ADVISORY COMMITTEE ON THE MICROBIOLOGICAL SAFETY OF FOOD

DRAFT REPORT FROM THE *AD HOC* GROUP ON RAW, RARE AND LOW TEMPERATURE (RRLT) COOKED FOOD

General Introduction

1. The ACMSF considered potential risks to consumers associated with recent changes in cooking and serving practices within commercial and domestic kitchens, including low temperature cooking of foods and the serving of food products in a "raw or rare" state. The ACMSF established an *Ad Hoc* Group to consider these issues in more detail, and to comment on the potential risks associated with the wider application of these processes.

Terms of Reference

2. To assess the microbiological risks to consumers associated with:

   - Use of low temperature cooking
   - Foods of animal origin served raw (excluding fish/seafood)
   - Foods of animal origin served rare (excluding fish/seafood)

   and to identify any gaps in the data that would assist a risk assessment
   Scope: Any sector of food production that uses low temperature/ slow cooking. Any sector of food production that produces raw and/or rare food of animal origin.

Selection of pathogens

3. Relevant zoonotic (bacterial) pathogens include *Salmonella* spp, Verocytotoxin (Shigatoxin) producing *Escherichia coli* (usually referred to as VTEC or STEC), *Listeria monocytogenes* and *Campylobacter* spp. The characteristics of *Clostridium perfringens* mean that this organism should also be considered in relation to RRLT foods.

4. Viruses and protozoa may also pose concerns in relation to RRLT foods, but have been, or are being, considered in detail by other ACMSF groups.

Low Temperature Cooked Foods

Definition of cooking

5. Cooking aims to produce foods where:

   - sensory qualities meet the expectations of consumers
   - microorganisms of concern are eliminated or reduced to an acceptable level (EC 2073/2005).

6. The antibacterial efficacy of any cooking process is dictated by the combination of two factors: treatment time and treatment temperature.

7. Traditional cooking processes use relatively high temperature treatments for relatively short time periods (e.g. 70ºC for 2 minutes) with the aim of reducing the number of potential pathogens in food products to levels that are considered of minimal risk to consumers.

Definition of Inadequate Cooking

8. Inadequate heat treatment in terms of cooking can be defined as foods that are cooked at inappropriate temperatures for a suitable period or cooked at an appropriate temperature for an unsuitable period of time or cooked at an inappropriate temperature for an unsuitable period of time. Such time temperature combinations can fail to reduce pathogens of concern to an acceptable level.

Low temperature cooking

Background

9. There are two dominant methods used for low temperature cooking, slow cookers and water baths. Slow cookers are principally used in domestic cooking and work over a restricted temperature range. Irrespective of the setting, the temperature of the liquid is raised to simmer point ($209^{o}F/98^{o}C$) and then maintained at that temperature. Water baths have recently been increasing in popularity both in restaurants and in the domestic market, where they are predominantly used in the sous vide process.

10. The industry standard cooking (pasteurisation) process is $70^{o}C$ for 2 minutes, which has been shown to provide at least a $\log_{10}$ 6 reduction in *Listeria monocytogenes,* the most heat resistant of the vegetative (non-spore forming) foodborne pathogens of concern within the food industry (Gaze *et al,* 1989). It is particularly important to ensure that the above time/temperature combination is reliably achieved throughout the treated product (i.e. this is not an oven time/temperature or a surface time/temperature, but the time temperature treatment to be achieved in the slowest heating part of the product). The latter is defined in EC 852/2004, Annex II Chapter XI.

11. Within this report low temperature cooking is defined as any process where the maximum temperature attained during the process in the slowest heating part of the product is below 70ºC).

Production of Safe Foods using Low Temperature Cooking

12. A number of reports have considered low temperature cooking, and have been used during subgroup discussions, and in the derivation of some of the conclusions produced within this report, including

    - (1) Safety of Sous Vide Foods: Feasibility of extending COMBASE to describe the growth/survival/death response of bacterial foodborne pathogens between 40ºC and 60ºC. (Stringer *et al* 2012)

    - (2) Sous Vide-food safety precautions for restaurants. New South Wales Food Authority. NSW/FA/CP058/1207. http://www.foodauthority.nsw.gov.au/_Documents/science/sous_vide_food_safey_precautions.pdf (accessed 08/08/2013),

    - (3) Cook-Chill Systems in the Food Service Sector (Revision 1), Food Safety Authority of Ireland Guidance Note 15, 2006. ISBN 1-904465-19-6. http://www.google.co.uk/#bav=on.2,or.r_qf.&fp=e992c6b1fba125de&q=cook+chill+guidance+note+15 (accessed 08/08/2013).

