[3] (n=234) for STEC O157:H7.

[3] To obtain a suitable overview of the available information about the heat resistance characteristics of *E. coli* O157:H7, *D*-values (n=234) were collected from the literature in the temperature range 50 °C to 70 °C. The resulting data set includes the following information (when available): strain(s) used, source of isolation, heating medium, heating temperature (°C), *D*-value (min), log *D*-value, *z*-value (°C), growth conditions, additional chemicals added to heating media/sample, and recovery medium. All the thermal inactivation studies used the *E. coli* serotype of interest (i.e. O157:H7), frequently with various other strains combined in a cocktail before inoculation.

Table 5 Examples of reported z-values for *Escherichia coli* O157

Organism	Matrix	z-value (°C)
E. coli O157:H7	Ground beef	4.94–5.98
E. coli O157:H7	Ground chicken	5.78–6.79
E. coli O157:H7	Ground beef	3.79
E. coli O157:H8	Ground beef	3.60
E. coli O157:H7	Broth and buffers	5.5
E. coli O157:H7	Apple juice	4.8
E. coli O157:H7	All meat	4.8
E. coli O157:H7	Poultry meat	5.1
E. coli O157:H7	Red meat	4.6
E. coli O157:H7	All menstrua	4.9

References: Juneja *et al*., 1997; Stringer *et al*., 2000; Smith *et al*., 2001; Huang, 2004.

Table 6 Examples of reported z-values for *Salmonella* spp.

Organism	Matrix	z-value (°C)
S. Montevideo	Buffered peptone water	6.6
S. Typhimurium	Buffered peptone water	7.0
S. Anatum	Buffered peptone water	7.4
S. Muenster	Buffered peptone water	6.2
S. Newport	Buffered peptone water	6.4
S. Mbandaka	Buffered peptone water	6.6
S. Dublin	Buffered peptone water	6.4
S. Reading	Buffered peptone water	6.9
S. Agona	Buffered peptone water	7.4
S. Give	Buffered peptone water	7.2
S. Thompson	Chicken broth	6.41–6.44
S. Enteritidis PT13A	Chicken broth	5.86–6.03
S. Enteritidis PT4	Chicken broth	6.43–6.46
S. Typhimurium	Chicken broth	5.53–5.8
S. Hadar	Chicken broth	6.56–7.0
S. Copenhagen	Chicken broth	5.91–5.97
S. Montevideo	Chicken broth	5.77–5.85
S. Heidelberg	Chicken broth	6.1–6.11
S. Senftenberg	Ground beef	4.51
S. Typhimurium DT104-10127	Ground beef	4.28–5.07

Organism	Matrix	z-value (°C)
S. Typhimurium DT104-10601	Ground beef	4.13
S. Typhimurium DT104-01071	Ground beef	4.77
Salmonella cocktail	Ground beef	3.9–4.29
S. Heidelberg	Ground beef	7.06

References: Juneja *et al.*, 2001; Smith *et al.*, 2001; Huang, 2004; Stopforth *et al.*, 2008.

Table 7 Examples of reported *z*-values for *Listeria monocytogenes*

Strain	Matrix	z-value (°C)
6 strain cocktail	Ground beef – 34% fat	6.0
Scott A	Lean ground beef	9.3
Scott A	Lean ground beef	9.8
Scott A	Fatty ground beef	11.4
Scott A	Fatty ground beef	13.2
5 strain cocktail	Ground beef – 10% fat	7.9
5 strain cocktail	Ground beef – 10% fat	7.5
Scott A	Tryptone soya broth	5.6
DA 3	Tryptone soya broth	3.9
LCDC 81	Phosphate buffer	6.0
Scott A	Phosphate buffer	5.9
F5069	Phosphate buffer	6.6
SLU 10	Physiological saline	5.6
SA	Tryptone soya broth	7.3
1151	Tryptone soya broth	7.1

References: Golden *et al.*, 1988; Fain *et al.*, 1991; Schoeni *et al.*, 1991; Sörqvist, 1993; Casadei *et al.*, 1998; Murphy *et al.*, 2004.

CHAPTER 3. MICROBIAL CONTAMINATION RISKS OF BEEF BURGERS

Muscle tissue is essentially sterile in the living animal. During normal post-slaughter butchering, the newly exposed muscle tissue surfaces become contaminated with microorganisms present in the slaughtering and processing environment, including bacteria which are present on the hides or in the intestines of the animals. The main pathogens of concern in beef and beef burgers are STEC and *Salmonella* spp. In the case of STEC, most of the thermal inactivation data are available for *E. coli* O157. However, from the limited studies on non-O157 STEC (Vasan *et al*., 2013; Luchansky *et al*., 2014) they reportedly have similar resistances to heat as O157 and therefore any thermal treatment killing of the latter is expected to ensure the destruction of all STEC.

After 24–48 hours chilling, beef carcasses are typically cut into primals, vacuum packaged and stored for up to six weeks at 0 to 2 °C. Although not commonly practised in Ireland, the more expensive beef cuts may be dry aged by being hung or stored on racks for several weeks unpackaged or in a moisture-permeable packaging dry bag. The primals are then cut into retail cuts and sold to consumers in retail shops. Bacteria such as *E. coli* O157 and *Salmonella* spp. survive during all of these processes, including dry ageing, and may multiply if chilled conditions are not maintained.

