

CHAPTER 7

MEASURES TO PREVENT *CAMPYLOBACTER* CONTAMINATION OF MEAT OTHER THAN CHICKEN AND OTHER POULTRY MEAT

Introduction

7.1 As noted in Chapter 3, while poultry meat is an important source of human *Campylobacter* infection, many studies point to numerous other sources and vehicles of infection.

Campylobacter levels in animals

7.2 *Campylobacter* spp. frequently occur in the gut flora and faeces of animals used for food production such as cattle, pigs and sheep. Information on the proportion of these animals carrying the organism is not extensive and what there is must be treated with some caution as a variety of methods and sampling regimes are likely to have been used. However, it is clear that rates can be high, in some cases as high as those reported for chickens. One source of information is the annual European Commission Report on Trends and Sources of Zoonotic Agents in the European Union and Norway.²⁴⁷ While information on carriage rates of *Campylobacter* is limited, a handful of European countries has provided data indicating carriage rates ranging from 0.4-72.4% in cattle, from 45.3-94.5% in pigs, and from 13-24.8% in sheep and lamb. The levels between countries, and indeed within countries when different years are compared, vary significantly.

7.3 Information on faecal carriage rates in the UK can be found in the annual Zoonoses Report published by Defra. The 2000 report²⁴⁸ gives the results of a survey of cattle, sheep and pig faeces in Great Britain, carried out in 1999/2000. This found :-

- 94.5% of 860 pigs positive for *Campylobacter*, the predominant species being *Campylobacter coli* (84%);
- 24.5% of 891 cattle positive for *Campylobacter*, with *C. coli*, *Campylobacter jejuni* and *Campylobacter lari* accounting for more than half the positives;
- 17% of 973 sheep positive for *Campylobacter*, *C. jejuni*, *C. coli* and *C. lari* accounting for over 90% of positives.

- 7.4 The results outlined above provide a baseline against which to measure any changes in prevalence and types of *Campylobacter* when similar surveys are carried out in the future. We are aware that Defra, in association with other Government Departments, is in the process of repeating this survey. We welcome this. It is important that up-to-date information on carriage rates in food animals is maintained.

***Campylobacter* levels in meat**

- 7.5 Leaving aside chickens and other poultry, although it is clear that there can be high gut and faecal carriage rates in animals, the available information indicates that these often do not carry through to the associated meats on retail sale. However, the data are very variable and high figures have been reported for some products. For example, 23.6% of 127 samples of beef meat were positive for *Campylobacter* in a 1989 UK survey.²⁴⁹ A further UK study²⁵⁰ has reported contamination rates of 72.9 and 71.7% respectively in lambs' and pigs' liver. Data from other surveys carried out in the UK and the USA show *C. jejuni* and *C. coli* in a variety of retail meats ranging from 0 to 18.4%.²⁴⁹ A study of campylobacters in, *inter alia*, samples of food on retail sale in the Reading area of the UK produced *Campylobacter* positives in a variety of meats sampled, ranging from 2.3 to 47%.²⁵¹ In Belgium, sampling of retail cuts of pork over the period 1997-1999 produced prevalence rates of between 2.6 and 12.5% of samples. In a Belgian survey of retail beef in 1997, 5% of samples were *Campylobacter*-positive.²⁴⁷ A US study²⁴⁵ reported low levels of contamination in pork (1.7%) and beef (0.5%). The ACMSF *Campylobacter* Working Group was provided with data from surveys, carried out by a leading UK multiple food retailer, of *Campylobacter* in the company's raw meat products on retail sale. No *Campylobacter* was found in 147 samples of fresh retail cuts of beef (53 samples), lamb (69) and pork (25) in February 2002. Nor was *Campylobacter* detected in 56 samples of fresh and frozen retail minced/reformed beef (41, of which 12 frozen), lamb (3, all fresh) and pork (12, all frozen) in March 2002. Finally, *Campylobacter* was also absent from 102 samples of fresh retail whole cuts of beef (39), lamb (36, of which 6 frozen) and pork (27) in September 2002.
- 7.6 Given the variations noted in the prevalence of *Campylobacter* in retail meat samples, it is very difficult to form any meaningful view on the risk to public health in the UK from such products. What is required is large-scale, structured surveillance of *Campylobacter* in red meat on retail sale.

Control of *Campylobacter*

- 7.7 The fact that the high carriage rates in red meat animals prior to slaughter does not always carry through to the final product is not perhaps surprising. Compared to poultry, there are significant differences in the way that animals such as cattle, pigs and sheep are reared, transported and slaughtered. There are control measures in

place which minimise faecal contamination of hides and fleeces, and hence *Campylobacter* contamination of carcasses during dehiding and evisceration. That said, in comparison to other enteric organisms, *Campylobacter* is rarely found on carcasses. Although this is thought to be due to the surface conditions, it is possible that isolation methods used in studies are not optimal. We note that the Food Standards Agency (FSA) is investigating this question.

7.8 Implementation of control measures in the UK is the responsibility of the Meat Hygiene Service (MHS) in Great Britain and the Department of Agriculture and Rural Development in Northern Ireland (NIDARD). MHS and NIDARD are responsible for ensuring that operators fulfil their duty to have appropriate hygiene controls in place at licensed slaughterhouses, cutting plants and cold stores handling red meat. Control measures comprise four main stages :-

- *ante mortem* inspection of animals;
- checking on maintenance by the operator of hygienic process control throughout all stages of slaughter and processing;
- *post mortem* inspection of carcasses; and
- health marking.

Each of these stages plays an important role in minimising the risk to public health from pathogens such as *Campylobacter*.

***Ante mortem* control in cattle and sheep**

7.9 In respect of *ante mortem* controls for cattle and sheep, a major advance in improving meat hygiene was the introduction in 1997 of the MHS Clean Livestock Policy (CLP).¹ The background to this was the recognition that, if the hide or fleece was contaminated with dung or dirt at the time of slaughter, there was a very real risk of the meat becoming contaminated with harmful bacteria. Even the highest standards of abattoir hygiene cannot be guaranteed to prevent contamination of the carcass and cross-contamination of nearby carcasses. Research results have shown that the dirtier the hide, the greater the potential for carcass contamination and the higher the human health risk. Wet hides and fleeces also increase the risk.

7.10 The CLP provides a cleanliness classification system which places animals presented by the operator for slaughter into one of five categories. Animals in categories 1 and 2, ie. those considered to be

¹ The CLP does not apply to pigs and there are no categories of cleanliness. However, under the Fresh Meat (Hygiene and Inspection) Regulations 1995, an MHS Official Veterinary Surgeon may require the detention in a lairage, or prohibit the slaughter, of any animal which is so dirty it would be likely to prevent hygienic dressing operations if taken into a slaughterhouse.

clean and dry, can be slaughtered for human consumption. Animals in categories 3 and 4 may only be slaughtered for human consumption after the animal has received special attention (eg. clipping or being allowed to dry in overnight lairage). Alternatively, other measures such as slowing the line speed to enable hygienic slaughter may be appropriate. Animals in category 5 are unsuitable for slaughter for human consumption. Such animals are killed separately and disposed of as an animal by-product. The CLP is operated by MHS and NIDARD staff who are able to reject for slaughter any animal that does not meet the required standards of cleanliness.

7.11 At the time the CLP scheme was launched, research was put in place to study the factors involved in producing cattle that were both visibly and microbiologically clean. The output from this work was the launch by the FSA in 2003 of an initiative on Clean Cattle and Meat Safety.²⁵² This initiative, which was produced in consultation with stakeholders, highlights 10 key messages for producing clean cattle. These are disseminated via promotional literature and a series of events aiming to provide advice to farmers, livestock hauliers, veterinarians, abattoir managers, butchers and retailers.

Hygiene control during slaughter

7.12 Compliance with hygiene legislation is the responsibility of plant operators. However, MHS and NIDARD staff work with plant operators to ensure that hygiene controls to minimise the risk of cross-contamination are maintained throughout the slaughter process. Specifically, the MHS and NIDARD enforce legislative requirements aimed at making sure that premises operate to recognised hygiene standards. Failure to meet these requirements may result in enforcement action against premises, and this could ultimately lead to prosecution and suspension and/or revocation of their licence to operate.

Hazard Analysis Critical Control Point (HACCP)

7.13 The ACMSF is a strong supporter of HACCP and we championed its cause in our Report on Poultry Meat.¹⁷¹ One of the major changes in relation to hygiene in red meat plants was the introduction of The Meat (Hazard Analysis and Critical Control Point) Regulations 2002,²⁵³ which require operators to put in place hygiene procedures based on HACCP principles and to undertake microbiological checks. To aid plants in introducing HACCP, the FSA has produced a range of materials, including :-

- HACCP guidelines²⁵² – a booklet explaining what the seven principles of HACCP are and how the legal requirements can be complied with in general terms;

- Meat Plant HACCP Manual²⁵² – produced with the benefit of feedback from pilot plants, this manual has been sent to all operators and their Official Veterinary Surgeons (OVSS);
- a CD-ROM version of the manual containing extra material including video clips, sample documentation and some model HACCP plans.²⁵²
- newsletters – a number have been issued, providing advice and information on implementation of the Regulations.²⁵²

Microbiological testing

7.14 The Meat (HACCP) Regulations 2002²⁵³ also introduce a requirement for microbiological testing in red meat plants, with the need to undertake both carcass tests (for Aerobic Colony Counts and Enterobacteriaceae) and surface tests (for Aerobic Colony Counts). The purpose of this testing is very much to look for trends, with plants using the results to identify the need to make improvements in slaughter hygiene or cleaning and disinfection processes. To assist operators and laboratories, the FSA has produced draft guidelines on microbiological testing – a booklet explaining how to undertake the sampling, testing calculation and expression of results.

***Post mortem* inspection and health marking**

7.15 Individual carcasses are assessed through *post mortem* inspection. Any visible faecal contamination must be trimmed off before a carcass can be presented as safe, wholesome and fit for sale for human consumption.

7.16 Fresh meat for sale for human consumption produced in licensed slaughterhouses must carry an official health mark. This indicates that the carcass has passed *ante* and *post mortem* inspection and that hygiene regulations have been complied with.

7.17 We note that changes are proposed to the EU's rules governing meat and poultry inspections in slaughterhouses. The current rules are based on the principle of individual inspection and, where necessary, palpation and incision of lymph nodes, offal and carcass meat, supplemented where applicable by bacteriological, parasitological or chemical examination.

7.18 Important features of the proposed new arrangements include all red meat animals and poultry having to be accompanied to slaughter by "chain information" supplied by the farmer. This will be information relevant to food safety, such as previous *post-mortem* inspection findings in respect of animals from the same herd, flock or holding, and the status of the herd or flock in relation to a zoonosis which is subject to monitoring (eg. the *Salmonella* status of a pig herd). If this information is not available, the animals will be slaughtered but their meat will be excluded from the food chain.