13. Science based discussion of the impact of time/temperature treatments on the survival of bacteria in heated foods frequently involves two key values:

    - D value - the time required at a single defined temperature to reduce the viable (surviving) numbers of particular species or groups of species of microorganisms by 1 log value (90% “kill”).

    - Z value - (a function relating D values across a range of different temperatures). The temperature required to obtain a one log change in D value (e.g. If an organism had a D value of 3 minutes at 60ºC, and the z value was 7Cº, then at 67ºC the D value would be 0.3 minutes).

14. In any cooking process, temperature should be accurately monitored to ensure food safety, using an appropriate calibrated temperature measuring device.

15. There may, on occasions be some misinterpretation about the application of process time and temperature criteria. A number of reports suggest that cooks/processors may misunderstand process time temperature guidance as referring to how long the product is in the cooking device (e.g. waterbath/oven etc.) set at the defined temperature. This is incorrect. Time temperature treatment advice relates to the treatment of the slowest heating part of a product. In most cases this means that the very centre or core of a food portion should attain the defined temperature, and should remain at (or above) that temperature, for the defined time. This approach is essential to ensure that food is correctly heat treated, and that target reductions in microbial numbers are achieved.

16. It may be possible to use heat treatment criteria based on 'time and temperature within a cooking device', but these can only be calculated in relation to the extent that such "indirect" criteria can be reliably related to the above criteria of "core" time and temperature treatments. Indirect criteria can be derived in cooking trials using temperature probes to monitor core temperatures, in parallel with overall measurements of cooking unit treatment times and temperatures (validation of the cooking procedure). Such validation allows indirect monitoring of core temperatures of specific products, and product configurations within specific cooking systems

17. Validation should consider any and all factors that may affect the achievement of the required temperature/time treatment at the food core. These include:

    - portion size (larger or thicker portions will require a longer time for the core to reach the required temperature)
    - the number of portions added to the cooking device at the same time (greater numbers will reduce the initial temperature within the cooking device and will require a longer time for the cores to reach the required temperature)
    - The temperature of the portions before they enter the cooking device (colder portions will require longer times for the cores to reach the required temperature);
    - other product properties which may affect the rates of heat transfer into the food core (e.g. fat content/distribution). (Ahmed *et al*, 1995; Juneja *et al*, 2000; Juneja *et al*, 2001)

18. The addition of cold food will reduce the temperature within cooking devices, slowing achievement of target time/temperature treatments. It is therefore important to ensure that any cooking device, returns to its set temperature sufficiently rapidly after addition of the food (NSW/FA/CP058/1207).

19. **Cooking temperatures**. As noted previously an accepted time and temperature used in the pasteurisation of higher water activity foods (e.g. meats, ready meals, etc) would be a process which achieved the equivalent of 70ºC for 2 minutes at the core of the product. It is possible to calculate process times and temperatures that give an equivalent microbiological reduction to 70ºC for 2 minutes, and these are widely reported e.g. FSA - Safer Food Better Business for Retailers (http://food.gov.uk/multimedia/pdfs/publication/sfbbretfull.pdf . Accessed 12/08/13)

20. **Come Up Time**, defined as the time taken for a product to move from its pre-cook storage temperature up to the target cooking temperature is important, as products are moving through a range of temperatures that support microbial

growth. It is therefore important to limit the time that products are at these “growth temperatures”. The New South Wales Food Authority report (NSW/FA/CP058/1207) includes US Department of Agriculture (USDA) and the US Food and Drug Administration (FDA) guidance on suitable come up times. The USDA mentions that dwell (come up) times in the 10ºC to 54.4ºC range are particularly hazardous, whilst the FDA Food Code is reported to allow a maximum of 4 hours between 5ºC and 57ºC. The NSW guidelines suggest a maximum of 4h between 5ºC and 60ºC. It is clear that long come up times could allow foodborne organisms to remain within a temperature range that allows growth for a period of time and this may increase risks to consumers.
EC regulation 852/2004 on the hygiene of foodstuffs and UK national legislation recognise the need for limited periods outside temperature control to accommodate practicalities of handling during preparation, transport, storage, display and service of food. However any such periods must not result in a risk to health. In low temperature cooking, both during heating up and cooling down, it is possible that foods will be within a temperature range that could allow the growth of foodborne organisms. Consideration should be given to the development of science-based guidance on time limits that foods can safely remain within a temperature range that could allow growth of foodborne microorganisms.