Anatomically intact meat cuts have a low likelihood of problematic bacterial loads anywhere other than their surface. Beef burgers are made from re-formed comminuted (minced and mixed) meat. Various meat cuts and/or beef trim are minced or chopped into relatively small pieces and reformed into a meat patty. Comminution creates a much larger surface area with resultant larger contamination potential per mass of meat, and the reformation into a patty internalises those potentially contaminated surfaces away from the external aspects of the reformed patty. Therefore, in the case of beef burgers, and all reformed comminuted meat products, there is a particular food safety risk of pathogenic bacteria being present within the internal structures of the food product, which does not exist for anatomically intact meat cuts.

CHAPTER 4. PREVALENCE OF *E. COLI* O157 AND *SALMONELLA* SPP. IN RAW BEEF AND BEEF BURGERS

In Ireland, the Food Safety Authority of Ireland (FSAI) survey of STEC and *Salmonella* spp. in raw minced beef and beef burgers from retail and catering outlets in 2011 suggested that 0.1%, 0.2% and 2.5% were contaminated with *Salmonella* spp., *E. coli* O157 and non-O157 STEC, respectively (FSAI, 2013). A study by Cagney *et al*. (2004) found that 2.8% of minced beef/beef burgers in Irish supermarkets and butcher shops were contaminated with *E. coli* O157, with counts ranging from 0.52 to 4.03 $\log_{10}$ CFU/g. Interestingly, of the products containing the pathogen, the highest prevalence (4.46%) was found in fresh packaged burgers purchased from supermarkets. More recent investigations have reported that 3% and 29% of minced beef samples in Ireland are contaminated with *Salmonella* spp. and *L. monocytogenes*, respectively (Khen *et al*., 2014; Khen *et al*., 2015).

CHAPTER 5. OUTBREAKS ASSOCIATED WITH BEEF BURGERS

There have been many outbreaks associated with beef burgers. Indeed, as the majority of foodborne outbreaks caused by *E. coli* O157:H7 were initially associated with minced beef, this organism was nicknamed the 'burger bug'. In the majority of cases, insufficient cooking was a contributing factor to the outbreak (Whelan *et al*., 2010; Soborg *et al*., 2013).

In 2016, an Irish STEC O157 outbreak involving 11 cases was linked to a restaurant serving undercooked beef burgers. In England, a cluster of beef burger-associated *E. coli* O157 cases occurred in May and June in 1992, while the following year an outbreak of *E. coli* O157 involving eight people occurred in Wales (Wall *et al*., 1996; Chapman, 2000).

A number of other European outbreaks related to beef or beef products have previously been reported. In 2005, a Danish outbreak of 22 cases of *S.* Typhimurium DT104 was linked to carpaccio made from contaminated raw beef imported from Italy (Ethelberg, 2005). Two years later, beef sausage was linked to 20 cases of STEC O26:H11 in Denmark (Ethelberg *et al*., 2007). A 2005 Norwegian outbreak involving four cases of *S.* Typhimurium DT104 was caused by contaminated minced beef imported from Poland. Three of the patients reported tasting raw meat before becoming ill. Proper cooking among others who bought the contaminated meat inactivated the pathogen, preventing a larger outbreak (Isakbaeva *et al*., 2005). In 2010, there was an outbreak in France of 554 clinical cases of *S.* Typhimurium in four schools caused by contaminated beef burgers. Thirty-one people were hospitalised for more than 24 hours and it was one of the largest *S.* Typhimurium foodborne outbreaks recorded in France. While the cooked status of the burgers could not be assessed, the study suggests that the differences in attack rates between schools and age groups may be due to differences in cooking practices and length of cooking times (Raguenaud *et al*., 2012). In 2006, an outbreak of seven cases of haemolytic-uremic syndrome (HUS) caused by enterohaemorrhagic *E. coli* was linked to contaminated minced meat (Schimmer *et al*., 2006). In December 2015, a *Salmonella* enterica serotype *Enteritidis* outbreak in France in which five children became ill was associated with the consumption of beef burgers from Poland.

The European Food Safety Authority (EFSA) and the European Centre for Disease Prevention and Control (ECDC) have regularly identified outbreaks linked to beef or beef products within Europe. In 2011, the EFSA and the ECDC reported that 1.9% of all European strong evidence outbreaks (n=701) were linked to bovine meat and its products (EFSA and ECDC, 2013). In 2012, out of 12 total *E. coli* (11 STEC + 1 *E. coli* positive for heat-labile enterotoxin genes) strong evidence outbreaks, six were associated with bovine meat, making it the most common food vehicle for this pathogen. For *Salmonella*, 2.8% (n=8) of all strong evidence outbreaks (n=283) were associated with bovine meat (EFSA and ECDC, 2014). Similarly, in 2013, bovine meat was again identified as the most common vehicle of transmission for STEC, being responsible for 4 out of 10 strong evidence outbreaks (EFSA and ECDC, 2015).

In the USA, between 2006 and 2016, the Centers for Disease Control and Prevention (CDC) investigated and reported 28 multi-state outbreaks of STEC illness. In six of the reported outbreaks, minced beef was among the products involved. Additional outbreaks involved meat products other than minced beef, raw leafy vegetables, sprouted seeds and cheese. All of the minced beef outbreaks were caused by *E. coli* O157:H7 whereas the non-minced beef outbreaks were caused by a variety of *E. coli* serotypes (O157:H7, O121, O26 and O145). In the minced beef-related outbreaks a total of 161 cases were identified (ranging from 11 to 49 cases). There were 105 patient hospitalisations, 11 of whom developed HUS, and two deaths were recorded. In a 2014 outbreak, some of the affected minced beef was used to prepare burgers in a restaurant which had a policy of cooking burgers to a temperature of 145 °F (62.8 °C), which is below the CDC guidance temperature of 160 °F (71 °C) by 15 °F and making a feature of it. In each of the minced beef-based outbreaks there were product recalls. Some of the product recalls affected enormous quantities of product. For example, an outbreak in 2008 resulted in 5.3 million pounds (2.4 million kg) of product being recalled. In 2014, another company recalled 1.8 million pounds (0.8 million kg) of meat contaminated with *E. coli* O157:H7.