- 7.19 Unnecessary *post-mortem* inspections for some conditions may not have to be carried out, where area or herd-based guarantees of freedom from disease can be provided. *Post-mortem* handling of carcasses and offal will be progressively minimised, following advice from the European Food Safety Authority on appropriate procedures for individual types of animal. *Ante* and *post-mortem* inspection findings of significance for public health (or animal health and welfare) will be required to be collected and communicated to public and animal health officials as appropriate, as well as to the farmer of origin of the stock and his/her veterinary surgeon.
- 7.20 Among the perceived advantages of the new proposals over the current meat inspection system are that, in extending official controls to the entire food chain, they allow controls to be made at the most effective points along the chain; in allowing only those animals with a known history to be slaughtered for human consumption, they will provide traceability and allow procedures to be put in place to manage identified risks (eg. slaughtering a group of animals last in the day, followed by a total clean down of the slaughterline so as to avoid cross-contamination); and in providing a risk basis for *post-mortem* procedures, they will reduce incision and palpation of otherwise normal but infected carcasses, and prevent resultant contamination and cross-contamination of meat.

Conclusions

- 7.21 *Campylobacter* spp., including those which cause human disease, are likely to be widespread in the environment, and it is not surprising that food producing animals such as cattle, sheep and pigs are exposed to this organism. In terms of risk management, it seems sensible to assume that all flocks and herds will contain animals which are likely to be colonised with *Campylobacter* and to take steps during the slaughter process to minimise the likelihood that these are transferred to the final products leaving the plant. The control measures required to achieve this aim will be essentially the same for *Campylobacter* as for organisms such as *Salmonella* and VTEC. We do not therefore consider that there is a need for *Campylobacter*-specific measures.
- 7.22 We recognise that both Government and industry have developed and put in place a number of measures to minimise the possibility of faecal material being transferred from the gut (or indeed the hide and fleece) during the slaughter process. We believe that, if properly applied, these will provide an effective barrier against *Campylobacter* contamination.
- 7.23 Cross-contamination is a potential risk and opportunities for cross-contamination should be avoided in relation to *Campylobacter*. We believe that the proposed new EU meat inspection requirements, by reducing the use of palpation and incision, will help reduce the risk of cross-contamination. We agree that improving the flow of information

across the food chain is likely to assist traceability and facilitate application of disease control and food hygiene measures at the most effective points. We believe the number of red meat carcasses at risk from cross-contamination will be lower than for poultry.

- 7.24 We believe that the quality of the information trail would be further enhanced if *Campylobacter* flock prevalence data were available at slaughter. We address this in Chapter 4.

Recommendations

- 7.25 In view of the variations noted above in the prevalence of *Campylobacter* in retail meat samples, and in order to obtain a clearer picture of the risk if any to public health from such products, **we recommend that the Food Standards Agency should undertake UK wide, large-scale, structured surveillance of the prevalence of *Campylobacter* in red meat on retail sale. (Priority A)** We note that the Agency has recently requested pilot work in this area.

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

CHAPTER 8

MEASURES TO PREVENT *CAMPYLOBACTER* CROSS-CONTAMINATION IN DOMESTIC AND CATERING ENVIRONMENTS

Risk factors for *Campylobacter* infection

8.1 In assessing the relative importance of domestic and catering practices in controlling *Campylobacter*, it is recognised that most incidents of infection with these bacteria do not form part of outbreaks (0.4% cases between 1995 and 1999 were outbreak-associated) and the causes of incidents are not clearly understood.¹⁰⁰ In the Study of Infectious Intestinal Disease (IID) conducted in England in 1995, one of only two factors identified as significant in elevating the risk of campylobacteriosis was the consumption of chicken at restaurants.^{110,254} The other factor was travel abroad.

Modes of transmission and outbreak settings

8.2 Investigation of the 50 outbreaks of campylobacteriosis in England and Wales between 1995 and 1999 identified, as modes of transmission, 35 (70%) foodborne; 4 (8%) waterborne (non municipal supply); 1 (2%) animal contact (chicks); 1 (2%) person-to-person; and 9 (18%) unknown.¹⁰⁰ Outbreaks mainly occurred in commercial catering premises (32/50, 64%) including 16 in restaurants, 10 in hotels, 4 in public houses or bars and 1 in each of a hall and canteen. The majority of the remainder occurred in schools (12%) and the armed services (8%). Of the 35 foodborne outbreaks, poultry products (13 chicken and 1 duck) were the most commonly identified likely vehicles. The reasons identified as contributing to the outbreaks included cross-contamination (18 outbreaks), inadequate heat treatment (10 outbreaks), and inappropriate storage (7 outbreaks).

Raw poultry meat as source of *Campylobacter* infection

8.3 Although a variety of animals, environments and foods are recognised as potential sources of *Campylobacter* spp., the most significant known source is raw poultry (whole or portioned, fresh and frozen), and chicken, in particular. Other raw foods, such as red meat, are also known to be contaminated with *Campylobacter*, but neither the levels nor the incidence in retail products appear to compare with those found in raw poultry. Nevertheless, raw foods such as meat are, like poultry and will continue for the foreseeable future to be, sources of *Campylobacter* into domestic and catering premises. Such foods must therefore be recognised at all times as presenting a risk if not adequately cooked, or if they come into contact with ready-to-eat foods.

8.4 Raw chicken is known to be contaminated with *Campylobacter* spp. at a high frequency, often in excess of 50%.^{7,255} In addition, the levels of the organism reported on fresh chicken carcasses can exceed 100,000 colony forming units (cfu).⁷

Tackling *Campylobacter* in domestic and catering environments

Excluding *Campylobacter* from domestic and catering environments

8.5 Given the often low infectious dose of the organism, with as little as 500 cells having been reported to be capable of causing an infection, foods such as raw chicken entering a domestic or catering facility represent a significant cross-contamination and in turn, infection, risk.¹ With levels of over 100,000 cfu on some chicken carcasses, as little as 0.5% of the original contaminants need to be transferred to a ready-to-eat food to cause a potential infection, and it is almost inevitable that even minor lapses in food hygiene practices will result in cross-contamination. Any attempt to reduce *Campylobacter* infections must address the high levels entering the food supply chain and kitchen, as well as the practices that should be in place in domestic and kitchen settings to destroy or prevent contamination with the organism. Indeed, a quantitative risk assessment of human campylobacteriosis associated with thermophilic *Campylobacter* spp. in chicken estimated that in order to achieve a 30-fold reduction in human disease, kitchen hygiene would have to improve by approximately 30-fold, whereas a reduction in the number of the *Campylobacter* on chicken carcasses by 2-log cfu would achieve the same effect.²⁵⁶

Temperature abuse

8.6 *Campylobacter* spp. do not grow at temperatures below approximately 30°C and are not believed to be especially heat resistant. We have previously reported the factors affecting the growth and survival of *Campylobacter* in foods.¹ As *Campylobacter* cannot grow at ambient and sub-ambient temperatures, the main risk in the domestic and catering kitchen will be associated with cross-contamination of raw foods to ready-to-eat foods, either directly or indirectly from hands and work surfaces/kitchen utensils, and undercooking of contaminated raw foods. **Notwithstanding the fact that *Campylobacter* cannot grow at temperatures below 30°C, we stress the importance of preventing temperature abuse by keeping hot foods at elevated temperatures eg. >63°C, or cooling them rapidly to temperatures precluding the growth of many pathogenic microorganisms eg. 5°C or less.**

Effective cooking

8.7 One of the most important intervention measures employed to control the organism is effective cooking. *Campylobacter* is not heat resistant and is readily destroyed by pasteurisation temperatures applied to milk (71.7°C, 15 seconds) and meat (70°C, 2 minutes). Previous advice given to producers and caterers on the heat processing requirements to ensure

safety of cooked meat (70°C for 2 minutes or an equivalent temperature) still remain valid.²⁵⁷ In the catering environment, it is essential that effective controls are put in place to guarantee that raw foods likely to be contaminated with *Campylobacter* are cooked to the correct temperature and time to destroy the organism. We believe that the proper and hygienic use of suitable meat thermometers in the catering and domestic settings would yield real benefits in terms of ensuring effective cooking. The benefits of meat thermometers should be more widely communicated. The Food Standards Agency may also, as part of its review of HACCP implementation in the catering sector, wish to consider whether documentary evidence of effective temperature control checks should be required to be kept.

8.8 As noted in Chapter 3, poultry liver consumption has been identified as a risk factor for human campylobacteriosis,¹¹⁶ as has eating raw or rare chicken.¹¹⁷⁻¹¹⁹ Consumers need to recognise that a current culinary trend of serving poultry liver 'pink' means that any *Campylobacter* present will not have been destroyed. We received anecdotal evidence of an even more worrying development, namely the addition of undercooked material and blood to poultry liver dishes to enhance the pinkness. This is clearly highly undesirable and dangerous from a food safety perspective.

Manufacturers' instructions

8.9 On-pack instructions are usually present on pre-packaged food to give guidance on the conditions necessary to ensure effective cooking. In our Report on Poultry Meat,¹⁷¹ we recommended that 'the food industry should introduce more informative labelling, in relation to raw, flash-fried poultry products, in order to make clear to consumers that such products require thorough cooking'. Cooking instructions, although offering guidance only, must be generated using appropriate, calibrated equipment and under controlled conditions, in order to be as precise as possible. Best practice for generation of such advice is available through some research associations, but it is not published or widely available. This needs to be remedied. Industry guidance produced through trade associations would help ensure a consistent approach to the generation of on-pack cooking instructions. Such instructions need to be displayed prominently on the packaging. In addition, it is not common practice for foods purchased over the counter (butchers, meat counters, etc) to be labelled with cooking instructions. Thought needs to be given to how appropriate cooking guidance can be provided for such products, and industry should examine the feasibility of providing cooking guidance on all raw meat and poultry products, including those sold from service counters, butchers and similar outlets.

Cross-contamination

8.10 Once a food is cooked, every effort must be made to prevent it becoming re-contaminated with *Campylobacter*. A variety of sources offer opportunities for post-process contamination in the kitchen or catering

premises, including people, pets, raw foods, and the environment.