21. Particularly in relation to low temperature cooking processes, it is important to accurately derive and consistently apply effective temperature/time treatments. Z values allow the calculation of equivalently lethal heat treatments, across a range of temperatures. However, it is important to carefully select and apply z values. Thus the calculation of alternative time and temperatures treatments that give an equivalent antimicrobial effect to 70ºC for 2 minutes will depend on the z value used, and the z value depends on the organism or group being considered. In UK literature, a z value of 7.5Cº has been used in FSA publications, whilst the ACMSF Report on the Safe Cooking of Burgers (ACMSF 2007) uses a z value of 6Cº. The variation in z value is due to the organisms being considered with 7.5 being used for vegetative pathogens such as *Listeria monocytogenes* and *Salmonella*, whilst the Safe Cooking of Burgers report specifically considered the heat resistance characteristics of *E. coli* O157. The effect of using different z values can be seen in Table 1 below.

Table 1. The effect of using alternative z values to calculate a cooking time equivalent to 70^{o}C for 2 minutes

Core temp (^{o}C)	Cooking time (mins) for z=7.5^{o}C	Cooking time (mins) for z=6^{o}C*
60	43.48	93
65	9.3	13.6
70	2	2
75	0.43	0.3
80	0.09	0.05

*ACMSF Report on the Safe Cooking of Burgers

22. Table 1 shows that the choice of z value influences the duration of the recommended heat treatment. Both values indicate the requirement for a 2 min cook time at the reference temperature of 70ºC. However, at higher temperatures, the use of a z of 7.5Cº indicates a longer cooking time, whilst at lower temperatures the use of a z of 6Cº indicates a requirement for a longer cook.

23. When calculating equivalent cook times, it is important to use the z value that is relevant to the organism(s) that are the target of the cooking process. Failure to do this may result in inadequate cooking and increased microbiological risks to consumers.

24. Throughout the FSA website, various papers, information and recommendations on alternative cooking times to the 70ºC for 2 minute process, utilise calculations based on a z value of 7.5Cº. It would appear appropriate to continue to use these figures in the future for processes primarily designed to eliminate vegetative pathogens such as *Salmonella* and *Listeria*. However, FSA should consider what they should recommend for processes which are more concerned with the elimination of other organisms.

Cooking at temperatures below 70^{o}C

Cooking temperatures between 60 and 70ºC

25. The current FSA website content indicates cooking time/temperature combinations between 60 and 69ºC which have been calculated to be equivalent to 70ºC for 2 minutes. These involve considerably extended treatment times. For

example, the equivalent treatment time at 60ºC is 45 min. Considerable amounts of data are available within the scientific literature (see list in Appendix 1) to suggest that at cooking temperatures between 60°C and 69°C, accurate, comprehensive, "core" application of appropriate temperature/time treatments equivalent to 70°C for 2 min, does not pose increased microbiological risk. **The FSA website does not present any cooking time/temperature combinations below 60ºC.**

Cooking temperatures between 55ºC and 60ºC

26. Substantial data has been collected on the effects of cooking food between 55 and 60ºC (see Appendix 1). This data would suggest that these temperatures, if applied for long enough, would reduce the numbers of vegetative pathogens to safe levels. However, it is also clear that process calculations based on z values developed for higher temperatures, should not be extrapolated in the determination of process times at these (lower) temperatures (Stringer *et al*, 2012). These authors reported that at lower temperatures, approaching the boundary for heat inactivation, bacterial strain type, the nature of the treated food, and other environmental factors have greater effects in relation to bacterial survival/death. It is clear that more research is required to reliably establish z values (for temperatures) between 55 and 60°C, to enable the derivation and application of safe temperature/time treatments, and reduce potential risks to consumers. Such research should also address the above-noted increased range of variations in bacterial kill rates, associated with strain to strain variation, food type (including issues such as fat levels) and environmental factors.

27. Cooking food at such low temperatures has the potential to introduce another risk to consumers, i.e. that some thermotolerant bacteria may in fact grow at marginal cooking temperatures. ComBase[1] predicts growth of *Clostridium perfringens* at temperatures of up to 52ºC, but the model contains no data at temperatures above this and is therefore unable to make accurate predictions in relation to safe processes. The potential for growth of *C. perfringens* would indicate that heating profiles must move rapidly through this temperature zone, to avoid the risk associated with the growth of this organism.

Use of cooking temperature below 55°C

28. Stringer *et al* (2012) noted that ComBase estimates the maximum growth rate of *C. perfringens* at 52ºC is greater than 1 log unit per hour. Heating a product that may contain *C. perfringens* at temperatures of 52ºC or below, introduces a risk of multiplication of this organism to levels that would constitute a risk to the consumer.