Other bacterial pathogens have also caused beef burger-associated outbreaks. For example, the CDC has selectively documented 53 multi-state *Salmonella* outbreaks in recent years with two of these being associated with minced beef. There were 11 cases, 7 hospitalised but no deaths. A 2011 minced beef-associated outbreak was also caused by a *S.* Typhimurium strain which was multidrug resistant. There were 20 cases, of whom 8 were hospitalised, but no deaths were recorded.

CHAPTER 6. CURRENT FSAI COOKING RECOMMENDATIONS FOR BEEF BURGERS

In 1999, the FSAI Scientific Committee recommended that '*caterers should ensure that their cooking procedures result in high risk meat products attaining at least 70 °C for two minutes or equivalent*'. This advice was based on the fact that 70 °C for two minutes achieves a minimum 6 $\log_{10}$ reduction in *Listeria monocytogenes*, which, as previously mentioned, is considered to be the most heat resistant of the vegetative foodborne bacteria (Mackey and Bratchell, 1989). In a 2010 review by the FSAI Scientific Committee, the advice was changed to: '*caterers should ensure that minced meat and high-risk minced meat products are cooked to a core temperature of 75 °C or equivalent, e.g. 70 °C by 2 mins'* (FSAI, 2010), which was a shift of emphasis from the reference time and temperature of 70 °C for two minutes to the equivalent temperature of 75 °C. This was for practical reasons, as it was easier for a caterer to check that the core/thickest part has reached 75 °C than to hold a thermometer to check that it had been at 70 °C for two minutes. The guidance to use 75 °C rather than precisely 75 °C for 26 seconds (i.e. the calculated time at 75 °C equivalent to 70 °C by two minutes) was on the basis that 26 seconds is such a short time that once it had been confirmed that the core temperature was at 75 °C it was reasonable to assume that the process equivalent to 70 °C for two minutes had been achieved.

In 2016, the FSAI asked its Scientific Committee for advice on the most appropriate way to calculate equivalent time and temperature combinations for cooking burgers. While waiting for this scientific opinion, the FSAI revised its factsheet on cooking burgers by removing reference to equivalent time temperature combinations (FSAI, 2017). The factsheet advises consumers to fully cook beef burgers to a core temperature of 75 °C. It also clarifies that any deviation from thorough cooking must be scientifically validated to ensure the production of safe food, and it highlights the fact that scientific validation is complex and requires technical microbiological expertise.

CHAPTER 7. CURRENT RECOMMENDATIONS FOR THE COOKING OF BEEF BURGERS IN OTHER COUNTRIES

The United Kingdom (UK)

The current UK recommendations on the safe cooking of burgers are based on The Food Standards Agency (FSA) Advisory Committee on the Microbiological Safety of Food (ACMSF) recommendations issued in 1997 and revised in 2007. The latter reviewed the advice issued by the Chief Medical Officer (CMO) on the safe cooking of burgers, to determine if the advice given was still appropriate. ACMSF (2007) concluded that the advice of the CMO in 1998 for the safe cooking of burgers should not change: '*Vendors of cooked burgers and other similar minced meat products, for example caterers, have a specific legal obligation to identify and control any process steps that are critical to food safety (Food Safety (General Food Hygiene) Regulations 2005, regulation 4(3)). The thorough cooking of minced meat products, including burgers, to a temperature of 70 °C for two minutes or equivalent, will be one such critical control*.' The ACMSF report (2007) also concluded that:

- The advice for cooking of burgers should remain at 70 °C for two minutes, as it presents a high level of confidence of delivering a widely accepted inactivation standard (6 $\log_{10}$), and ensures a wide safety margin in the face of considerable real-world variation.
- Cooking burgers at 70 °C for two minutes falls in between the 95% and 99% confidence limits for a 6 $\log_{10}$ reduction of *E. coli* O157:H7 cells in minced meat.
- Using the ACMSF equivalent temperature-time parameters (published in 1995), the confidence would increase for temperatures above 70 °C and decrease for those below.
- While it was recognised that an argument could be made for a lower time/temperature combination (e.g. 70 °C for 1.3 minutes, if a 95% confidence of achieving a 6 $\log_{10}$ reduction of *E. coli* O157 was deemed acceptable), the implications of any changes to temperature-time requirements for cooking of burgers would need to be considered more widely, as the 70 °C for two minutes temperature-time recommendation is currently applied to a wide range of foods for a wide range of pathogens.
- Temperature-time equivalents when cooking beef burgers should be set using a *z*-value of 6.0 °C where *E. coli* O157:H7 is the organism of concern, particularly if the intended cooking temperature is below 65 °C.
- A temperature-time combination for cooking of burgers of 70 °C for two minutes (or equivalent) delivers a significant pathogen reduction, which is sufficient to minimise the risks posed by foodborne pathogens such as *E. coli* O157, *Salmonella* and *L. monocytogenes*.