- 8.11 *Campylobacter* has been found to be readily spread in the kitchen during preparation of raw foods such as chicken, and studies examining consumer behaviour in the kitchen have shown that practices likely to lead to cross-contamination of *Campylobacter* from raw foods, especially chicken, to ready-to-eat foods are common.²⁵⁸⁻²⁶⁰ One study involving the observation of 108 consumers from all socio-economic backgrounds making prescribed meals found 58% occurrence of the handler not washing their hands after handling raw meat/poultry.²⁵⁸ In the same study, one-third of consumers washed raw chicken, and 15% failed to cook foods to a temperature of at least 74°C. A questionnaire/interview-based study of 1,030 consumers assessing practices in relation to the handling of raw meat identified that the majority routinely washed raw meat, with whole chicken being the highest (80%).²⁵⁹
- 8.12 Research has shown that *Campylobacter* can be spread significant distances in the kitchen and improvements in isolation techniques have demonstrated that the bacteria can also survive for long periods of time.¹⁴ The exact risk that this presents clearly depends on the levels of the organism and the likelihood of it contaminating a ready-to-eat food but, nevertheless, any practice which spreads these organisms within the kitchen should be minimised. Washing raw meat and poultry is likely to spread *Campylobacter* in the kitchen through splashes, droplets and aerosols and should be actively discouraged. Consumers should, if required, do no more than wipe down a chicken with a disposable paper towel.
- 8.13 In a study of the cross-contamination potential of *Campylobacter* during the preparation of Sunday lunch made from raw chicken, 25 participants were allowed to prepare a meal in their own kitchens. Of the 11 where *Campylobacter* was isolated from the raw chicken, the organism was recovered from hands (3), oven handles (2), counter tops (3) and the draining board (4) following preparation of the chicken.²⁶¹
- 8.14 We note with interest the UK national survey of in-use kitchen cloths which failed to detect any *Campylobacter* in 1,009 cloths taken from homes in 2001.²⁶² The survey did, however, find other organisms, including *Salmonella* spp. (1 sample), *Escherichia coli* (367 samples) and *Listeria monocytogenes* (14 samples), indicating the potential for cloths to be colonised with microorganisms and become a vehicle for cross-contamination.
- 8.15 Levels of contamination with *Campylobacter* can be effectively reduced in the domestic kitchen by adherence to a prescribed cleaning regime using detergent, hot water and disinfectant. Some research has shown that using the former two alone is less effective on surface contamination.²⁶³ It is also clear that effective hand washing makes an important contribution to improving hygiene. A recent review determined that washing hands with soap could be expected to decrease the risk of

diarrhoeal disease in the community by almost half.²⁶⁴

Hygiene advice

- 8.16 We note that, despite the existence of an industry code of practice,²⁶⁵ on-pack hygiene advice (with the exception of cooking instructions) is infrequently provided on food products such as raw meat and poultry, which may be contaminated with enteric pathogens. Some retailers provide food safety advice on such products, but this does not appear to be common practice. More needs to be done, and all producers and retailers of food where pathogens such as *Campylobacter* may be present should provide advice on key safety steps. This should be applied as a minimum to raw poultry products. Advice should include measures for effective cooking, and avoidance of cross-contamination. Washing raw poultry should be discouraged.
- 8.17 Barbecued foods have frequently been highlighted as a potential risk factor for campylobacteriosis, although neither the Study of IID in England, nor the *Campylobacter* Sentinel Surveillance Scheme in England and Wales, found evidence to support this practice being significantly associated with infection.^{110,266} Nevertheless, we believe that barbecuing raw meats, particularly poultry, represents an important potential risk, from cross-contamination when handling contaminated raw foods, and from undercooking due to the use of poorly controlled or unfamiliar heating sources/methods. The FSA has, in the past, provided targeted barbecue hygiene and cooking advice to consumers, and this should be repeated each summer. In addition, industry should provide food safety and hygiene advice on the packaging for barbecues and raw meats intended for barbecuing.

Companion animals

- 8.18 Risks in the domestic kitchen are also presented by companion animals which can carry *Campylobacter* spp. In one survey, the organism was isolated from 32% of faecal samples from dogs suffering diarrhoea.²⁶⁷ Moreover, surveys of consumer practices have shown that it is not uncommon for pets to remain in the kitchen during the preparation of a meal.^{259,260} The extent to which these animals also present a risk of *Campylobacter* infection to their owners due to factors other than foodborne transmission eg. stroking dogs, dogs licking people's faces, etc., are not clear. An association was found between *Campylobacter* infection in dogs, and diarrhoea in human households, although this was not considered statistically significant.²⁶⁷ Indications from the *Campylobacter* Sentinel Surveillance Scheme do however reveal an elevated risk of infection (27 cases per 100,000) associated with dog ownership, in comparison to other pet ownership (0.7 cases per 100,000).²⁶⁶ The FSA should consider how best to communicate the potential risks associated with the carriage of *Campylobacter* in companion animals and the hygienic precautions applicable to them.

Food handlers

- 8.19 Any attempt to control *Campylobacter* in domestic and catering premises cannot overlook the importance of education and training of food handlers in the basic principles of food hygiene and safety. We are aware of the difficulties associated with ensuring adequacy of such knowledge in a large and disparate population both in the home, and in catering where a large number of the businesses employ few people (<10) and have a high staff turnover. Catering businesses have a legislative obligation to provide safe food using a hazard analysis approach. Under revised European Union hygiene legislation, which is likely to apply from 1 January 2006, they will be required to put in place food safety management systems based on HACCP principles. Infected food handlers and ancillary staff working in food handling areas are an important route of transmission of foodborne infections. We addressed this subject in some depth in Chapter 5 of our Report of Foodborne Viral Infections²⁶⁸ and reiterate the importance of the advice given therein about pre-employment health assessment, good hygiene practice, and excluding from food handling areas staff who are ill.
- 8.20 We are encouraged by the continued efforts of the FSA to build food hygiene into its own promotional campaigns and, in collaboration with other Government Departments, into education syllabuses. However, we believe that further measures are required in order to embed food hygiene and safety principles into the education of primary and secondary school pupils.
- 8.21 We note the increased activity the Food Standards Agency has undertaken in recent months to highlight the need for adoption of effective hygienic precautions in catering businesses, as part of its Food Hygiene Campaign. We are aware of the intention to extend this to consumers and we endorse this approach. However, we feel that more needs to be done to draw attention to the enhanced risks associated with raw poultry. As basic precautions may be insufficient to prevent *Campylobacter* cross-contamination from highly contaminated foods like raw chicken, the FSA should consider how best to highlight to caterers and consumers the heightened risks associated with foods such as raw poultry.

Conclusions

- 8.22 Raw poultry meat, particularly chicken, is, and will continue for the foreseeable future to be, a significant vehicle by which *Campylobacter* is introduced into the domestic and catering environments. Levels of *Campylobacter* contamination of $>10^5$ cfu are seen on some chicken carcasses. The human infectious dose is reported to be as low as 500 cells. Given the likely difficulties involved in controlling high levels of contamination in the kitchen, especially from sources such as raw poultry, we reiterate the critical significance of reducing the levels and incidence of *Campylobacter* on such products to lessen the burden on domestic and catering premises in dealing with such hazards.

8.23 If *Campylobacter* can be effectively tackled at the primary production stage, then the anticipated reduction in the number of *Campylobacter* cells reaching the kitchen would enhance the effectiveness of normal hygiene measures taken there. We make a number of recommendations below designed to enhance the effectiveness of action in the domestic and catering environments.

Recommendations

8.24 We strongly recommend the proper use in catering of meat thermometers, as a means of ensuring the effective cooking of raw poultry products in particular. The use of such devices in the home may also yield benefits and we recommend that the Food Standards Agency (FSA) considers communicating the benefits of the use of cooking thermometers for domestic and catering settings. We also recommend that, as part of its review of HACCP implementation in the catering sector, the FSA considers whether documentary evidence of effective temperature checks should be required to be kept. (Priority A)

8.25 We recommend that industry guidance is produced through trade associations, to ensure a consistent approach to the generation of on-pack cooking instructions. In addition, where guidance is provided, this should feature prominently on the packaging. (Priority A)

8.26 In the case of meat which is not pre-packed, we recommend that the industry examines the feasibility of providing cooking guidance on all raw meat and poultry products, including those sold from service counters, butchers and other similar outlets. (Priority A)

8.27 We believe that the practice of washing raw meat and poultry is likely to lead to increased risk of spread of *Campylobacter* in the kitchen through splashes, droplets and aerosols, given the high levels which may be present on raw chicken. We recommend that this practice be actively discouraged by the FSA and industry. If necessary, consumers should be advised only to wipe down a chicken with a disposable paper towel. (Priority A)

8.28 Whilst it is understood that the consumer does not always read such advice, we recommend, in the public interest, that all producers and retailers of foods, where enteric pathogens such as *Campylobacter* may be present, should provide advice on the key food safety steps which should be taken to prevent infection. This should, as a minimum, be applied to all raw poultry products, as the levels of the organism are known to be high. Advice should include measures for effective cooking and for the avoidance of cross-contamination from the raw food to ready-to-eat food (through separation of foods and utensils, and through hand washing).

(Priority A)

- 8.29 We are aware of previous activity by the FSA to provide targeted advice to consumers regarding improved cooking/hygiene practices when barbecuing and we recommend that this approach be repeated prior to each summer period. (Priority A)**
- 8.30 We recommend that the industry provides food safety/hygiene advice on the packaging of foods for barbecues, particularly raw meats, and especially poultry. (Priority A)**
- 8.31 We recommend that attention is drawn to the potential risks associated with carriage of *Campylobacter* in domestic pets, and to the hygiene precautions applicable to them. (Priority A)**
- 8.32 We recommend that further measures are taken to embed food hygiene and safety principles into the education of primary and secondary school children. (Priority C)**
- 8.33 In light of the fact that basic precautions may not be sufficient to prevent *Campylobacter* cross-contamination from highly contaminated foods such as raw chicken, we recommend that the FSA considers what measures can be taken to highlight to caterers and consumers the heightened risks associated with certain foods such as raw poultry. (Priority A)**

CHAPTER 9

CAMPYLOBACTER DETECTION AND TYPING

Introduction

- 9.1 Since the ACMSF last considered *Campylobacter* detection and typing, a number of developments has occurred.
- 9.2 In 1997, a national *Campylobacter* Reference Unit was established by the Public Health Laboratory Service (PHLS), and the reference service was piloted in Wales and the North West of England.⁹³ A routine reference service was subsequently rolled out across England and Wales on a sentinel basis in 2000. Through the *Campylobacter* Sentinel Surveillance Scheme (CSSS), standardised epidemiological and microbiological reference typing data have been captured for about 15% of all laboratory-confirmed *Campylobacter* infections in England and Wales.⁷⁴
- 9.3 There are many typing methods available, and these have served to emphasise the complexity of the epidemiology of *Campylobacter* infection in humans and food animals. A European Study to attempt to standardise and harmonise molecular sub-typing techniques for *Campylobacter jejuni* (CAMPYNET) has been undertaken (www.svs.dk/campynet). Despite numerous developments in typing methods, evidence to support their value in informing the epidemiology of *Campylobacter* infection is hard to find. Thus there has been no clear success in developing interventions and the proportion of foodborne infections has not been established.
- 9.4 The publication of the Chief Medical Officer's strategy for health protection in England signalled the dissolution of the PHLS and the creation of a Health Protection Agency (HPA).²⁶⁹ This, along with other developments in the National Health Service (NHS), has had implications for the future delivery of clinical and food, water and environmental laboratory services, including reference services.

Campylobacter detection

- 9.5 Various methods for the isolation of thermophilic *Campylobacter* from clinical specimens are published, and the bacteria can be isolated from human diarrhoeal faecal samples using any of the four microaerobic-atmosphere-generating systems available.²⁷⁰ What is not known is the extent to which protocols for screening clinical specimens are standardised across clinical laboratories in the United Kingdom, except for the former PHLS laboratories, where standard operating procedures for the handling of food, water and clinical specimens were employed. The development of the HPA affords the opportunity to standardise testing protocols across the NHS. There is also a need to determine

the extent of technique bias with regard to the strains and species of *Campylobacter* isolated.