[1] http://www.combase.cc/index.php/en/predictive-models/134-combase-predictor (accessed 13/08/13)

29. There would appear to be little or no data available on the risks of *C. perfringens* growth in food between held between 52 and 55ºC. Bearing in mind the risks associated with such growth it is clear that there are significant risks associated with cooking food products which contain (or may become contaminated with) these bacteria at temperatures between 52 and 55ºC. It is recommended that further research is carried out to gain an effective understanding of the growth potential of *C. perfringens* under such conditions.

Post-cooking

30. After heat treatment low temperature cooked foods should be hygienically managed in the same manner as other cooked products i.e. rapidly cooled to a temperature that minimises risks of any surviving organisms growing, or held hot in accordance with UK temperature control legislation.

31. FSA should consider the inherent conflict between current legislation on 'hot holding' of foods and low temperature cooking, and may wish to consider additional/alternative guidance/legislation to adequately reduce the above-noted dangers associated with holding (cooked or uncooked) foods at temperatures which facilitate rapid growth of persisting or contaminating pathogens.

32. It is possible that low temperature cooking at levels that are equivalent to a 70ºC for 2 min process may produce meat products that still appear pink/red. This would conflict with current advice to consumers about cooking until no pink/red is observable. FSA should consider the need to modify the advice given to consumers.

Sous Vide (Translation from French: under Vacuum) Cooking

33. Sous Vide cooking is a particular type of low temperature cooking process in which food is sealed within a gas impermeable plastic bag, from which most of the air is removed to pull the bag tightly around the food item. The product is then heat treated within a temperature controlled water bath for a specified (relatively long) period of time. The removal of air from the bag ensures good heat transfer to the product from the water and a faster heating up time, while the sealed pack reduces the risks of post cooking recontamination. As sous vide cooking uses low temperatures, it involves a number of the previously noted risks associated with bacterial survival and/or growth. In addition, this method involves storage under low oxygen conditions, which means that Food Standards Agency guidance on the 'safety and shelf-life of vacuum and modified atmosphere packed chilled foods with respect to non-proteolytic *Clostridium botulinum,*[2] should be considered in relation to storage temperature, product shelf life, and safety of these products.

[2] http://www.food.gov.uk/multimedia/pdfs/publication/vacpacguide.pdf. accessed 13/08/2013

Animal products served raw or rare

Outbreak Data

34. An outbreak is defined by PHE as an incident in which two or more people experiencing a similar illness are linked in time or place. Outbreak data was provided by PHE covering incidents linked to inadequate heat treatment/cooking[3] of meat products. The data for 2009-2012 is given in Appendix 2. It covers 66 outbreaks that were reported to have affected 1927 individuals. Table 2 presents the food types and Table 3 the organisms associated with these outbreaks.

Table 2. Outbreak data: food types

Meat Type	Number of incidents reported by PHE between 2009 and 2012
Chicken	37
Beef	12 (note one outbreak was attributed to a mixed meal including Beef & Pork. This is included twice in the table)
Lamb	3
Pork	7 (note one outbreak was attributed to a mixed meal including Beef & Pork. This is included twice in the table)
Goat	1
Duck	4
Venison	1
Composite meals	2

[3]The criteria used for identifying inadequate cooking have been defined by Public Health England (PHE) according to the EFSA manual for reporting foodborne outbreaks (EFSA 2010). An outbreak will be said to be due to inadequate cooking if the inadequate treatment occurred during cooking or reheating of the suspected food item. This is if food is cooked at an inadequate temperature (for example <70^{o}C) and/or for an inadequate period of time or the heat treatment of the core of the food is insufficient to kill pathogenic microorganisms.

Table 3 Outbreak data: associated organisms

Organism	2009	2010	2011	2012
Bacillus cereus	1			1
Campylobacter spp.	6	14	12	5
Clostridium perfringens	2	3	4	2
mixed	1	1		
Salmonella Enteritidis non-PT4	7	1		1
Salmonella Enteritidis PT4	1			1
Salmonella Typhimurium	2	1		
Salmonella spp		1	7	
VTEC O157	2			2
Norovirus		1		
Other	2	1	5	1

36. These PHE data show that
    - chicken products, and *Campylobacter* are the biggest causes of reported outbreaks, with chicken liver products reported as responsible for 30 out of the 37 chicken related outbreaks (note: duck liver parfait/*Campylobacter* caused one outbreak and one chicken liver product was reported to be responsible for a *Salmonella* Typhimurium outbreak) .
    - Over 50% of reported cases occurring between 2009 and 2012 were caused by undercooked poultry liver products. There is a need to ensure that such products are produced in a way that would reduce the risk of pathogenic microorganisms being present in the end product.
    - No outbreaks were associated with steak tartare or beef carpaccio (higher risk raw/rare products). This may be because relatively small amounts of these dishes are consumed, and, as specialist dishes provided by specialist venues, the inherent risks are being more effectively controlled. For example, the latter items are usually prepared from high quality meat from known supply sources, and with greater control over cross contamination risks during storage and preparation of the meats. (Le Blanc, 2010)