In May 2016, the FSA UK published *The safe production of beef burgers in catering establishments: advice for food business operators and local authority officers* (FSA, 2016). The purpose of that document was to help food business operators (FBOs) and local authority inspectors to understand the controls and systems that should be in place to ensure the safety of beef burgers, including those that will be less than thoroughly cooked. That document states that the service of burgers which are not thoroughly cooked is only acceptable when; [1] there are steps throughout the beef supply chain to minimise and/or reduce the risk of contamination of meat used to make burgers, including a process or processes which achieve a minimum reduction of bacteria of 4 $\log_{10}$ (equivalent to killing 99.99% bacteria) and [2] information is provided that warns consumers of the potential risks from burgers that are not thoroughly cooked.

The FSA also states that '*burgers that are less than thoroughly cooked should not be served to children and there should be information to other potentially vulnerable people about the risks before they order a burger to ensure they can make an informed choice*'.

The United States of America (USA)

In the USA, the cooking of minced beef requirements issued by the US Food and Drug Administration (US FDA, 2013) specify that these products must be cooked to heat all parts of the food to a minimum temperature of 63 °C for 3 minutes, 66 °C for 1 minute, 68 °C for 15 seconds or 70 °C. The recommendation of these temperature-time combinations is based on the application of other control interventions along the beef chain (some of which are not permitted in the EU), to reduce the bacterial load in the meat before cooking.

Thus, the US Department of Agriculture Food Safety Inspection Service (USDA FSIS, 2017) has issued guidance on reducing the risk of STEC and *Salmonella* in beef that includes such activities as: [1] implementing effective sanitary dressing procedures to prevent carcass contamination; [2] implementing effective decontamination and antimicrobial interventions; [3] assessing microbial testing results, including results for indicators of process control, at any point during slaughter; and [4] using the results from the implementation of these components of the food safety systems to assess the effectiveness of the overall Hazard Analysis and Critical Control Point (HACCP) system. The guidance document, for example, gives examples of effective antimicrobial interventions such as hide-on carcass washes, stream vacuum systems, pre-evisceration washing and final carcass organic acid wash, pre-evisceration washing and final carcass hot wash and steam pasteurisation. One such intervention is the application of lactic acid as a part of a HACCP system to reduce pathogenic bacteria on the surface of carcasses, primals and trimmings. The USDA FSIS permits the use of up to 5% lactic acid spray and reductions of 1–3 $\log_{10}$ (between 90% and 99.9%) of *Salmonella* and *E. coli* O157:H7 are claimed by producers of decontamination products. In Europe, Regulation EU No 101/2013 governs the use of lactic acid to reduce microbiological surface contamination on bovine carcasses. The regulation permits the use of between 2% and 5% lactic acid solution in potable water at temperatures up to a maximum of 55 °C to decontaminate carcasses by spraying or misting.

Other countries

The Government of Canada (2015) advises caterers and domestic food preparers to cook minced meat, including beef burgers, to a safe internal temperature of 71 °C. A New Zealand Government report, entitled *Standardising D and z values for cooking raw meat* (05/2016), from the Ministry of Primary Industries suggested extending the recommended cooking time at 70 °C from 2 minutes to 2.4 minutes for inactivation of pathogens in all raw meat products including those with a high fat content (that would enhance the survival of bacteria during cooking). In Australia, the New South Wales Food Safety Authority advice on the cooking temperature in relation to *Hamburger Food Safety* (NSW/FA/F1258/1602) may be summarised as follows: '*In order to reduce the potential for foodborne illness, minced meat should be cooked right through to the centre. No pink should be visible and juices should run clear. Some guidelines suggest cooking hamburgers until the thermometer reads at least 71 °C internal temperature. To ensure your meat is free from harmful bacteria, it is important that a clean and sanitised thermometer is used and placed in the thickest portion of the meat to check the temperature of the food.*'

CHAPTER 8. ASSESSING THE ADEQUACY OF COOKING BY VISUAL INSPECTION ALONE

One of the frequently applied indices of adequate cooking of beef is the colour change from red tissues and pink juices to brown tissues and clear juices. However, such colour changes are not reliable indicators of a beef burger having attained any particular combination of temperature and time. The colour of raw beef is a factor of the state of the molecule myoglobin which functions in life to accept and transport oxygen molecules in muscle tissue. The deep purple colour of freshly cut beef is a reflection of the high content of deoxy-myoglobin present in *post-mortem* muscle tissue. Exposure to air (oxygen) gives a brighter red colour as oxy-myoglobin arises. As raw beef ages, the myoglobin molecule oxidises to become met-myoglobin and its iron ion becomes incapable of binding oxygen and produces a brown colour in aged raw beef. Cooking of any of the states of myoglobin, deoxy-myoglobin, oxy-myoglobin or met-myoglobin produces a haemachrome pigment comprising denatured myoglobin and oxidised haeme, which is also brown in colour. *Post-mortem* muscle chemistry, and the resultant pigment present in muscle tissue, can vary significantly depending on a large range of factors such as, for example, animal handling in the immediate pre-harvest phase, pH, temperature, time *post-mortem*, and packaging atmosphere or additives use in meat processing. A brown colour can therefore arise from beef ageing without adequate cooking. Conversely, a red/pink colour can persist in beef muscle despite cooking in particular scenarios involving high pH typically associated with *ante-mortem* stress, or post-harvest practices such as salt addition or modified atmosphere packaging. Thus, the colour of the beef is not a reliable indicator of sufficient heat application to kill any bacterial pathogens present and temperature-time combinations are the only objective measurement to ensure that beef burgers are properly cooked.