- 9.6 Most clinical laboratories do not perform speciation. For example, in 2001, only 9.4% of *Campylobacter* reported to the Communicable Disease Surveillance Centre (CDSC) had been identified to the species level. This has fallen from 17% at the time of our Interim Report.¹ Results from the CSSS show that there might be important differences in the epidemiology of *C. coli* and *C. jejuni*, so speciation is valuable.⁷⁴
- 9.7 Isolating *Campylobacter* from food specimens usually requires an enrichment step, although the choice of enrichment broth can significantly affect recovery of organisms.²⁷¹ As with clinical specimens, it is also likely that the choice of enrichment media in particular will influence the population structure of strains isolated from food and environmental specimens. This will occur because *Campylobacter* strains differ in sensitivity to the antibiotics in selective media²⁷² and are likely to grow at different rates. Given the continued debate about the importance of various food animal species as sources of human infection, it is important that there is as much standardisation as possible in the isolation methodologies used with foods, food animals and human cases. *Campylobacter* spp. do not always produce what are regarded as 'typical' colonies on selective agars, and there are potential problems in recognising these pathogens. This may reduce isolation rates. In addition, the method of sampling the food can influence the numbers of *Campylobacter* recovered.¹²³ This latter point has implications for microbiological risk assessment where enumeration of organisms, as well as detecting their presence or absence, is important.
- 9.8 Success with molecular method development affords the opportunity to detect *C. jejuni* in food samples much more quickly than is possible using traditional methods,^{273,274} bearing in mind that molecular methods may identify non-viable, as well as viable, organisms.
- 9.9 Finally, it appears that no single method will lead to isolation of all strains from clinical or non-clinical samples. It is, therefore, important that a decision is made at the outset of any investigation about the most appropriate method to be used. The isolation of *Campylobacter*, particularly, from non-clinical samples, has suffered from the same developmental issues that have bedevilled typing. There are a lot of methods available but most have not been rigorously tested in multi-laboratory trials and there are marked variations in efficacy.²⁷⁵ As with any pathogen in a mixed population, the isolation of *Campylobacter*, requires a proper balance between suppressing competing flora while encouraging the growth of the target pathogen. This can be particularly difficult with *Campylobacter* as it is easily damaged by exposure to the extra-intestinal environment. This will lead to sensitivity to selective agents, which may affect viability in selective media.^{276,277} It would seem that the strategies adopted for *Salmonella*,

where foods are inoculated in non-selective media, will not always be successful for *Campylobacter* because of over-growth by competing bacteria.²⁷⁸ There is a need for a properly structured study of isolation media sensitivity and selectivity.

***Campylobacter* typing**

9.10 Scientific debate about the utility of typing methods for *Campylobacter* spp. continues unabated. There would seem to be general agreement that *Campylobacter* typing in the outbreak situation is an important tool for helping to unravel epidemiology. However, information derived from the use of phenotypic and/or genotypic typing methods in outbreaks gives two types of picture :-

- outbreak cases linked epidemiologically, patients all infected with the same strain; and
- outbreak cases linked epidemiologically, but patients infected with different strains.¹⁰⁰

9.11 A typing method is any technique which can distinguish between epidemiologically unrelated strains. There is no assumption that different laboratories using the same method on the same strains would necessarily get the same results. Many of the genotypic methods developed for *Campylobacter* are fingerprinting methods ie. they produce patterns. These can be compared with patterns from other strains for similarities. A typing method should provide a type designation or label to these patterns. This has been a major challenge for PulseNet in the United States where a key development has been the creation of a standardised nomenclature system for pulsed field gel electrophoresis (PFGE) patterns.²⁷⁹ Typing methods are useful in investigating certain problems such as a localised outbreak investigations, but are not necessarily useful for larger epidemiological studies.²⁸⁰

9.12 A typing scheme is one used for discrimination between epidemiologically unrelated isolates belonging to the same microbial species. It should be capable of identifying strains accurately (type designations) and reproducibly at different times and in different laboratories.

9.13 Three main characteristics that need to be considered when evaluating a typing method/scheme are typeability, reproducibility and discriminatory power. Cost, ease of use, and turnaround time are also important considerations.²⁸⁰

9.14 Typeability is the proportion of isolates that can be typed using the method in question.

9.15 Reproducibility includes three concepts :-

- *in vitro* reproducibility (the proportion of strains which are typed with the same result on repeat examination);
 - *in vivo* reproducibility (requiring repeat testing of multiple strains over time to assess the stability of the organism under study, and hence its type); and
 - reproducibility between centres (the extent to which identical methods used in different centres produce identical results).²⁸⁰
- 9.16 Discriminatory power is defined as the probability that two strains, chosen at random from the population or unrelated strains, will be distinguished by the typing method used.²⁸⁰
- 9.17 Tables 9.1 and 9.2, at the end of this Chapter, describe the features of the main phenotypic and genotypic methods employed for typing using the six parameters described in paragraph 9.13.
- 9.18 Probably the only widely accepted phenotypic typing scheme is serotyping using the Penner scheme.²⁸¹ Indeed, this was considered the only practical method for surveillance on a broad scale.^{282,283} Despite the effort that has gone into typing on a broad scale, typing studies to below species level have yet to add significantly to our understanding of the epidemiology of *Campylobacter* infections. Relatively high levels of non-typeability, especially when applied to poultry or environmental isolates,²⁸⁴ coupled with reproducibility problems²⁸⁵ has led researchers on a quest to find improved methods for *Campylobacter* typing.
- 9.19 Where typing methods have been used in targeted, hypothesis-driven studies, there has been greater achievement. Random amplification of polymorphic DNA (RAPD), PFGE and flagellin gene restriction fragment length polymorphism (*fla* typing) have been used with success in tracing organisms across the food chain.^{130,179,286-290} However, multilocus sequence typing (MLST), which has also been used in this way, offers the advantage that direct comparison between laboratories can be made much more easily than with some of the other methods.²⁹⁰⁻²⁹² The scientific consensus that seems to be emerging is that MLST is probably the most promising of the genotyping methods to date.
- 9.20 Many typing methods have been developed using, and/or applied to, small and/or eccentric collections of strains. The national *Campylobacter* Reference Unit at Colindale has amassed a large, representative set of clinical isolates with accompanying standardised epidemiological surveillance data collected through the CSSS. Analyses of the dataset are not yet complete but, early on, the benefits of speciation and antimicrobial resistance testing were demonstrated.^{74,293} In judging the importance of *C. coli* as a foodborne

pathogen, it is worth reflecting that, in 2000, *C. coli* was estimated to account for over 25,000 cases of illness, and cost patients and the NHS nearly £4 million.²⁹⁴ Tackling even the smaller portion of *Campylobacter* infection in England and Wales is likely to have important public health benefits.

- 9.21 If the objective of typing is to unravel the epidemiology of *Campylobacter* infection, and hence inform control measures, using the CSSS strain collection affords the opportunity to determine the utility of methods like MLST in a public health setting where good epidemiological data are also available.

Lessons from typing studies

- 9.22 A summary of the features of the main methods for typing *Campylobacter* is given in Table 9.3, also at the end of this Chapter. There is not yet a universally accepted solution to the question of *Campylobacter* typing. First, no matter what method is employed, some well-defined clonal lines can be identified readily, although these are in the minority, and there is a wide range of variation within the remainder, which comprise the majority. Second, although there has been much work on method development, each new method spawns a series of slight adaptations, so-called “creeping featurism”. This makes direct comparison between slightly different methods very difficult, and comparisons between laboratories even harder. Third, although there has been much activity in the research setting, there is less evidence of the application of these methods in a public health service setting so that, despite the large investment in typing methods over recent years, there have been few tangible epidemiological or public health benefits. However, where typing methods have been used in focused studies, eg. for local outbreak investigation or for targeted studies across the food chain, there has been greater success.

DNA microarrays

- 9.23 Although a wide variety of typing approaches has been developed for *Campylobacter*, the availability of whole genome sequence data offers the prospect of another potentially valuable approach. It is established that DNA microarrays based on the complete set of sequenced genes offer a unique opportunity to investigate and compare genome composition for individual isolates of a species. This approach has been applied to *Campylobacter*^{295,296} and its further development and validation may provide a more complete genome-based data set and a novel typing approach of practical value for the future.

Conclusions

Detection

- 9.24 It is likely that, for the foreseeable future, traditional culture techniques

will be employed for the examination of clinical and non-clinical samples for *Campylobacter* spp. More rapid methods are now available but there is a need to ensure that they have sufficient sensitivity. Any method will suffer from inherent bias and this will continue to be a problem in studies on epidemiology and in comparison of different surveillance schemes. The isolation of *Campylobacter* would seem to be more difficult than for *Salmonella*, for example, and there is a need for more rigour in method choice and for a properly structured, multi-laboratory study of the most commonly used methods. This is an area our *Campylobacter* Working Group will need to consider in reviewing research needs relating to *Campylobacter* (see Chapter 1).

Typing

9.25 Speciation of *Campylobacter* has proved useful in differentiating epidemiologically between *C. coli* and *C. jejuni*.

9.26 *Campylobacter* typing should be driven by objectives and/or specific hypotheses. These might be :-

- tracing sources and routes of transmission of human infection;
- identifying and monitoring, both temporally and geographically, strains with important phenotypic or genotypic characteristics;
- developing strategies to control organisms within the food chain;
- monitoring trends in antimicrobial resistance; and
- outbreak identification

The method(s) chosen should then be dictated by specific objectives and/or hypotheses. In addition to this, appropriate sampling frames should be used.

9.27 Typing has confirmed the complexity of the epidemiology of *Campylobacter* infection but, on a broad scale, has not yielded the expected public health benefits in terms of identifying a big target amenable to control. Routine typing is probably not useful for source tracing and global epidemiology because of the carriage of multiple strains in animals, and the extreme diversity of those strains.²⁹⁰ Completing the analyses of the CSSS is, however, needed since the requirement for national strain-specific epidemiological studies might yet be demonstrated.⁹³

9.28 Where the objective is to make an assessment of *Campylobacter* across the food chain in relation to human infection, veterinary, food and clinical laboratories should use the same methods. One of the problems with comparative epidemiology is that different techniques have been applied to different specimen types. It is important that,

when carrying out research and surveillance in animals, isolation and typing methods should take the lead from, and be consistent with, methodologies used for clinical isolates unless there are specific reasons not to do so. This recognises the fact that *Campylobacter* is primarily of public health significance.

- 9.29 The technological revolution in clinical medicine means that, in future, direct detection and typing using clinical samples will be possible.²⁹⁷ An obvious benefit of this approach is the speed of diagnosis and the potential for real time epidemiology. DNA sequence-based methods like MLST therefore have the greatest potential to be “future-proof”.
- 9.30 The variability and genetic instability of *Campylobacter* cautions us against believing that there exists some magical solution to the typing of all campylobacters of human health significance. However, any improvement in the tools available for differentiating the origins or food sources of *Campylobacter* spp. would greatly assist the Food Standards Agency in tackling human campylobacteriosis. Examination of the history of the many typing methods summarised in Tables 9.1 and 9.2 prompted much discussion within the *Campylobacter* Working Group as to whether the ACMSF could make a firm recommendation in this area. We have now concluded that the DNA sequence-based MLST method offers an opportunity in the short to medium-term to improve our knowledge of what is a very complex epidemiological story.
- 9.31 The availability of whole genome sequence data offers the prospect of another potentially valuable approach to typing. DNA microarrays based on the complete set of sequenced genes offer a unique opportunity to investigate and compare genome composition for individual isolates of a species. This approach has been applied to *Campylobacter* and its further development and validation may provide a novel typing approach of practical value in the future.