Distribution of pathogens

37. Although the external surface of food animal tissues are frequently contaminated with a wide range, and considerable number, of pathogens, the interior of intact mammalian (muscle) meat is generally considered unlikely to contain bacteria, unless the animal has a systemic infection (and such animals are routinely

identified at slaughter and excluded from the human food chain). However, there is some evidence that chicken muscle may be internally contaminated with *Campylobacter* (ACM 1009). If the integrity of food animal muscle is breached during or after slaughter and processing, e.g. by contaminated slaughter equipment (e.g. captive bolts, stick knives, etc) bacterial contamination may be transferred from the (frequently contaminated) meat surface into the deeper tissues (Anon 1998). As well as such accidental introductions, post slaughter treatments such as tenderisation by physical penetration to cut the muscle fibres, or injection of curing solution, marinades etc (Tuntivanich *et al*, 2008) have the potential to introduce contamination into the deeper tissues. Similarly, shotgun pellets may introduce contamination into deeper tissues of game birds. Of perhaps wider significance, at least in terms of the significance in the UK diet, portions of comminuted (chopped/minced, e.g. burgers, sausages) meats are very likely to contain significant number of undesirable bacteria which have been dispersed from the initially contaminated external surface throughout such products during chopping/mincing – which radically changes the risks posed during potential undercooking prior to consumption. More widely, offal of any kind may contain and/or concentrate bacteria, including pathogens (Anon 1998; ACM 1009). The nature and status (intact/comminuted /injected) of meat tissue becomes very important when considering the risks posed by whole cuts of muscle that are cooked well on the outside, but left 'undercooked' in the centre (i.e. whole cuts that are served rare) – in comparison with comminuted meats. The knowledge of the overall risks from whole cuts served rare would be informed by more data on the internal contamination of such products and the effects of pre-cook practices on introducing internal contamination into these products.

Sear and Shave

38. This method of producing rare meat products is currently suggested to reduce microbiological risk for consumers (http://www.westminster.gov.uk /press-releases/2012-12/the-facts-westminster-city-council-is-not-banning/ accessed 15/08/13). In this approach the outside surfaces of whole muscle cuts of meat are briefly heated to a high temperature (seared), while the deeper tissues remain essentially raw (this may be considered to be very rare "cooking"). The seared surfaces are separated from the uncooked inner tissues, which are used to produce raw/rare products. The reported advantage of this method of preparation is that the most heavily microbiologically contaminated part of any whole muscle cut of meat, i.e. the outer surface is not consumed, but the inner parts, considered to contain minimal contamination can be safely consumed. The sear and shave procedure is an attempt to produce a raw/rare product, that has a reduced microbiological risk to the consumer.

39. There are a number of points to consider in relation to sear and shave:

- Whilst the procedure will undoubtedly reduce microbiological numbers on the outside of whole muscle cuts of meat, it will have little effect on any organisms that are internalised. Little information can be collected on the internal contamination of whole muscle cuts. There is some information that would indicate slaughter practice and pre-cook practices such as tenderisation, could introduce contamination into the centre of muscle tissue. More information is required on the internal contamination of whole muscle cuts before the microbiological risks of this procedure can be fully assessed.

- The effectiveness of "sear and shave" is in part very dependent on the hygiene standards achieved during the post sear dissection of the seared surfaces. Removal of seared areas would need to be carried out very carefully under strictly controlled conditions using clean/sterilised knives/boards/ surfaces/equipment, with effective means of preventing cross-contamination of the shaved meat. As an "effectively raw" product, shaved meat should be considered a ready-to-eat product and handled accordingly at all stages of further processing and service. The "raw" nature of this product means that any use of a sear and shave approach would require careful control and some guidance to users on the correct approaches to minimise post shave cross-contamination to help reduce risks from this procedure. We recommend research is needed to establish if this procedure can reliably produce a safe product, and if so to define the appropriate controls/guidance that need to be put in place.

Raw meat dishes

40. Raw meat products are commonly seen in the cuisine of many nationalities and there is good evidence to show that many 'ethnic' food business operators within the UK serve such raw products.

41. Bearing in mind the levels of contamination of many raw retail meats, and the readiness with which such products may support and disseminate a number of significant agents of human food borne illness, it is surprising that the available PHE outbreak data does not provide any evidence that raw meat containing dishes have caused outbreaks in the UK. Reasons why this is so may include the following hypotheses:
    - Cases of food poisoning do occur, but have never been reported or reliably traced back to raw meat products.
    - In overall population terms, the amounts of such food consumed are very low, and significant health issues are therefore never identified

- Those processing or providing such dishes have sufficient expertise, and this expertise leads them to follow appropriate risk reduction strategies (good quality raw materials, inherent knowledge of hygienic preparation/storage and serving practices).