CHAPTER 9. MEASURING TEMPERATURE OF COOKING OF BEEF BURGERS

Burgers (beef patties) tend to be disc-shaped and flat. They are cooked by exposing the largest surfaces to a heat source, e.g. a hot plate, or hot pan with flip-over to cook the other side, or hot oven air permeating all surfaces. Heat is conducted from the heated external surfaces to the centre of the burger. The central part of the burger is, therefore, likely to heat up more slowly and be exposed to the temperatures applied later and for a shorter time than the surface tissues directly exposed to heat during cooking. The various temperature-time combinations described pertain to all components of the burger. Therefore, it should be reasonable to assume for most cooking processes that attaining these temperatures in the central (normally the thickest) parts of the burger will ensure that the entire burger is properly cooked. Surface temperature checks are, therefore, inadequate, and checking the core temperature is necessary.

In brief, temperature probes used in the food industry depend on either thermistor or thermocouple technology. Thermistors are resistor-based devices made of a semiconductor material or a wire coil of a pure metal in which electrical resistance varies with temperature, and thermocouples are based on the voltage generated at the contact point of two different metals, which varies with temperature. Thermistors depend on a temperature change across the length of the conductor and therefore, in a probe format, measure temperature over the probe length. Thermocouples measure temperature at the tip, where the contact point of the two metals is located. Inserting a probe into a beef patty will require active attention to detail in the placement of the probe's temperature sampling point or length to ensure that the reading reflects the core of the burger. Particular attention is required to avoid pushing the probe past the centre of the burger, and therefore measuring the temperature close to the cooking hot plate. It is also important to use a decontaminated probe, in accordance with the manufacturer's instructions.

CHAPTER 10. WHICH z-VALUE (6.0 °C OR 7.5 °C) SHOULD BE USED WHEN CALCULATING 'EQUIVALENT COOKS'?

With regard to advice on the most appropriate z-value (6.0 °C or 7.5 °C) to be used when calculating different temperature-time combinations (equivalent to a core temperature of 70 °C for two minutes), Figure 1 shows the time required at each temperature (from 60 °C to 78 °C) to achieve a reduction in *L. monocytogenes* equivalent to that which would be achieved at 70 °C for two minutes. As expected, at temperatures below 70 °C, using a z-value of 6.0 resulted in longer time requirements whereas at temperatures above 70 °C, the same z-value suggested that shorter times are needed to achieve a cook equivalent to 70 °C for two minutes. However, at temperatures above 70 °C these time differences (between the time predicted using a z-value of 6.0 and 7.5) were small (6.6 seconds at 71 °C, 9.6 seconds at 72 °C, 10 seconds at 73 °C and 9 seconds at 74 °C, etc.) and are of no practical significance. Thus, it was concluded that a z-value of 6.0 was more appropriate as it would require longer cooking times for temperatures below 70 °C and cooking times that were practically the same as those predicted using a z-value of 7.5 °C for temperatures above 70 °C. The predicted temperature-time combinations (using a z-value of 6.0 °C) equivalent to 70 °C for two minutes are shown in Table 8.

Figure 1 The equivalent temperature-time combinations required calculated using z-values of 6.0 °C (based on the ACMSF thermal inactivation of *E. coli* O157 studies) and 7.5 °C (based on the thermal inactivation of *L. monocytogenes*)