Recommendation

- 9.32 As with all typing methods for food poisoning pathogens, different laboratories will take different approaches, and agreement will be difficult to reach. **We therefore believe that the FSA needs urgently to take a firm initiative in bringing together laboratories capable of applying MLST so that investigative programmes can be designed to improve our epidemiological understanding in the next few years. We so recommend. (Priority A)**
- 9.33 We want to be very clear that this is in no way a recommendation that, at this stage, the FSA should be funding large research programmes on typing methods. Rather, it is a recommendation that advantage is taken of the opportunity to get the most out of MLST in the shorter-term.

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

Table 9.1: Summary of the features of the main phenotypic methods for typing *Campylobacter*

Method	Typeability	Reproducibility	Discriminatory Power	Cost	Ease of use	Turnaround time	Comments
Serotyping <ul style="list-style-type: none"> • Penner²⁹⁸ • Lior²⁹⁹ • Frost³⁰⁰ 	70-90% ^{282,304} 70-90% ^{282,304} 80% ³⁰⁵	Good ³⁰⁶ Good ³⁰⁶ Not available	0.898 ³⁰⁷ 10 serotypes accounted for 53% of <i>C. jejuni</i> isolates tested; 3 serotypes accounted for 69% of <i>C. coli</i> isolates tested. ³⁰⁵	Low, although set-up costs are high	Easily applied by both clinical and reference laboratories, provided that antisera are available. ²⁸²	Less than 24 hours ³⁰⁶	Main disadvantage of serotyping methods is the lack of commercially available, high quality antisera. ²⁸² It has been said that subculturing, storage and freezing may affect stability of phenotyping ³⁰⁶ although this experience is not universal. ³⁰⁵ Serotyping generally produces around 80% typeability for poultry isolates ^{308,309} although at least one author suggests that up to 40% of poultry isolates are untypeable using the scheme described by Frost <i>et al.</i> ²⁸⁴
Biotyping <ul style="list-style-type: none"> • Lior³⁰¹ • Preston biotyping³⁰² • Resistotyping^{281, 303} 	100% ²⁸² 100% 100% ³⁰³	 >98%, ³⁰³ occasionally problematic ²⁸¹	 0.945 ³⁰⁷ Good – no single resistotype accounted for more than 25% of isolates ³⁰³	Low	Easy and available to most laboratories.	24-48 hours ^{281,303}	Produces only a few markers among strains when used alone. Needs to be used in conjunction with another method. ^{281,282,307}

Table 9.1 (continued): Summary of the features of the main phenotypic methods for typing *Campylobacter*

Method	Typeability	Reproducibility	Discriminatory Power	Cost	Ease of use	Turnaround time	Comments
Phage typing <ul style="list-style-type: none"> Grajewski³¹⁰ 	88-94%, ³⁰⁸ 82% ²⁸²	94% ³⁰⁸	46% of isolates represented by the four most common phage patterns ³⁰⁸			24 hours	Typeability improves when serotyping and phage-typing are used in combination (around 97%) ³¹³ Repeatability and reproducibility depend on individual interpretation of lysis reactions so that a standard procedure for recording lysis reactions is needed, and a standard taxonomy of types is needed. ^{313,314}
<ul style="list-style-type: none"> Salama³¹¹ 	94% ³¹³	Good	0.908 ³⁰⁷				
<ul style="list-style-type: none"> Khakhria³¹² 	81% overall	Good	Nine phage types represented 57% of strains				

Table 9.2: Summary of the features of the main genotypic methods for typing *Campylobacter*

Method	Typeability	Reproducibility	Discriminatory Power	Cost	Ease of use	Turnaround time	Comments
Flagellin gene restriction fragment length polymorphism (<i>fla</i> typing)	100% ^{306,315-317}	Good ³¹⁷	Fair, ³⁰⁶ Better than ribotyping but not as good as PFGE ³²²	Low ³⁰⁶	Relatively quick and simple ³²² Equipment becoming widely available	<24 hours	Method samples a small proportion of the genome. Procedures (especially primers and restriction enzymes used) need to be standardised otherwise inter-laboratory comparisons are impossible. Vulnerable to genetic instability. ²⁸⁴
Pulsed field gel electrophoresis (PFGE)	100%, ³⁰⁶ 95% ³¹⁸	Good ³²¹	Good, ³⁰⁶ Better than ribotyping and phage-typing ³²¹	Needs specialised and expensive equipment ³²⁴	Preparation process for the DNA samples is lengthy, labour-intensive, not amenable for use with large numbers of samples	3 to 5 days generally although shorter protocols have been published ^{325,326}	This is the method of choice for PulseNet in the US but application of a standard method is strictly adhered to and enforced. ³²⁶ Conditions used in different studies vary widely (especially restriction enzymes and electrophoretic conditions), interpretation of results is difficult since genetic instability, even during <i>in vitro</i> culture, can lead to minor or major changes in profile. ^{284,327}
Ribotyping	100%, ²⁸² >89% ³¹⁹	Good ³⁰⁶	Poor ³²³	Expensive	Low throughput, complicated technique		Choice of restriction endonuclease is of critical importance ³²³ and variations in the restriction enzymes and probes used make inter-laboratory comparisons difficult. ³⁰⁶
Automated ribotyping	100% ³²⁰	Good ³⁰⁶	0.97 ²⁸⁴	High cost (both equipment and consumables)		Within the working day	Automation enhances reproducibility and enables inter-laboratory comparisons. ²⁸⁴

Table 9.2 (continued): Summary of the features of the main genotypic methods for typing *Campylobacter*

Method	Typeability	Reproducibility	Discriminatory Power	Cost	Ease of use	Turnaround time	Comments
Random amplification of polymorphic DNA (RAPD)	87%, ³²⁸ 100% ^{286, 287}	Poor ³²⁹	0.999 using computer-based analysis ²⁸⁷	Low ³⁰⁶	Quicker and cheaper than PFGE	< 24 hours	Unlike other PCR-based identification and typing methods, does not require prior knowledge of the target DNA sequence. Less sensitive to, but is affected by, genetic instability. ²⁸⁴
Amplified fragment length polymorphism (AFLP)	100% ³⁰⁶	94.2%, ³³⁰ 98% ³³¹	Better than PFGE ^{332,333}	Average ³⁰⁶	Interpretation of AFLP is complex. ³³² Interpretation of single-enzyme AFLP is less so. ³³³	2-3 days ³⁰⁶	A random portion of the whole genome is sampled and AFLP is not dependent on prior sequence knowledge. ²⁸⁴ Not susceptible to genetic instability. ³⁰⁶
DNA sequencing e.g. Multilocus sequence typing (MLST)	100%	High ²⁹¹	High ²⁹¹	\$37 per isolate ³³⁴	Automatable, high throughput possible. ³³⁴		Not vulnerable to genetic instability. ³³⁴ Direct comparison between laboratories possible. ^{291,292}

Table 9.3 : Summary of the features of the main methods of typing *Campylobacter*

	Typeability	Reproducibility	Discriminatory power	Cost	Ease of use	Turnaround time
Serotyping						
Biotyping						
Phage typing				?	?	
<i>fla</i> typing						
PFGE						
Ribotyping						?
Automated ribotyping					?	
RAPD						
AFLP						
MLST						?

Key	Good		Intermediate		Poor		Not reported	?
------------	------	--	--------------	--	------	--	--------------	---

CHAPTER 10

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Introduction

- 10.1 For ease of reference, this Chapter summarises the conclusions we have reached throughout this Report and the recommendations we have made.
- 10.2 As noted in the Summary to this Report, we have endeavoured to prioritise our recommendations. The summary of recommendations which follows is thus listed as Priority A (where action is required in the short-term to assist the Food Standards Agency (FSA) in developing and implementing its *Campylobacter* strategy); or Priority B (where the Committee feels that work should start in the next year or so); or Priority C (where we consider that work can be put in hand as and when possible, and in the light of competing priorities).

Chapter 1 : Background

- 10.3 Having published an Interim Report on *Campylobacter* in 1993, the ACMSF decided in 2000 to revisit the subject with a view to identifying means of reducing the incidence of *Campylobacter* infection in humans. This decision reflected the fact that *Campylobacter* is the major cause of infectious intestinal disease in the UK and was taken against the background of the FSA's targets for reducing the incidence of foodborne disease and *Campylobacter* contamination of retail chicken.
- 10.4 As a first step, we held a workshop in February 2002 to take stock of research findings and to identify major knowledge gaps justifying on-going research. The workshop also aimed to help us decide whether there were food chain interventions which would reduce consumer exposure to *Campylobacter* and which would assist the FSA in its efforts to reduce the burden of foodborne disease. We were seized of the need to make our advice available to the FSA as soon as possible, given the fact that its foodborne disease target was time-bound. We therefore fed our advice into the Agency in tranches as soon as it was ready. We also resisted taking an in-depth look at research opportunities and needs where there were significant knowledge gaps.
- 10.5 Despite the scientific advances made, *Campylobacter* remains a poorly characterised microorganism and this impacts on its epidemiology and control. There is therefore a need for continued fundamental research,

especially in the area of functional genomics. While the focus of this Report has been on the practical measures which will help the FSA develop its strategy for tackling *Campylobacter* in the shorter-term, the ACMSF *Campylobacter* Working Group will meet again with the aim of identifying where research outputs, had they been available, would have contributed to progressing the objectives identified as desirable in this Report more quickly. It should be recognised, however, that any research requirements identified through this planned review can only yield results in the medium to longer-term, given the time lag involved between identifying research and being able to apply practical outputs.