If the last point is considered important, then any expansion of the production and/ or wider consumption of such raw meat containing products may lead to use of inexperienced staff and poorer practices and therefore increased risk in naïve populations.

42. Compared to fully cooked meats, there will always be a higher risk that raw meat will be contaminated with viable pathogens irrespective of the kind of meat, its source or the format in which it is served.

43. Whilst raw meats are being served in restaurants within the UK and outbreak data indicates would indicate they have caused no problems, this is likely to be due to the small amounts consumed and/or the expertise of individual kitchens producing these items.

<u>Burgers and other comminuted products</u>

44. The advice in the ACMSF report on the safe cooking of burgers (ACMSF 2007) is still valid. However, a number of developments in relation to the nature and production of these products have raised a number of concerns in more recent times.

45. The ACMSF report dealt with burgers made from beef, whereas burgers now include a variety of other meats. It is assumed that these are still being consumed in much smaller numbers than beef based burgers. However, as most meats fall within the overall meat hygiene regulations, it is considered that meat species is unlikely to significantly influence the risks faced by a consumer consuming an individual burger.

46. The ACMSF report only considers the risk from VTEC, as the most pressing challenge in burgers at that time. Given the variety of meats that is now used to produce the current diverse range of burger/comminuted products, other vegetative pathogens may now be equally or perhaps more significant in the overall population. Even so, the advice provided within the above remains relevant, and should form a key element in the derivation of FSA advice in this area.

Rare Cooked Burgers

47. The other, perhaps more significant change in relation to burger production and consumption since that report was issued, relates to the current trend whereby some food businesses are increasingly offering burgers cooked rare.

48. The conclusions of the previous ACMSF report on the safe cooking of burgers apply equally to rare burgers, i.e. in line with the advice from the CMO to cook burgers at a temperature of 70^{o}C for 2 min or equivalent (using a z value of 6^{o}C) The importance of ensuring adequate time/temperature of the core of burger products may in fact be of even more importance now, than at the time of issue of the ACMSF report. This is related to the increasing trend to produce and serve "gourmet" burgers which are not only rare – but also much thicker than traditional burgers, posing great risks in relation to surface to core temperature treatments, as previously described.

49. The use of a sear and shave approach in preparing burgers has been considered – i.e. preparing burgers by mincing a piece of meat remaining after searing and shaving of an intact cut of meat (see paragraphs 38-39) and cooking the mince patty to form a rare burger. Whilst this approach may reduce the considerable risks associated with the external microbiological contamination of the raw whole meat, it does carry the same risks and uncertainties noted in the section on sear and shave, and poses additional challenges in relation to hygienic mincing and hygienic further processing of the rare meat. Additional concerns remain in relation to any meats which may be more likely to contain parasites within muscle tissue, as such parasites (normally killed during adequate cooking) will remain viable during the "sear, shave and serve rare" process, and infect consumers. Bearing in mind the challenges in the establishment and consistent application of the very high standards required to ensure the safety of such products, additional work would be required to understand and adequately control the risks associated with sear, shave and serve rare burgers.

50. In reviewing the area of low temperature cooking, it is apparent that there are cooking procedures (i.e. equivalent to a 70ºC for 2 min process) available that can result in meat that still appears pink/red. While such procedures can produce a safe, pink burger, there are considerable dangers associated with a general move away from the established advice of "cook until there are no pink bits". Such a move may lead to consumer confusion and wider consumption of "unsafe" pink burgers in the absence of a clear understanding among producers and consumers of the continuing risks of serving or consuming raw and undercooked meat. As such procedures would be dependent on the exact product specifications (size/thickness/fat content/raw material quality/ other

ingredients etc.), it would be up to producers to demonstrate that such products were safe to eat, and that they can develop, validate and consistently apply the more complex systems necessary to consistently present safe raw, rare and low temperature cooked foods in commercial and domestic kitchens.

Recommendations

51. Consideration should be given to science-based guidance on time limits that foods can safely remain within a temperature range that could allow growth of foodborne microorganisms.

52. Throughout the FSA website, various papers, information and recommendations on alternative cooking times to the 70ºC for 2 min process, utilise calculations based on a z value of 7.5^{o}C. It would appear appropriate to continue to use these figures in the future for processes primarily designed to eliminate vegetative pathogens such as *Salmonella* and *Listeria monocytogenes*. However, FSA should consider what they should recommend for processes which are more concerned with the elimination of other organisms.