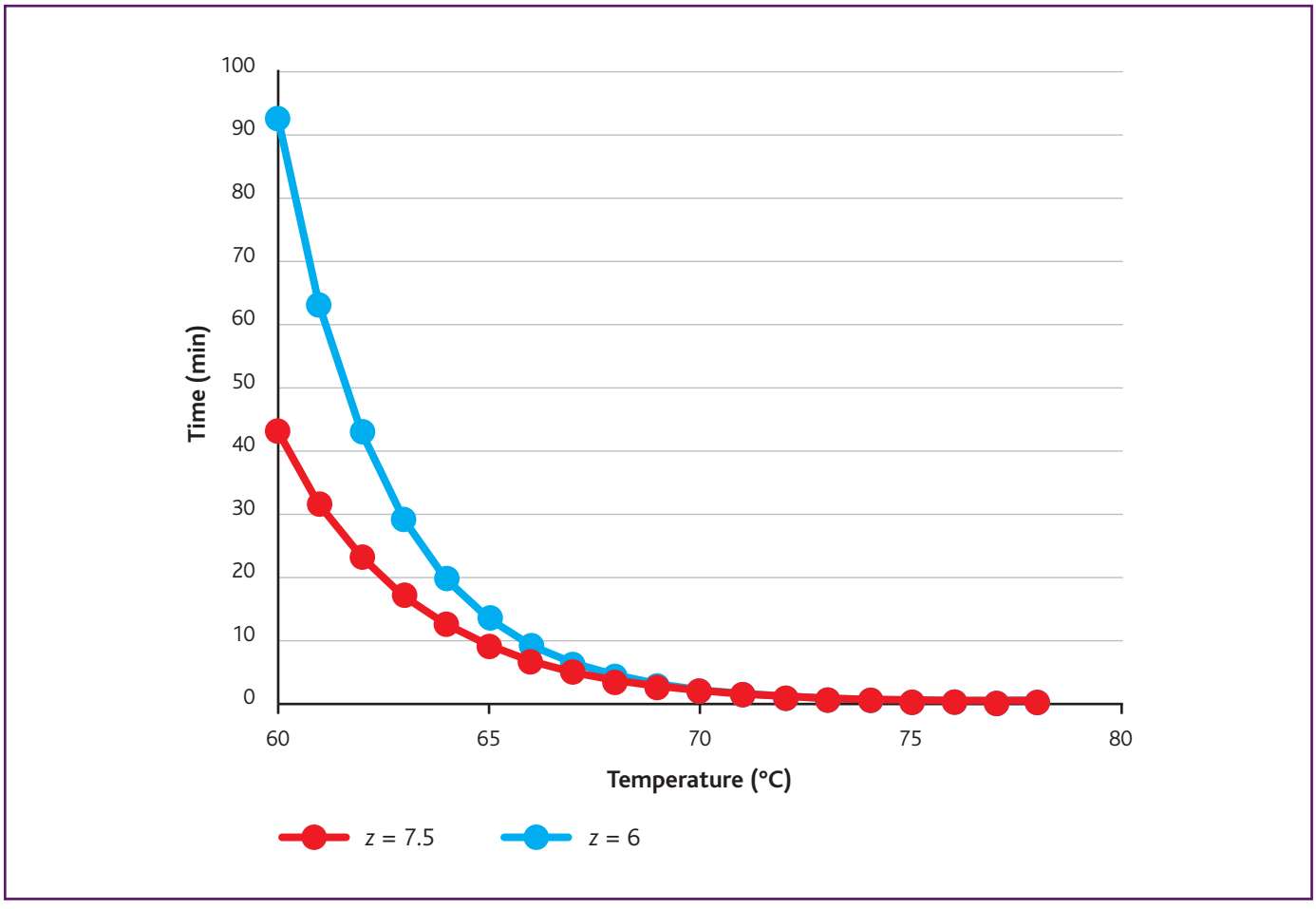

Table 8 The indicative core temperature-time-cooking combinations equivalent to 70 °C for two minutes, using a *z*-value of 6.0 °C

Core temperature (°C)	Time (minutes)	Times (hours, minutes and seconds)
60	92.8	1 hour, 32 minutes, 50 seconds
61	63.2	1 hour, 3 minutes, 15 seconds
62	43.0	43 minutes, 5 seconds
63	29.3	29 minutes, 21 seconds
64	20	20 minutes
65	13.6	13 minutes, 38 seconds
66	9.28	9 minutes, 17 seconds
67	6.32	6 minutes, 19 seconds
68	4.30	4 minutes, 19 seconds
69	2.93	2 minutes, 56 seconds
70	2	2 minutes
71	1.36	1 minute, 22 seconds
72	0.928	56 seconds
73	0.632	38 seconds
74	0.430	26 seconds
75	0.293	18 seconds

CHAPTER 11. RECOMMENDED MINIMUM COOKING TEMPERATURES AND TIMES FOR BEEF BURGERS

The *z*-value of 6.0 °C is appropriate for calculating an equivalent cook only over the range 60 °C for 93 minutes to 75 °C for 18 seconds. If alternative temperature-time combinations to those in Table 8 are proposed, they must first be scientifically validated. This recommendation of not cooking to below 60 °C is based on the following: [1] the 'equivalent cook' equation should only be used within the temperature range for which the model has been validated and [2] at temperatures below 60 °C sub-populations of pathogens such as *E. coli* O157 and *Salmonella* spp. may survive.

It is also highlighted that an effective food safety management system including good hygiene practices (GHPs) and monitoring of cooking temperature is important in assuring the safety of beef burgers. In addition, it is important that the beef raw materials are stored and prepared under correct chilling and hygienic conditions, the absence of which might facilitate an increase in the concentration of *E. coli* O157 or *Salmonella* spp. and therefore an increased probability of some of the pathogens surviving cooking.

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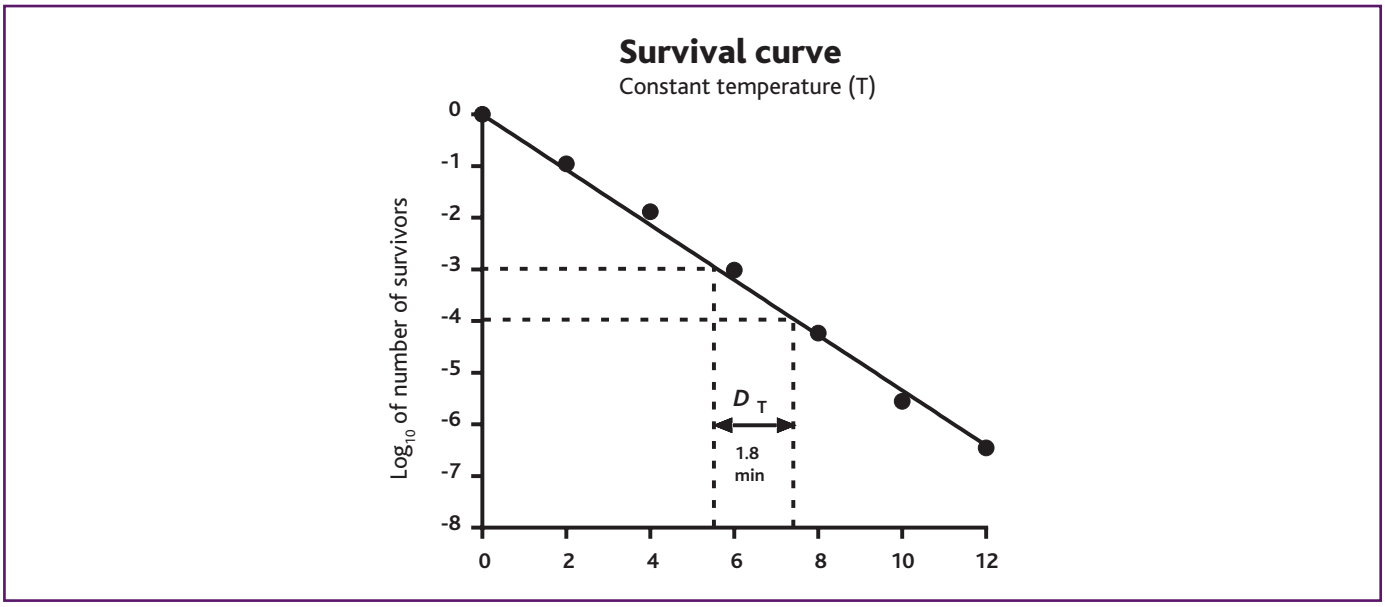
CHAPTER 13. GLOSSARY