Chapter 2 : The organism, human immune response, and pathogenesis

- 10.6 The debate about the role, indeed the very existence, of the VNC form of *Campylobacter* seems unlikely to be resolved in the short-term. It is a complex area and not one where we have been able to draw any firm conclusions. However, we are not aware of any evidence to suggest that current uncertainties give cause for concern in relation to food safety. We are not, therefore, recommending that the FSA should commit funds to further research on the VNC issue. We note that the research community continues to carry out work in this area. This should be monitored and we hope that a consensus view will eventually emerge.
- 10.7 *Campylobacter* isolation methods have been improved since much of the work on VNC was performed, and it is now possible to recover cells previously thought to be non-culturable. What is not yet clear is whether very highly damaged cells of *Campylobacter* now recoverable from a variety of environments, and after a variety of treatments, pose an infection threat.
- 10.8 It is clear that infectious intestinal disease causes a considerable burden of ill health over and above the initial event. However, little information is available on the incidence and economic cost of long term *sequelae* and it would be useful to have a more reliable measure.
- 10.9 We recommend that the Government should instigate a primary care-based sentinel surveillance system, aimed at measuring directly the incidence and economic cost of long-term *sequelae* among cases of *Campylobacter* infectious intestinal disease. (Priority B)**
- 10.10 We recommend that serological markers for recent infection and prior immunity be developed and tested through structured, epidemiologically robust, population-based studies. This should assist with estimating the prevalence of asymptomatic infection in the population (and hence estimating more accurately the magnitude of *Campylobacter*-associated *sequelae*). (Priority C)**

Chapter 3 : *Campylobacter* epidemiology

- 10.11 *Campylobacter* infection is a major public health problem. The epidemiology is complex. There are extensive animal and environmental reservoirs and multiple risk factors for infection. Although epidemiological patterns, such as marked seasonality, are well described, their underlying explanations are still elusive despite much study.
- 10.12 Poultry appears to be an important source of infection. It is noteworthy that eating food, including poultry, on commercial catering premises has been identified as a risk in several case-control studies.
- 10.13 In the case of poultry, some progress has been made in reducing the role of the food chain as a vehicle for *Campylobacter* infection. However, in addition to the contribution of poultry to human *Campylobacter* infection, many studies also point to numerous other sources and vehicles of *Campylobacter* infection. It is important that these are not overlooked.
- 10.14 The contribution of foodborne transmission (as opposed to other transmission modes) to the human toll of *Campylobacter* needs to be better defined and we note that the FSA has already funded a research project designed so to do. **We support this course of action. (Priority A)**
- 10.15 **We recommend that population studies to investigate the seasonality of *Campylobacter* infection be undertaken. An approach combining epidemiological, microbiological, environmental and veterinary expertise is likely to be needed. (Priority A)**
- 10.16 **We recommend that population studies to investigate cultural/behavioural risk factors for *Campylobacter* be undertaken. (Priority B)**
- 10.17 **We recommend that more extensive data are gathered on the levels of *Campylobacter* spp. in specific foods (eg. water, dairy products, vegetables, poultry and red meat) as well as in food-producing animals and companion animals. These are all potential sources of exposure for humans. We recommend that consideration be given to on-going surveillance as well as to “snap-shots” which tend to be the norm. It is very important that the microbiological methods employed allow meaningful comparisons to be made across the food chain (see Chapter 9). (Priority A)**

Chapter 4 : Measures to prevent *Campylobacter* contamination of chicken meat

10.18 It is becoming clear that control of *Campylobacter* on-farm is now a practical proposition, at least with birds that are housed. We brought this view to the attention of the FSA in September 2002 to assist the Agency in developing its *Campylobacter* strategy. The first commitment must be to rigorous biosecurity, combined with high standards of stockmanship and attention to good flock health and stress control. This will involve such measures as restricting farm visits to essential personnel; ensuring visits are undertaken as hygienically as possible; and appropriate staff training on flock infection. The control of *Campylobacter* on-farm presents a greater challenge than that associated with the control of *Salmonella*.

10.19 Our *Campylobacter* Working Group received different views, both formally and anecdotally, about the possibility of the UK poultry industry adopting 'Scandinavian style' systems of on-farm biosecurity. Where these systems have been trialed in the UK, they have been seen to be successful, although industry argues that long-term maintenance would be difficult. While Scandinavian and UK systems of production and control measures do differ in some respects, reflecting the different sizes of the industries and the very different climates, we firmly believe that the application of biosecurity, such as changing footwear, and other hygiene measures, will either delay or prevent the entry of *Campylobacter* into broiler flocks and thus reduce the incidence of colonised birds. Studies in the Netherlands support this view. Changing of footwear was found to be important in a UK context, and another UK study found that frequent replenishment of boot dip disinfectant was one of a few factors which reduced broiler flock infection by over 50%. In the future, given current research effort, it may be possible to supplement biosecurity with pre- or probiotic approaches, competitive exclusion, and/or vaccination.

10.20 In addition, it is clear that a well-run broiler farm can reduce the incidence of *Campylobacter* through adherence to a number of key principles. It should:-

- be species mono-specific (ie. farm only chickens);
- supply the birds with water of potable quality;
- properly clean and disinfect houses after flock removal, which should include disinfection of the water supply system;
- protect the house from entry by wild birds and rodents;
- supply feed which has received treatment sufficient to have

eradicated *Salmonella* (and, hence *Campylobacter*), and protect it from re-contamination;

- only carry out thinning if done in association with proper crate washing (so that crates are not contaminated with *Campylobacter* spp. or other pathogenic microorganisms) and proper biosecurity measures covering eg. clothing and footwear;
- ensure that transport crates and vehicles are cleaned and disinfected properly on every occasion; and
- maintain general biosecurity and hygiene barriers at a high level, to prevent infection from the farm environment.

10.21 We strongly believe that concerted effort is needed by industry to improve the microbiological safety of thinning. If this cannot be achieved, then the case for discontinuing the practice, and taking the necessary measures to protect the welfare of stock, becomes very strong.

10.22 In risk assessment terms, a lower incidence of *Campylobacter* in broiler flocks is also likely to be reflected in lower numbers of the organism in individual birds in the flock, and on finished carcasses. Reducing the number of *Campylobacter*-positive flocks can be expected to have a significant impact on the numbers of contaminated birds leaving the slaughterhouse and may also facilitate flock testing to enable positive birds to be put through the slaughterhouse at the end of the day, immediately before plant and machinery are shut down and cleansed. It might also offer the option of directing positive flocks to heat treatment or freezing if these were found to be helpful in reducing *Campylobacter* loadings. An important factor in consumer exposure to *Campylobacter* in poultry meat is the frequency and level of contamination of the chicken brought into the home or into catering kitchens.

10.23 We accept the advice we have received from various parts of the poultry industry that broiler chicken production is extremely price competitive and that the industry is faced with continuing threats of import penetration.

10.24 We do recognise that many of the measures for controlling *Campylobacter* in chicken imply additional production costs. However, there is increasing evidence that there are direct links between the general health status of birds and their susceptibility to *Campylobacter* infection. In addition, the maintenance of good flock health conveys economic benefits. Measures put in place for the control of *Campylobacter* might also help reduce the risk of introducing other infections into the flock.

10.25 In order to be able to evaluate the effectiveness of measures to tackle *Campylobacter*, good quality data are needed on the *Campylobacter*

status both of flocks and retail product. Flock prevalence studies are an essential feature of any evaluation process, to establish a baseline and to monitor progress under commercial conditions. We believe that Defra should organise such studies. In addition, we assume that the FSA will continue to use routine surveillance of retail chicken for *Campylobacter* to assess the effectiveness of *Campylobacter* reduction programmes. The potential value of industry data as an output measure should not be overlooked even if, for reasons of commercial sensitivity, such information cannot be made publicly-available outside the Agency. We discuss the valuable contribution a standardised approach to typing can make to tracing sources and routes of transmission of human *Campylobacter* infection in Chapter 9.

10.26 We recognise that free range and organic chicken production is now a small but significant feature of the UK market. Given the importance of the environment as a source of *Campylobacter*, we think it likely that chickens reared extensively will come into more frequent contact with *Campylobacter* and that robust biosecurity arrangements aimed at reducing the exposure of birds to *Campylobacter* spp. will be more difficult to apply in extensive production systems. It is important that consumers are aware of this, not least because one of the main reasons given for buying free range and organic chicken is that they see it as a healthier product (see Annex E). We believe that information based on structured UK surveillance of *Campylobacter* infection in extensively-reared broiler flocks and the *Campylobacter* status of extensively-produced, including free range and organic, chicken meat would be valuable in informing consumer choice. Means also need to be identified of controlling *Campylobacter* in extensive production systems.

10.27 Our principal recommendation is that the Food Standards Agency utilises the conclusions we have drawn to intensify its work with the poultry industry and other stakeholders to achieve wider acceptance that *Campylobacter* control of housed birds is now possible. A primary aim should be to develop an industry-wide programme to spread the “good farming” practices and biosecurity measures which lie at the heart of the matter. (Priority A)

10.28 We recommend that the FSA, in collaboration with Defra, as appropriate, should explore with industry the options for modifying thinning practices to reduce the threat to the biosecurity of broiler farms. If the necessary improvements cannot be made, the FSA and Defra should explore with industry the conditions which would allow the practice of thinning to be discontinued, notwithstanding the economic pressures to which industry has drawn attention. (Priority A)

10.29 If thinning is to continue, crate washing and other biosecurity measures (including clothing and footwear) need urgent improvement. We recommend that the FSA pursues this with stakeholders. (Priority A)

10.30 In order to facilitate evaluation of the effectiveness of *Campylobacter* reduction measures, and to improve controls at slaughter, we recommend that Defra carries out surveillance of *Campylobacter* in broiler flocks. We also recommend that the FSA continues to perform routine surveillance of *Campylobacter* in retail chicken. (Priority A)

10.31 Extensive chicken production is a minor but nevertheless important feature of the UK market. We believe that consumers would benefit from knowing more about the *Campylobacter* status of this type of product. We therefore recommend surveillance :-

- by Defra to determine the prevalence of *Campylobacter* in extensively-reared flocks and the *Campylobacter* spp. involved; (Priority B)
- by the FSA to determine the *Campylobacter* status of free range, organic and other extensively-produced chicken meat on retail sale in the UK. (Priority B)

10.32 We also recommend further research into how *Campylobacter* can be more effectively controlled in extensively-reared chickens. We note that the FSA is already considering funding research in this area and welcome the fact that the Agency has invited Expressions of Interest from researchers. (Priority B)

Chapter 5 : Measures to prevent *Campylobacter* contamination of chicken meat in Scandinavia

10.33 The ACMSF's overall conclusions drawn from visits to Denmark and Norway by some of the members of its *Campylobacter* Working Group are that :-

- nothing that the sub group saw in either Denmark or Norway served to undermine the Committee's views on the feasibility of the on-farm control of *Campylobacter* in housed chickens;
- indeed, the Norwegian experience especially offered further encouragement that on-farm control in housed birds is achievable on a commercial scale;
- Denmark appears to have established a premium market for *Campylobacter*-free chicken;
- Norway has succeeded in getting the contamination rate for fresh chicken products in retail outlets down below 10%;

- the UK broiler industry still has some catching up to do but is, for the most part, on the right track;
 - however, the UK industry needs to be encouraged to maintain its best endeavours;
 - opportunities for collaboration between researchers here and those in Denmark and Norway were identified;
 - some thought needs to be given to the efficacy and wider implications of heat treating or freezing *Campylobacter*-positive carcasses;
 - the potential for airborne transmission of *Campylobacter* on farms may need further investigation but could necessitate some quite detailed research.
- 10.34 Sweden has succeeded in reducing overall *Campylobacter* infection in flocks to below 10%. It is encouraging that, within this figure, around half of all broiler farms were able to keep *Campylobacter* out of flocks completely. The methods used to achieve these results (eg. robust biosecurity, dry litter) are not innovative and are readily applicable to the UK setting. This information about the situation in Sweden provides further support for the observations made and the conclusions drawn by members of our *Campylobacter* Working Group following their visit to Denmark and Norway.

Chapter 6 : *Campylobacter* in poultry other than chicken

10.35 Such evidence as we have seen suggests that all commercial poultry species are as susceptible as chicken to *Campylobacter* colonisation. However, we note that there appears to be little hard information available about the UK situation, and most of the data quoted in this Report come from abroad.

