ADVISORY COMMITTEE ON THE MICROBIOLOGICAL SAFETY OF FOOD

RARE BURGERS - TIME/TEMPERATURE COMBINATIONS FOR A 4 LOG REDUCTION IN *E.COLI* O157

Introduction

1. At the ACMSF meeting on 30th January the committee was presented an update on the Agency's work on burgers. The committee's views and assistance were sought on two areas, time/temperatures for achieving a 4 log reduction and modelling the impact of interventions in the burger production chain. Work to inform the impact of interventions is addressed in a separate paper (ACM.1222a). This paper concerns the time/temperatures for achieving a 4 log reduction and factors which may influence or impact on achieving this.

Time temperatures combinations for a 4 log reduction

2. As part of the work to develop guidance to the industry and local authority regulators the FSA would like to provide them with information on time/temperature combinations to achieve at least a 4 log reduction in Shiga-toxin producing *Escherichia coli* (STEC) O157 and other bacterial pathogens when cooking burgers. It is important to emphasise that this is intended for commercial operations serving burgers and not for consumers cooking burgers at home or in outdoor settings such as barbecues where existing guidance would still apply.

3. There is an expectation that other interventions/controls would be in place to reduce contamination in the burger sourcing and production chain and the modelling of interventions work is intended to inform this. Where it can be clearly demonstrated that there is appropriate source control to reduce contamination with STEC O157 by 2 logs then there would no longer be a dependency on achieving a 6 log reduction during cooking to deliver a safe burger in catering outlets. There is already long standing FSA advice on the time/temperature combinations for achieving at least a 6 log reduction in foodborne pathogens (Table 1). This was discussed in the ACMSF reports on VTEC (ACMSF 1995), safe cooking of burgers (ACMSF 2007) and more recently in the paper on raw, rare and low temperature cooked foods (ACMSF 2014).

Table 1. Time temperature combinations for achieving at least a 6 log reduction in foodborne pathogens. Source: ACMSF VTEC report (1995).

Temperature	Time
60	45 min
65	10 min
70	2 min
75	30 s
80	6 s

APHA and RIVM work on thermal inactivation

4. In 2014 the FSA commissioned the National Institute for Public Health and the Environment (RIVM) and the Animal and Plant Health Agency (APHA) to apply a thermal inactivation model to assess the risk to human health from consumption of STEC O157 in beef burgers and this work informed the development of the FSA Board paper. The RIVM report provides the predicted times required to achieve inactivation of STEC O157 in burgers of different thicknesses (1cm, 2.5cm, 5cm) and also the time required for the core to reach different temperatures and achieve different log reductions. It is important to emphasize that the work assumed well defined cooking conditions and did not take into account variability which might occur in these practices for example between different establishments.

5. For the 6 log reduction the work showed that the ACMSF guidelines are appropriate for all burger types cooked to a core temperature of 70^{o}C for 2 minutes. For small burgers cooked at 80^{o}C for 6 seconds the study suggests that about 30 seconds may be required. The data also suggests that the guidelines might be over precautionary for the specified time/temperatures below 70^{o}C. The RIVM work (ACM/1204) suggests that to achieve a 4 log reduction, it is possible to cook all burger types for approximately 1 minute at a core temperature of 70^{o}C. It also suggests that a 4 log reduction may be achieved by cooking (under the conditions specified in the research) any of the 3 types of burgers (1cm, 2.5cm, 5cm thickness) for 2.5 minutes at a core temperature of 60^{o}C. However, there were concerns about the complexity of the approach, its wider applicability given that it was based on very specific cooking conditions and the lack of information on uncertainty associated with the estimates provided. It was felt that other approaches should be considered which might include determining time/temperatures based on pre-existing lethality data.

Current ACMSF guidance

6. The current ACMSF guidance was largely based on work done using *Listeria monocytogenes.* It is intended to achieve at least a 6 log reduction in pathogenic bacteria in food and is recognised in the food industry and enforcement sectors. The updated Department of Health Guidelines document on Cook-Chill and Cook-Freeze Catering Systems (1989) stated that "*The time and temperature of the cooking should be sufficient to ensure that heat penetration to the centre of the foodstuffs will result in the destruction of non-sporing pathogens. This is normally achieved when the centre of the food reaches a temperature of 70°C (to ensure the destruction of Listeria monocytogenes the temperature throughout the food should be held at above 70°C for not less than 2 min)*".

7. The work on *Listeria monocytogenes* showed that at 70^{o}C the time required for achieving a 6 log reduction ranged from 0.6-1.2 minutes depending on the type of food present. A time of 2 minutes is more stringent but was intended to account for uncertainties associated with application such as if the food were

contaminated with levels of pathogens exceeding 10^6 per container and probably also the potential for uneven heating of the food. In the case of STEC O157 it seems unlikely that such levels will be present in burgers prior to cooking based on data in literature.