53. More research is required to reliably establish z values (for temperatures) between 55 and 60^{o}C, to enable the derivation and application of safe temperature/time treatments, and reduce potential risks to consumers. Such research should also address the above-noted increased variations in killing bacteria, associated with strain to strain variation, food type (including issues such as fat levels) and environmental factors.

54. Further research should be carried out to gain an effective understanding of the growth potential of *Clostridium perfringens* between 52^{o}C and 55^{o}C.

55. FSA should consider the inherent conflict between current legislation and low temperature cooking, and may wish to consider additional/alternative guidance/legislation to adequately reduce the above-noted dangers associated with holding (cooked or uncooked) foods at temperatures which facilitate rapid growth of persisting or contaminating pathogens.

56. It is possible that low temperature cooking at levels that are equivalent to a 70^{o}C/2min process, may produce meat products that still appear pink/red. This would conflict with current advice to consumers on cooking until no pink/red is observable. FSA should consider the need to modify its advice to consumers.

57. The knowledge of the overall risks from whole cuts served rare would be informed by more data on the internal contamination of such products and pre-cook practices on introducing internal contamination into these products.

Appendix 1

Selected references on heat inactivation of food pathogens

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Appendix 2

Outbreak data attributed to the inadequate heating of meat

Year	Pathogen	food vehicle description	No. of people affected	Details
2009	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	5	DELIBERATELY UNDERCOOKED TO BE PINK IN MIDDLE
2009	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	3	
2009	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	5	EHO REPORTED THE PATE WAS SERVED UNDERCOOKED
2009	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	26	
2009	CAMPYLOBACTER SPP.	DUCK - LIVER PARFAIT	2	DELIBERATELY UNDERCOOKED. BAIN MARIE IMPROPERLY USED
2009	CLOSTRIDIUM PERFRINGENS	BEEF - ROAST JOINT	28	GRAVY FROM MEAL SAVED AND EATEN WITHOUT COOKING
2009	MIXED	BEEF - LIVER	11	RAW MEAT DELIBERATELY CONSUMED
2009	SALMONELLA ENTERITIDIS NON-PT4	CHICKEN - NOODLES	13	
2009	SALMONELLA ENTERITIDIS NON-PT4	CHICKEN	160	
2009	SALMONELLA TYPHIMURIUM	CHICKEN - LIVER PATE	59	
2009	SALMONELLA TYPHIMURIUM	PORK - HOG ROAST	12	
2009	CLOSTRIDIUM PERFRINGENS	CHICKEN - JEERA CHICKEN	93	REHEATING OF FOOD INADEQAUTE
2009	VTEC O157	BEEF - BURGER	2	FOOD NOT COOKED THROUGHOUT
2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	15	
2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	36	INADEQUATE COOKING OR USE OF THERMOMIX APPLIANCE
2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	34	DELIBERATE INADEQUATE COOKING LEAVING PATE MEAT INTENTIONALLY PINK
2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	6	DELIBERATE INADEQUATE COOKING OF CHICKEN LIVERS. CORE TEMPERATURE IN 56-63°C RANGE DURING COOKING
2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	26	
2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	4	PATE PINK BUT APPARENTLY HEATED TO 80C
2010	CAMPYLOBACTER SPP.	CHICKEN - THIGH	19	
2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	17	TEMPERATURE CONTROL OF FOIE GRAS INADEQUATE
2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	9	
2010	CAMPYLOBACTER SPP.	BEEF BURGERS + SAUSAGES	21	
2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	2	INADEQUATE COOKING TEMPERATURE FOR A SHORT PERIOD
2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	8	CHEF COPIED A FAULTY RECIPE WHICH WAS TAKEN FROM A BBC WEBSITE. THE RECIPE HAS BEEN AMENDED SINCE THE OUTBREAK