Comminuted includes fish or meat products that are reduced in size and restructured or reformulated, such as gefilte fish, gyros, minced (ground) beef, and sausage; and a mixture of two or more types of meat that have been reduced in size and combined, such as sausages made from two or more meats.

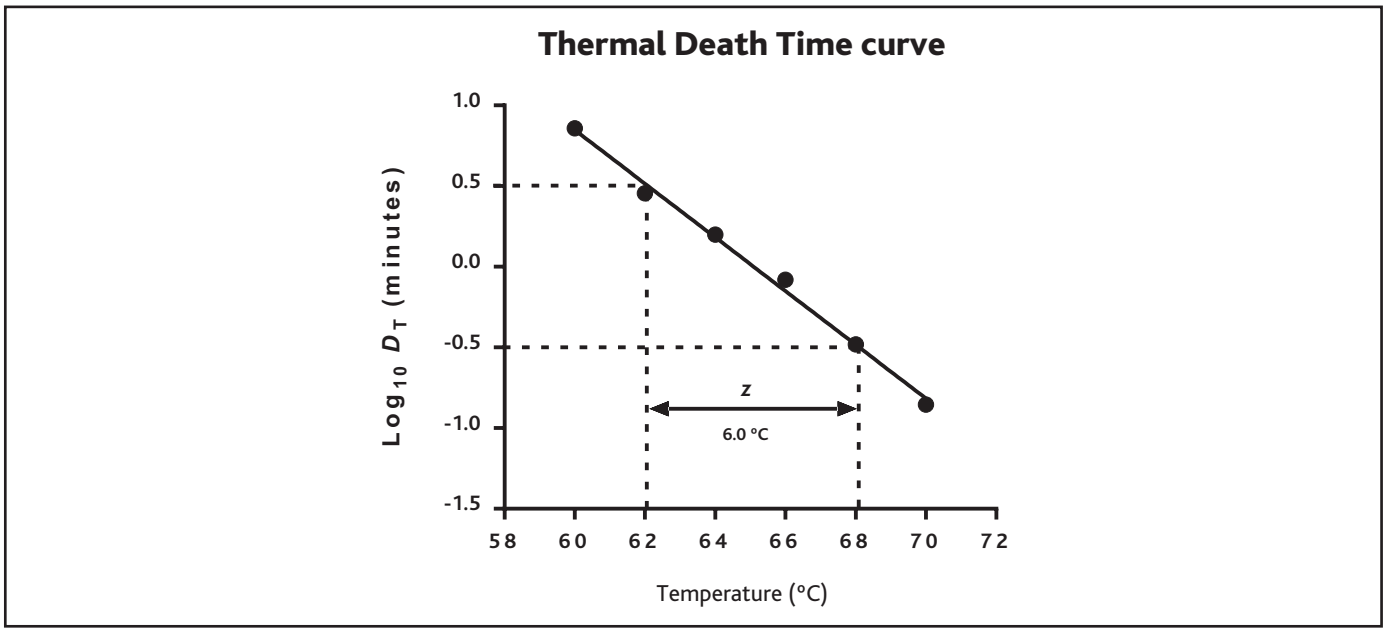
***D_T*-value** of an organism is the time in minutes required in a given medium at a given temperature (T), for a tenfold (1 $\log_{10}$ or 90% of the population) reduction in the number of organisms. If the microbial inactivation follows the traditional first order kinetics, the D_T value, often called decimal reduction time (min), is mathematically the negative inverse of the slope of the regression line of the survival curve at a constant treatment temperature (T). A survival curve is obtained by plotting the $\log_{10}$ number of surviving organisms *versus* the treatment time (min) (Figure 2).

Figure 2 Survival curve of a microbial population exposed to heat at a constant temperature



***z*-value** is the number of degrees Celsius (°C) that the temperature has to change to achieve a tenfold (i.e. 1 $\log_{10}$) change in the D_T-value. The *z*-value is mathematically the negative inverse of the slope of the regression line of the Thermal Death Time Curve. A Thermal Death Time Curve is obtained by plotting the calculated log D_T values (min) versus the corresponding treatment temperatures (T) (Figure 3). Note: Anywhere along the curve represents the same degree of thermal lethality.

Figure 3 Thermal death time curve of a microbial population



Heat shock is the effect of subjecting a population of microorganisms to a temperature high enough for the organisms to stress and synthesise a number of heat shock proteins as a survival mechanism.