Report on Safe Cooking of Burgers

8. The ACMSF report on cooking of burgers (ACMSF 2007) considered a substantial body of thermal death data to derive predictions for a 6 log reduction of STEC O157. These findings are summarised in Annex A and Figure 1 and demonstrate that the predicted times to achieve a 6 log reduction at specified temperatures were consistently lower than for the values which formed current ACMSF recommendations, particularly if the equivalent temperatures were based on the same z value (6°C). The impact of z value (for definition see Table 2) on the ACMSF recommendations was also highlighted in the committees' paper or raw, rare and lightly cooked foods (ACMSF 2014) which also suggest that a z value of 6°C should be used rather than 7.4°C.

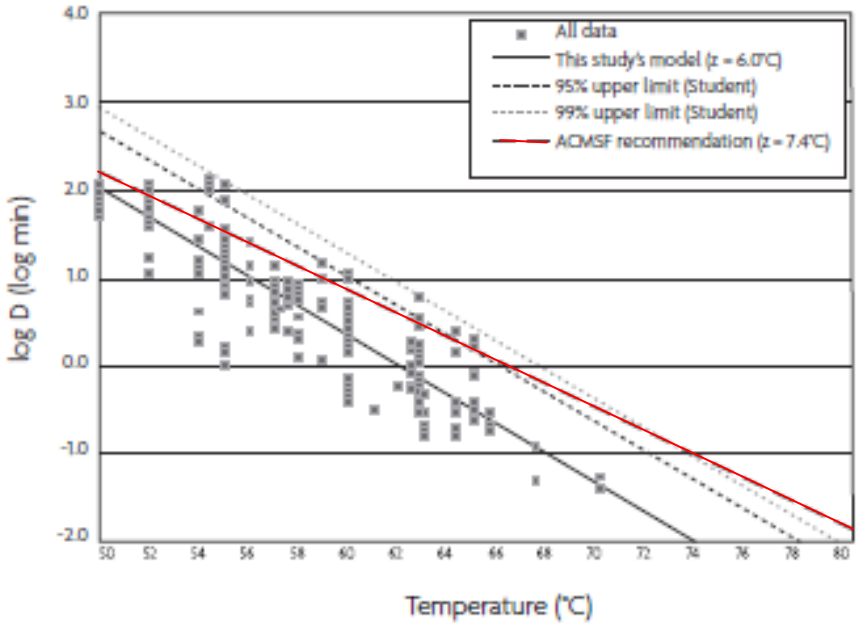


Fig.ure 1 Comparison between the thermal death curve for *E. coli* O157:H7 obtained in this study and the thermal death curve derived from the current ACMSF recommendations for safe cooking of beef burgers.

Source ACMSF (2007)

Other bacteria

9. The original work on which the ACMSF advice was derived was based on work with *Listeria monocytogenes* in various food suspensions (Gaze *et al*. 1989) but there are also a significant number of studies for other pathogens notably *Salmonella*. In burgers the main hazard of concern has been STEC O157 but it is likely that other STEC will also occur. *Salmonella* and *Campylobacter* are also recognised as potential hazards associated with bovine meat. Other

hazards could include commensals carrying antimicrobial drug resistance traits of potential public health concern although current evidence does not point to such strains being more heat resistant than antimicrobial susceptible strains (Duffy *et al*. 2006; Akhatar *et al*. 2016).

10. There appears to be little heat resistance data on STEC other than O157 although a PhD thesis by Valladares (2015) provides data from heat resistance studies using 5 strain cocktails of *E.coli* O157 and non-O157 (O145; 026; O121; O111; O103). There was no significant difference in D-values (for definition see Table 2) between the 2 cocktails at 58 and 60^{o}C whereas at 56^{o}C the D-value of the *E.coli* O157 cocktail was significantly higher. It should also be noted that there are a few reports of *E.coli* strains (not STEC) which appear to be more heat resistant. Dlusskaya *et al.* (2011) reported strains of *E.coli* from a beef processing facility in Canada which had D values at 60^{o}C more than 10 times those in the literature for *E.coli* although it is unclear how common such strains are.

11. A thermal death model for *Listeria monocytogenes* in ground beef in the USDA Pathogen Modelling Programme (PMP) gives D values at 70^{o}C, 65^{o}C and 60^{o}C of 0.22 min, 1.29 min and 8.15 min respectively. D values at 60^{o}C of 0.48-1.75 were observed for *Salmonella* Typhimurium DT104 in ground beef depending on the fat content (Juneja and Eblin 2000). D and z values for a wider range of *Salmonella* serovars in meat were provided by Juneja *et al*. (2001) and Jarvis *et al*. (2016).