2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	6	DELIBERATE INADEQUATE COOKING - PATE COOKED AT 65°C FOR ONLY 5 MINUTES INSTEAD OF THE REQUIRED 10 MINUTES
2010	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	13	DELIBERATE INADEQUATE COOKING OF CHICKEN LIVERS - CORE TEMPERATURE OF 50˚C INSTEAD OF REQUIRED 70˚C
2010	CLOSTRIDIUM PERFRINGENS	GOAT - CURRY	5	
2010	CLOSTRIDIUM PERFRINGENS	BEEF - CARVERY	23	INADEQUATE COOKING OF MEAT SERVED AT MEAT CARVERY
2010	CLOSTRIDIUM PERFRINGENS	BEEF - ROAST	25	ROAST BEEF WAS BONED AND ROLLED AND NOT COOKED ALL THE WAY THROUGH, BLOOD IN JUICES
2010	NOROVIRUS	BEEF	26	INADEQUATE COOKING TIME FOR THE SIZE AND TYPE OF JOINT OF RIB BEEF/BEEF TOO BLOODY
2010	NOT KNOWN	CHICKEN	9	FOOD SUPPLIED COOKED, THEN COOLED AND REHEATED
2010	SUSPECT BACTERIAL	LAMB - CURRY	40	FOOD FROM CATERING COMPANY WAS REHEATED ON SITE AND SERVED - TEMPERATURE WAS NOT COMPLIANT WITH TEMPERATURE REQUIREMENTS
2011	OTHER	CHINESE - MIXED MEAL	22	
2011	CLOSTRIDIUM PERFRINGENS	INDIAN - BUFFET MEAL	4	
2011	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	29	DOCUMENTED CORE TEMPERATURE FOR CHICKEN LIVER PARFAIT AT END OF COOKING PROCESS WAS 61 C
2011	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	23	LACK OF PROPER DOCUMENTED PROCESS
2011	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	23	PROBABLY INADEQUATE COOKING OF CHICKEN LIVERS
2011	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	9	UNDERCOOKED CHICKEN LIVER PARFAIT. NO HOT FOOD PROBED TO ENSURE ADEQUECY OF COOKING PROCESS.
2011	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	46	
2011	CAMPYLOBACTER SPP.	DUCK - LIVER PATE	18	
2011	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	13	POSSIBLE, HOWEVER EHO REVIEWED PROCESSES AND NO PROBLEMS IDENTIFIED, TEMPERATURE RECORDS KEPT
2011	CAMPYLOBACTER SPP.	CHICKEN - LIVER PARFAIT	26	
2011	CAMPYLOBACTER SPP.	DUCK - LIVER PATE	97	
2011	CAMPYLOBACTER SPP.	CHICKEN - LIVER PATE	263	TEMERATURE RECORDS NOT COMPLETE. PATE PINK + SLOPPY.
2011	CLOSTRIDIUM PERFRINGENS	CHICKEN - CURRY	8	
2011	OTHER	CHICKEN - VARIOUS CHICKEN DISHES	12	FOOD PROCURRED PRIOR TO TRIP AND INADEQUATELY STORED AND PREPARED
2011	SALMONELLA SPP.	DUCK - CRISPY DUCK	101	
2011	CLOSTRIDIUM PERFRINGENS	LAMB - MIXED GRILL	12	
2011	CLOSTRIDIUM PERFRINGENS	BEEF - STEW	34	FOOD WAS COOKED, LEFT OVERNIGHT, REHEATED AND SERVED

2011	SALMONELLA SPP.	PORK - HOG ROAST	40	FARMER WHO RAN THE HOG ROAST PUT HEAD ON TRAY UNDERNEATH ROASTER AND WITH HINDSIGHT DOESN'T BELIEVE IT WAS COOKED PROPERLY AND NOT HOT ENOUGH UNDER ROASTER.
2011	SALMONELLA SPP.	PORK - HOG ROAST	14	NO RECORD OF FINAL COOKING TEMPERATURE TAKEN. NO MANUFACTURER'S INSTRUCTIONS AVAILABLE TO THOSE USING THE MACHINE AND STAFF UNAWARFE OF ITS 50 KG WEIGHT LIMIT
2011	SALMONELLA SPP.	PORK - HOG ROAST	18	EVIDENCE THAT TEMPERATURE PROBES USED NOT SUFFICIENT TO REACH DEEP MUSCLE OF HOG ROAST
2011	SALMONELLA SPP.	PORK - VARIOUS	10	
2011	OTHER	VARIOUS VENISON DISHES	41	
2012	CAMPYLOBACTER	LAMB SHOULDER WITH LAMB LIVER	2	
2012	CAMPYLOBACTER	CHICKEN LIVER	3	
2012	CLOSTRIDIUM PERFRINGENS	ROAST PORK JOINT	6	
2012	CLOSTRIDIUM PERFRINGENS	ROAST BEEF AND ROAST PORK	18	INADEQUATE REHEATING/REGENERATION
2012	CAMPYLOBACTER JEJUNI	CHICKEN LIVER	5	
2012	CAMPYLOBACTER	CHICKEN LIVER PARFAIT	4	
2012	CAMPYLOBACTER	CHICKEN LIVER PATE AND CARVERY CHICKEN	39	
2012	VTEC O157	BEEF BURGERS	10	POSSIBLE CONTRIBUTING FACTOR
2012	VTEC O157	BEEF BURGERS	2	BURGER SERVED UNCOOKED
2012	BACILLUS CEREUS	MINCE BEEF	200	

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