Heat shock proteins are a class of stress proteins whose expression is induced by heat shock and a variety of other stresses and that have a protective effect for the cells.

Primals – A primal cut or cut of meat is a piece of meat initially separated from the carcass of an animal during butchering.

CHAPTER 14. ANNEX I

Request for advice from the Scientific Committee

Topic title: Advice on cooking of burgers

Date requested: 30 September 2016

Date accepted: 2 December 2016

Target deadline for advice: Draft with Scientific Committee by 2 December 2017

Form of advice required: A report which addresses the questions posed

Background/Context

The 2010 Scientific Committee *Report on The Prevention of Verocytotoxigenic Escherichia coli (VTEC) Infection: A Shared Responsibility – 2nd Edition* made recommendations regarding the cooking of minced meat and burgers (section 4.6, page 47). It states:

> ***'Caterers should therefore ensure that minced meat and high-risk minced meat products are cooked to a core temperature of 75 °C or equivalent, e.g. 70 °C by 2 mins.'***

The FSAI has recently been asked for examples of equivalent heat treatments, in addition to the example in the 2010 report.

In the past, when advising on equivalent time and temperature combinations, the FSAI has used the data in Table 1 (of FSAI Guidance Note No. 20) which have been calculated using a *z*-value (see Appendix 1) of 7.5 °C (for *Listeria monocytogenes*) with a reference temperature of 70 °C. *L. monocytogenes* is used as it is considered to be the most heat resistant of the vegetative foodborne pathogens. The heat treatment of 70 °C for two minutes has been validated to achieve a 6 $\log_{10}$ (6-D) reduction in *L. monocytogenes*. In Table 1, the time required at 75 °C is 26 seconds. For practical purposes the FSAI advice on thorough cooking is for the core or thickest part of the food to reach 75 °C; since such a short time (26 seconds) at this temperature is required, it is assumed that when 75 °C is reached the process equivalent to 70 °C for two minutes has been achieved. The reason for this approach is that it is easier for a chef or someone cooking at home to check if 75 °C has been reached rather than holding a thermometer to check that the core/thickest part has been at 70 °C for two minutes.

In the case of minced meat and burgers, the pathogens of greatest concern or highest risk would be VTEC/STEC and *Salmonella*, which have different *z*-values than that for *L. monocytogenes* and each other. The systematic review by van Asselt and Zwietering (2006) demonstrates the variability in *z*-values and *D*-values (see Appendix 1) between pathogens and for pathogens within different food matrices.

By way of example of the impact of the chosen *z*-value, the UK ACMSF in their 2007 report on the safe cooking of burgers used a *z*-value of 6 °C based on modelling of heat inactivation data for *E. coli* O157:H7 in the published literature at the time. When the table of equivalence using a *z*-value of 6 °C is compared to a table of equivalence using a *z*-value of 7.5 °C for *L. monocytogenes*, it is noted that at lower cooking temperatures a lower *z*-value results in longer equivalent cooking times (see Table 2).

Table 1 Equivalent heat treatments to achieve a 6 $\log_{10}$ reduction in *L. monocytogenes* based on a *z*-value of 7.5 °C[a] (FSAI Guidance Note No. 20)

Temperature (°C)	Time
60	43.1 min
65	9.3 min
70[b]	2 min
75	26 s[c]
80	5.6 s

(a) Assuming a linear *z*-value = 7.5 °C with a reference temperature of 70 °C. The interaction between foods' intrinsic and extrinsic properties may alter these equivalent lethal rates and as such values must only be used as an indication of the lethal effect of the heat process on *L. monocytogenes*.

(b) Recommended by the FSAI as the reference temperature and time required for a 6-D reduction in numbers of *L. monocytogenes*.

(c) With such short times above the reference temperature of 70 °C, it is assumed that when 75 °C is reached, the equivalent process to 70 °C for two minutes has been achieved.

Table 2 Equivalent heat treatments to achieve a 6 $\log_{10}$ reduction in *E. coli* O157:H7 based on a *z*-value of 6.0 °C (ACMSF 2007)

Temperature (°C)	Time
60	93 min
65	13.6 min
70	2 min
75	18 s
80	3 s

Question for the Scientific Committee

What is the Committee's view on the most appropriate *z*-value to use when calculating equivalent heat treatments to 70 °C by two minutes for cooking minced beef burgers?

References

FSAI (2006) Guidance Note No. 20: *Industrial Processing of Heat-Chill Foods*

FSAI Scientific Committee (2010) *The Prevention of Verocytotoxigenic Escherichia coli (VTEC) Infection: A Shared Responsibility – 2nd Edition*

ACMSF (2007) *Report on the Safe Cooking of Burgers*

van Asselt ED and Zwietering MH (2006) A systematic approach to determine global thermal inactivation parameters for various food pathogens. *Int J Food Microbiol*. 107: 73–82

Appendix 1

- ***D*-value (decimal reduction)** – the time required at a defined temperature to reduce the numbers of microorganisms by 1 $\log_{10}$ value (90% "kill").
- ***z*-value** - the number of degrees the temperature has to change to obtain a 1 $\log_{10}$ change in *D* value, e.g. if an organism had a *D*-value of three minutes at 60 °C, and the *z*-value was 7 °C, then at 67 °C the *D*-value would be 0.3 minutes.

Members of the Working Group on "An Investigation of the Most Appropriate *z*-Value to be used in Calculating 'Equivalent Cooks' for Beef Burgers in Food Business Establishments"

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