Other meats

12. Burgers are also produced using other types of meat for example, lamb, pork and venison and these will vary in the types of hazards which might be present as well as the extent of any contamination. There is less data concerning thermal death of specific pathogens in some of these matrices. Variation in fat levels is one of the considerations as this has been shown to influence the effect of heating on destruction of microorganisms in meat such as burgers (Juneja and Eblin 2000; ACMSF 2007). Gurman *et al.* (2016) in a study which examined the thermal inactivation of 3 strains of *Salmonella* in pork burger patties observed that the fat level in the mince had a significant impact with survival being greater when the pork mince contained higher fat levels.

Existing data

13. Table 2 provides estimated times to achieve a 4 log reduction at different temperatures (55-80^{o}C) for STEC O157. The z values that have been applied in the various studies are different and in the discussions held with the 3 ACMSF members it was suggested that z=6 should be used at temperatures below a reference temperature of 70^{o}C and z=7.4^{o}C for temperatures at 70^{o}C or above. This has been reflected in Table 2 where appropriate. The table shows that there is a wide variation in estimated holding times for STEC O157 particularly at the lower temperatures with the ACMSF recommendations (using different z values) being appreciably longer than for those using the APHA/RIVM report or for the predicted values derived from modelling a large dataset of thermal death data for *E.coli* O157 as presented in the ACMSF report on safe cooking of burgers (ACMSF 2007 – see Annex A).

Table 2. Estimated times (minutes or seconds) to achieve a 4 or 6 log reduction in STEC O157 at different temperatures. The figures are based on applying different z values (z=7.4 or 6) and using different sources of data, the APHA/RIVM study, ACMSF report on cooking of burgers (2007) and ACMSF recommended time temperatures. Estimated times were derived from existing data (Annex 1) or were computed for different temperatures using the model of Mullan (2010).

Parameter(s)	80°C	75°C	70°C	65°C	60°C	55°C
Z value °C	7.4	7.4	7.4	6.0	6.0	6.0
ACMSF (70°C for 2 min) 6 log reduction	6 sec	30 sec	2.0 min	13.7 min	93 min	635 min
ACMSF (70°C for 2 min) 4 log reduction	4 sec	20 sec	1.3 min	9.1 min	62 min	423.3 min
ACMSF (2007) Expected value 4 log reduction	0.26*sec	1.6* sec	0.2* min	1.3 min	8.9 min	60.7 min
ACMSF (2007) 95% Upper limit 4 log reduction	1.1* sec	14.7*sec	0.86* min	5.9 min	40 min	-
ACMSF (2007) 99% Upper limit 4 log reduction	2.2* sec	7.7*sec	1.6* min	11 min	75 min	-
APHA/RIVM (ACM/1204)(z=6.0° C; D 60°C 1.8min) 4 log reduction	0.2* sec	1.4*sec	0.16* min	1.1 min	7.2 min	-

***Z=6°C**

D value - Decimal reduction time (in minutes). The time required, at a given temperature, to reduce the number of viable cells or spores of a given microorganism to 10% of the initial number.

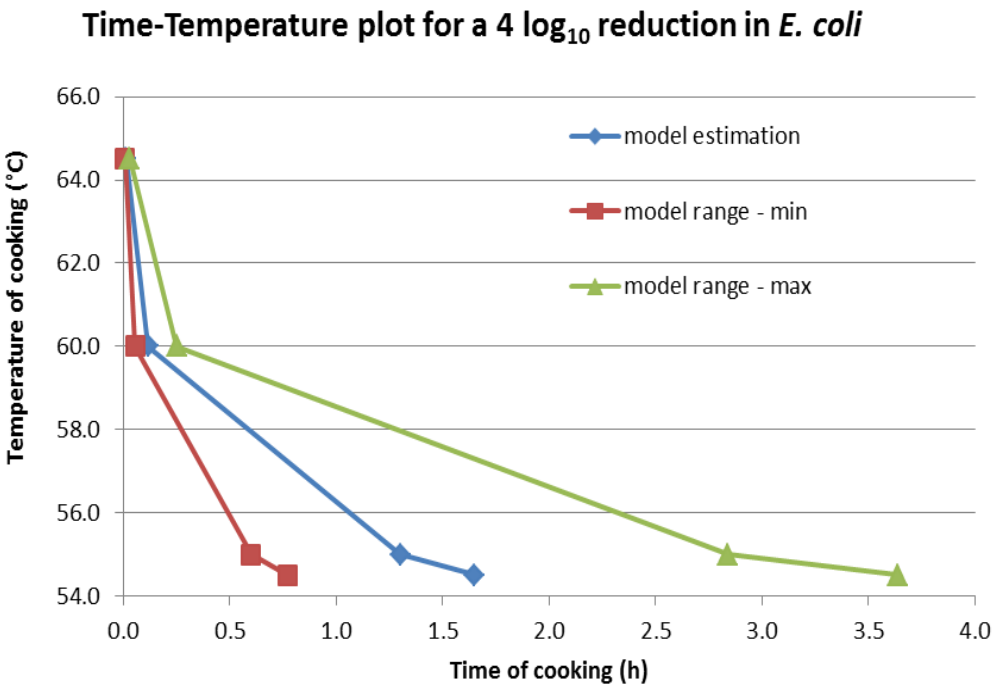
Z value - The increase in temperature (°C) required for a 10-fold decrease in the D value.