10.36 We recommend that, in addition to the work it is doing on chicken meat, the FSA carries out surveillance to establish the *Campylobacter* status of other types of poultry meat on retail sale in the UK. (Priority A)

Chapter 7 : Measures to prevent *Campylobacter* contamination of meat other than chicken and other poultry meat

10.37 *Campylobacter* spp., including those which cause human disease, are likely to be widespread in the environment, and it is not surprising that food producing animals such as cattle, sheep and pigs are exposed to this organism. In terms of risk management, it seems sensible to assume that all flocks and herds will contain animals which are likely to be colonised with *Campylobacter* and to take steps during the slaughter

process to minimise the likelihood that these are transferred to the final products leaving the plant. The control measures required to achieve this aim will be essentially the same for *Campylobacter* as for organisms such as *Salmonella* and VTEC. We do not therefore consider that there is a need for *Campylobacter*-specific measures.

10.38 We recognise that both Government and industry have developed and put in place a number of measures to minimise the possibility of faecal material being transferred from the gut (or indeed the hide and fleece) during the slaughter process. We believe that, if properly applied, these will provide an effective barrier against *Campylobacter* contamination.

10.39 Cross-contamination is a particular concern in relation to *Campylobacter*. We believe that the proposed new EU meat inspection requirements, by reducing the use of palpation and incision, will help reduce the risk of cross-contamination. We agree that improving the flow of information across the food chain is likely to assist traceability and facilitate application of disease control and food hygiene measures at the most effective points.

10.40 We believe that the quality of the information trail would be further enhanced if *Campylobacter* flock prevalence data were available at slaughter. We address this in Chapter 4.

10.41 In view of the variations in the data for the prevalence of *Campylobacter* in retail meat samples, and in order to obtain a clearer picture of the risk if any to public health from such products, **we recommend that the Food Standards Agency should undertake UK wide, large-scale, structured surveillance of the prevalence of *Campylobacter* in red meat on retail sale. (Priority A)** We note that the Agency has recently requested pilot work in this area.

Chapter 8 : Measures to prevent *Campylobacter* cross-contamination in domestic and catering environments

10.42 Raw poultry meat, particularly chicken, is, and will continue for the foreseeable future to be, a significant vehicle by which *Campylobacter* is introduced into the domestic and catering environments. Levels of *Campylobacter* contamination of $>10^5$ cfu are seen on some chicken carcasses. The human infectious dose is reported to be as low as 500 cells. Given the likely difficulties involved in controlling high levels of contamination in the kitchen, especially from sources such as raw poultry, we reiterate the critical significance of reducing the levels and incidence of *Campylobacter* on such products to lessen the burden on domestic and catering premises in dealing with such hazards.

10.43 If *Campylobacter* can be effectively tackled at the primary production stage, then the anticipated reduction in the number of *Campylobacter* cells reaching the kitchen would enhance the effectiveness of normal hygiene measures taken there. We make a number of

recommendations below designed to enhance the effectiveness of action in the domestic and catering environments.

- 10.44 We strongly recommend the proper use in catering of meat thermometers, as a means of ensuring the effective cooking of raw poultry products in particular. The use of such devices in the home may also yield benefits and we recommend that the Food Standards Agency (FSA) considers communicating the benefits of the use of cooking thermometers for domestic and catering settings. We also recommend that, as part of its review of HACCP implementation in the catering sector, the FSA considers whether documentary evidence of effective temperature checks should be required to be kept. (Priority A)**
- 10.45 We recommend that industry guidance is produced through trade associations, to ensure a consistent approach to the generation of on-pack cooking instructions. In addition, where guidance is provided, this should feature prominently on the packaging. (Priority A)**
- 10.46 In the case of meat which is not pre-packed, we recommend that the industry examines the feasibility of providing cooking guidance on all raw meat and poultry products, including those sold from service counters, butchers and other similar outlets. (Priority A)**
- 10.47 We believe that the practice of washing raw meat and poultry is likely to lead to increased risk of spread of *Campylobacter* in the kitchen through splashes, droplets and aerosols, given the high levels which may be present on raw chicken. We recommend that this practice be actively discouraged by the FSA and industry. (Priority A)**
- 10.48 Whilst it is understood that the consumer does not always read such advice, we recommend, in the public interest, that all producers and retailers of foods, where enteric pathogens such as *Campylobacter* may be present, should provide advice on the key food safety steps which should be taken to prevent infection. This should, as a minimum, be applied to all raw poultry products, as the levels of the organism are known to be high. Advice should include measures for effective cooking and for the avoidance of cross-contamination from the raw food to ready-to-eat food (through separation of foods and utensils, and through hand washing). (Priority A)**
- 10.49 We are aware of previous activity by the FSA to provide targeted advice to consumers regarding improved cooking/hygiene practices when barbecuing and we recommend that this approach be repeated prior to each summer period. (Priority A)**

10.50 We recommend that the industry provides food safety/hygiene advice on the packaging of foods for barbecues, particularly raw meats, and especially poultry. (Priority A)

10.51 We recommend that attention is drawn to the potential risks associated with carriage of *Campylobacter* in domestic pets, and to the appropriate hygiene measures that should be adopted. (Priority A)

10.52 We recommend that further measures are taken to embed food hygiene and safety principles into the education of primary and secondary school children. (Priority C)

10.53 In light of the fact that basic precautions may not be sufficient to prevent *Campylobacter* cross-contamination from highly contaminated foods such as raw chicken, we recommend that the FSA considers what measures can be taken to highlight to caterers and consumers the heightened risks associated with certain foods such as raw poultry. (Priority A)

Chapter 9 : *Campylobacter* detection and typing

Detection

10.54 It is likely that, for the foreseeable future, traditional culture techniques will be employed for the examination of clinical and non-clinical samples for *Campylobacter* spp. More rapid methods are now available but there is a need to ensure that they have sufficient sensitivity. Any method will suffer from inherent bias and this will continue to be a problem in studies on epidemiology and in comparison of different surveillance schemes. The isolation of *Campylobacter* would seem to be more difficult than for *Salmonella*, for example, and there is a need for more rigour in method choice and for a properly structured, multi-laboratory study of the most commonly used methods. This is an area our *Campylobacter* Working Group will need to consider in reviewing research needs relating to *Campylobacter* (see Chapter 1).

Typing

10.55 Speciation of *Campylobacter* has proved useful in differentiating epidemiologically between *C. coli* and *C. jejuni*.

10.56 *Campylobacter* typing should be driven by objectives and/or specific hypotheses. These might be :-

- tracing sources and routes of transmission of human infection;
- identifying and monitoring, both temporally and geographically, strains with important phenotypic or genotypic characteristics;

- developing strategies to control organisms within the food chain;
- monitoring trends in antimicrobial resistance; and
- outbreak identification

The method(s) chosen should then be dictated by specific objectives and/or hypotheses. In addition to this, appropriate sampling frames should be used.

- 10.57 Typing has confirmed the complexity of the epidemiology of *Campylobacter* infection but, on a broad scale, has not yielded the expected public health benefits in terms of identifying a big target amenable to control. Routine typing is probably not useful for source tracing and global epidemiology because of the carriage of multiple strains in animals, and the extreme diversity of those strains. Completing the analyses of the CSSS is, however, needed since the requirement for national strain-specific epidemiological studies might yet be demonstrated.
- 10.58 Where the objective is to make an assessment of *Campylobacter* across the food chain in relation to human infection, veterinary, food and clinical laboratories should use the same methods. One of the problems with comparative epidemiology is that different techniques have been applied to different specimen types. It is important that, when carrying out research and surveillance in animals, isolation and typing methods should take the lead from, and be consistent with, methodologies used for clinical isolates unless there are specific reasons not to do so. This recognises the fact that *Campylobacter* is primarily of public health significance.
- 10.59 The technological revolution in clinical medicine means that, in future, direct detection and typing using clinical samples will be possible. An obvious benefit of this approach is the speed of diagnosis and the potential for real time epidemiology. DNA sequence-based methods like MLST therefore have the greatest potential to be “future-proof”.
- 10.60 The variability and genetic instability of *Campylobacter* cautions us against believing that there exists some magical solution to the typing of all campylobacters of human health significance. However, any improvement in the tools available for differentiating the origins or food sources of *Campylobacter* spp. would greatly assist the Food Standards Agency in tackling human campylobacteriosis. Examination of the history of the many typing methods summarised in Tables 9.1 and 9.2 prompted much discussion within the *Campylobacter* Working Group as to whether the ACMSF could make a firm recommendation in this area. We have now concluded that the DNA sequence-based MLST method offers an opportunity in the short to medium-term to improve our knowledge of what is a very complex epidemiological story.

- 10.61 The availability of whole genome sequence data offers the prospect of another potentially valuable approach to typing. DNA microarrays based on the complete set of sequenced genes offer a unique opportunity to investigate and compare genome composition for individual isolates of a species. This approach has been applied to *Campylobacter* and its further development and validation may provide a novel typing approach of practical value in the future.
- 10.62 As with all typing methods for food poisoning pathogens, different laboratories will take different approaches, and agreement will be difficult to reach. **We therefore believe that the Food Standards Agency needs to take a firm initiative in bringing together laboratories capable of applying MLST so that investigative programmes can be designed to improve our epidemiological understanding in the next few years. We so recommend. (Priority A)**
- 10.63 We want to be very clear that this is in no way a recommendation that, at this stage, the FSA should be funding large research programmes on typing methods. Rather, it is a recommendation that advantage is taken of the opportunity to get the most out of MLST in the shorter-term.

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

ANNEX A

Membership of the Advisory Committee on the Microbiological Safety of Food and the *Campylobacter* Working Group. Participants in the ACMSF *Campylobacter* workshop

Advisory Committee on the Microbiological Safety of Food

Terms of reference

To assess the risk to humans from microorganisms which are used or occur in or on food and to advise the Food Standards Agency on any matters relating to the microbiological safety of food

Membership

Chairman

Professor D L Georgala Retired Director of the Institute of Food Research

Members

Dr G R Andrews	Head of Technical Services, Northern Foods plc
Dr D W G Brown	Director, Enteric, Respiratory and Neurological Virus Laboratory, Health Protection Agency
Ms S Davies	Principal Policy Adviser, Consumers' Association
Professor M J Gasson	Head of Food Safety Science Division, Institute of Food Research
Dr K M Hadley	Senior Lecturer, Department of Immunology and Bacteriology, University of Glasgow. Honorary Consultant in Clinical Microbiology, North Glasgow University Hospitals NHS Trust, Western Infirmary, Glasgow
Professor T J Humphrey	Professor of Food Safety, University of Bristol
Professor P R Hunter	Professor of Health Protection, University of East Anglia
Professor A M Johnston	Professor of Veterinary Public Health, Royal Veterinary College, University of London
Mr A Kyriakides	Head of Product Safety, Sainsbury's Supermarkets Ltd
Ms E Lewis	Computer consultant. Consumer representative
Mr P Mepham	Environmental Health Manager (Policy and Support), Leeds City Council
Dr S J O'Brien	Head of Gastrointestinal Diseases Division, Health Protection Agency Communicable Disease Surveillance Centre

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

Mr B J Peirce	Caterer
Mr D J T Piccaver	Farmer
Dr Q D Sandifer	Director of Public Health, Swansea Local Health Board. Consultant in Public Health Medicine, Velindre NHS Trust
Dr T D Wyatt	Consultant Clinical Scientist, Mater Hospital Trust, Belfast