Temperatures below 60°C

14. The paper on raw, rare and low temperature cooked foods (ACMSF 2014) noted that more research was required to reliably establish z values which would cover the temperature range between 55 and 60°C if safe temperature/time treatments were needed for such temperatures. This could be a consideration if rare burgers are likely to be cooked to core temperatures in this range. The committee also noted that strain variation, food type and environmental factors could be important at these "lower" temperatures

15. Predicted holding times at 55°C for a 4 log reduction in STEC O157 are considerably longer than for those at 60°C (Table 2). ComBase predictions for thermal death of *E.coli* (not specifically STEC O157) under otherwise ideal conditions (water activity (a_w) 0.992; pH 6.2) suggests that the length of cooking time required for a 4 log reduction would vary between less than a minute at 64.5°C and 1.65 hours at 54.5°C. However, taking uncertainty into account the time required could be as much as 3.64 h at 54.5°C (see Figure 2).

Figure 2. ComBase predictions for thermal death of *E.coli.* Model estimate and range (uncertainty) at 54.5°C, 55.0°C, 60.0°C and 64.5°C.



Practical considerations

16. On the issue of the 4 log reduction, the committee commented at their meeting in January that advice needed to be practical and achievable across the diverse range of operations that might be seeking to serve rare or lightly cooked burgers. This would be in addition to the other measures they would be expected to take into account prior to the cooking step.

17. Cooking conditions are likely to vary based on the type of burger being produced and the formulation including any added ingredients. The key time/temperature should be at the core or thickest part of the burger but temperature variations can also occur. With larger diameter and or thicker burgers there is a possibility that the hottest point may not always be at the exact centre.

18. Ground beef cooking juices and absence of redness in the meat juice and meat are not always reliable indicators for doneness. There is likely to be a perceived trade-off between the desire to serve a rare burger which exhibits a degree of pinkness and the recommended time/temperate for a 4 log reduction at the core of the burger. For example Lyon *et al.* (2000) observed that burgers browned prematurely at 65.6°C, a temperature which would have been insufficient to eliminate foodborne pathogens without appropriate holding times. Suman *et al.* (2016) highlighted factors which can impact on the internal colour of cooked meat including how meat pH and redox potential can affect the thermal stability of myoglobin and resulting colour of ground beef.

Action

19. The Committee is invited to comment on the paper and to provide comments on the following points.

    a) The time/temperature combinations for achieving a 4 log reduction in STEC and other bacterial hazards in burgers.

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    b) At core cooking temperatures below 70^{o}C the predicted holding times to achieve a 4 log reduction in STEC based on the modelled data in ACMSF (2007) are markedly less than those based on existing ACMSF cooking time/temperatures. The ACMSF cooking times fall between the 95% and 99% upper limits for the modelled data.

    c) The risks associated with cooking burgers when the target core holding temperature is below 60^{o}C.

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63. Table 4 shows a comparison between the predicted time/temperature equivalent treatments to obtain a 6-log reduction of *E. coli* O157:H7 cells from this study and the current ACMSF recommendations. The required times at 70°C have been shaded to facilitate visualisation.

Table 4. Equivalent heat treatments for a 6-log reduction of *E. coli* O157:H7 - Comparison between current ACMSF recommendations and predictions obtained in this study based on the fitting of thermal inactivation data published in the literature (n = 234) to Eq. 1.

Temperature (°C)	Time			
	ACMSF recommendations	Predictions from this study		
		Expected value	95% upper limit	99% upper limit
60	45 minutes	13.4 minutes	60 minutes	112.5 minutes
65	10 minutes	1.9 minutes	8.8 minutes	16.5 minutes
70	2 minutes	0.3 minutes	1.3 minutes	2.4 minutes
75	30 seconds	2.4 seconds	11.5 seconds	22 seconds
80	6 seconds	0.4 seconds	1.7 seconds	3.3 seconds

Equivalent temperatures based on a z-value of 6°C

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