Assessors

Dr L Doherty	Northern Ireland Department of Health, Social Services and Public Safety
Mr P J R Gayford	Department for Environment, Food and Rural Affairs
Dr J Hilton	Food Standards Agency
Dr G McIlroy	Northern Ireland Department of Agriculture and Rural Development
Dr S Pryde	Food Standards Agency (Scotland)
Mr S Wearne	Food Standards Agency (Wales)

Secretariat

Administrative Secretary

Mr C R Mylchreest Food Standards Agency

Scientific Secretary

Dr P E Cook Food Standards Agency

Administrative Secretariat

Mrs E A Stretton Food Standards Agency

Miss C L Wilkes Food Standards Agency

***Campylobacter* Working Group**

Terms of reference

To identify any important gaps and omissions in action taken to reduce *Campylobacter* in food and food sources and in the knowledge base; and to develop advice which will assist the Food Standards Agency in evolving its strategy for reducing the incidence of foodborne *Campylobacter* infection in humans

Membership

Chairman

Professor D L Georgala

Members

Ms S Davies

Professor M J Gasson

Professor T J Humphrey

Professor P R Hunter

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

Professor A M Johnston

Mr A Kyriakides

Ms E Lewis

Dr S J O'Brien

Mr B J Peirce

Mr M Attenborough Technical Director, Meat and Livestock Commission

Dr E Berndtson² Svenska Klackeribolaget AB, Sweden. *Campylobacter*
consultant to the Swedish Poultry Association

Assessors

Mr P J R Gayford

Dr J Hilton

Professor C H McMurray³ Northern Ireland Department of Agriculture and Rural
Development

Dr S Neill⁴ Northern Ireland Department of Agriculture and Rural
Development

Secretariat

Administrative Secretary

Mr C R Mylchreest

Scientific Secretary

Dr J P Back Food Standards Agency

Administrative Secretariat

Mrs E A Stretton

Miss C L Wilkes

Participants in ACMSF *Campylobacter* Workshop : Britannia International Hotel, London Docklands : 13-14 February 2002

Participants

ACMSF members

Professor D L Georgala

Dr G R Andrews

Dr D W G Brown

Ms S Davies

Dr K M Hadley

Professor T J Humphrey

² Until December 2002

³ Until 16 August 2002

⁴ From October 2002

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

Mr A Kyriakides

Ms E Lewis

Professor P Mensah

Dr S J O'Brien

Mr B J Peirce

ACMSF assessors

Mr P J R Gayford

Professor C H McMurray

Dr S Pryde

Dr R Skinner Food Standards Agency

ACMSF Secretariat

Dr J Hilton

Mr C R Mylchreest

Mrs E A Stretton

Miss C L Wilkes

External participants

Mr M Attenborough

Dr J P Back

Dr E Berndtson

Dr K Callaghan Food Standards Agency

Miss M Castle Food Standards Agency

Dr P E Cook Food Standards Agency

Dr J M Cowden Scottish Centre for Infection and Environmental Health

Miss O Doyle Food Standards Agency

Mrs J Frost Public Health Laboratory Service Central Public Health Laboratory

Dr E Hartnett Department for Environment, Food and Rural Affairs
Veterinary Laboratories Agency

Dr K Jones Lancaster University

Dr J Knight Food Standards Agency (Scotland)

Mrs J Lock Food Standards Agency

Professor D Newell Department for Environment, Food and Rural Affairs
Veterinary Laboratories Agency

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

Dr R L Salmon	Public Health Laboratory Service Communicable Disease Surveillance Centre, Wales
Dr W van Pelt	National Institute of Public Health and the Environment, the Netherlands
Dr M Wooldridge	Department for Environment, Food and Rural Affairs Veterinary Laboratories Agency
Dr B Wren	London School of Hygiene and Tropical Medicine

Presentations

Mrs J Frost	<i>Campylobacter</i> detection and typing research : an overview
Dr K Callaghan	<i>Campylobacter</i> : the disease and the immune system : summary of FSA-commissioned work
Miss O Doyle	Other <i>Campylobacter</i> research
Professor D Newell	Animal models of <i>Campylobacter jejuni</i> disease
Dr B Wren	What has the <i>Campylobacter</i> genome sequence/genomics done for us ?
Dr J Cowden	<i>Campylobacter</i> in the Infectious Intestinal Disease (IID) Study
Dr S O'Brien	What are the main sources/vehicles for human <i>Campylobacter</i> infection ?
Dr W van Pelt	Some questions and possibilities for studies on <i>Campylobacter</i> : a Dutch point of view
Mr P Gayford	Prevalence of <i>Campylobacter</i> in animals
Dr P Cook	Prevalence of <i>Campylobacter</i> in meat and poultry
Miss O Doyle	Epidemiological studies of <i>Campylobacter</i> in Iceland
Professor D Newell	<i>Campylobacter</i> seasonality in human beings and food-producing animals
Dr K Jones	<i>Campylobacter</i> seasonality in food animals
Dr E Hartnett	Quantitative risk assessment for <i>Campylobacter</i> in chicken meat
Professor T Humphrey	The on-farm control of <i>Campylobacter</i> spp. : is this an achievable objective ?
Dr K Jones	Environmental presence and persistence of <i>Campylobacter</i>

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

Organisations supplying information to the ACMSF

B.1 Organisations representing a wide range of interests and expertise were invited to supply the ACMSF *Campylobacter* Working Group with information. Not all responded. Those who did, to whom we are especially grateful, are detailed below.

Oral evidence

B.2 The following organisations gave oral evidence to the Working Group :-

- Assured Chicken Production
- British Poultry Council
- Farm Fed Chickens
- Institute for Animal Health
- Lloyd Maunder Ltd
- Marks and Spencer plc
- Moy Park Ltd
- Northern Ireland Department of Agriculture and Rural Development
- O’Kane Poultry Ltd
- University of Nottingham

Written evidence

B.3 The following organisations provided written evidence to the Working Group :-

- Advisory Committee on Animal Feedingstuffs
- Danish Veterinary Institute
- Food and Drink Federation
- Local Authorities Coordinators of Regulatory Services (LACORS)
- Meyn Food Processing Technology BV
- Norwegian Zoonosis Centre

Visits

B.4 Some members of the Working Group undertook a familiarisation visit to Swanham’s Farm, a broiler farm supplying Lloyd Maunder Ltd, and a Lloyd Maunder processing plant.

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

B.5 Three Working Group members visited Denmark and Norway. A report on this visit is included in Chapter 5.

ANNEX C

Advisory Committee on the Microbiological Safety of Food

Administrative Secretary, Room 813C, Aviation House
125 Kingsway, London WC2B 6NH
Telephone : 0207-276-8951 Fax : 0207-276-8907
E. mail : colin.mylchreest@foodstandards.gsi.gov.uk

Dr J R Bell
Acting Chief Executive
Food Standards Agency
Aviation House
125 Kingsway
London
WC2B 6NH

24 January 2003

ACMSF *CAMPYLOBACTER* WORKING GROUP

1. In connection with the efforts being made to tackle *Campylobacter*, especially in chickens, I thought it appropriate at this time to let you have the ACMSF's views on the situation in Scandinavia.
2. Three members of the *Campylobacter* Working Group (Tom Humphrey, Mac Johnston and Alec Kyriakides) made a short visit to Denmark and Norway in the week beginning 17 November 2002. We wanted the group to investigate whether the incidence of *Campylobacter* in commercially-reared chickens really was lower in these countries. We also asked the group to look at how the Danes and Norwegians were tackling *Campylobacter* in chickens, and to see whether there were any lessons which could be applied in a UK context. Jonathan Back (who is the *Campylobacter* Working Group's Scientific Secretary) also participated in the visit so is well placed to use the information gathered in developing the Agency's *Campylobacter* strategy.
3. Because, in setting up the *Campylobacter* Working Group, we had co-opted Dr Eva Berndtson, a *Campylobacter* consultant to the Swedish Poultry Association, we had not planned a visit to Sweden, the other major player in Scandinavia. Unfortunately, Dr Berndtson has recently had to resign from the Working Group because of pressure of other work. We nevertheless hope that she will be able to provide us with useful material on the situation in Sweden and we are currently pursuing this with her.

Denmark

4. There were 4,620 recorded cases of human *Campylobacter* infection in Denmark in 2001, although the true figure is believed to be much higher, and similar to the UK incidence. There is a much more pronounced summer peak of infection than in the UK. The consumption of poultry meat is a significant risk factor and the Danes have carried out a risk assessment which shows that, where the number of campylobacters on chicken carcasses is reduced by freezing or other means, the risk of human infection is also reduced.

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

5. All poultry flocks in Denmark are subject to surveillance to determine their *Campylobacter* status. Standard protocols are used throughout Denmark, Norway and Sweden. Control of *Campylobacter* in broiler flocks is closer to the current UK position (and less developed than in Norway).
6. The Danes are sceptical about the possibilities for on-farm control. Very hot Danish summers present particular difficulties. Some broiler houses are left open for welfare reasons, and this undermines biosecurity. Danish action against *Campylobacter* is thus more focussed on intervention during or after processing. *Campylobacter* is thought to be particularly sensitive to freezing and work is in hand on the effects of freezing at -18°C for 10 days. The possible use of heat treatment at 75°C for 15 seconds is also being investigated.
7. The group visited a typical, broiler farm. There are broiler farms in the UK of a comparable standard. There were 7 houses each containing 31,000 birds. The farmer operated an all in/all out system. The farm was in good order and the buildings, though over 30 years old, were in good condition. There were 5-10 metres between houses and the site was coated with coarse gravel which was routinely sprayed for weeds. Each house had a 40 cm high, physical hygiene barrier. A wash hand basin was located away from the barrier and the house was not entered via an enclosed ante-room.
8. The group also visited a processing plant, similar to most in the UK. The company does, however, market *Campylobacter*-free chickens, sold at a premium. The requirement of Danish legislation is that "the flock shall be controlled to give a 95% guarantee that less than 1% of birds are infected with *Campylobacter*." 300 samples per flock must be tested. The company has been involved in the development of a PCR method to provide information on *Campylobacter* status within 5 hours.
9. Overall, the group concluded that the current situation in the UK was close to that in Denmark. However, the Danes seemed to derive a real benefit, in terms of the quality of data produced, from a closer integration of the human and animal health surveillance systems. It was also apparent that the regular testing of poultry flocks yielded important information about *Campylobacter* prevalence and seasonality, as well as about geographical differences in colonisation rates.

Norway

10. There has been a marked increase in the number of human cases of *Campylobacter* in Norway since 1997, the annual incidence being around 100 cases per 100,000 of the population. There is an approximate 50:50 split between numbers of cases acquired in Norway and those acquired abroad. There is a marked peak in human infections, approximately 75% of cases occurring in July-September. It is thought that many more cases are caused by water in Norway than in the UK. The consumption of poultry purchased raw is among the principal risk factors although, unfortunately, authoritative data on the level of chicken-associated human cases prior to the introduction of broiler intervention arrangements (see paragraph 11) are not available.
11. Given the rising incidence of human campylobacteriosis, and the association with poultry meat, Norway has introduced an Action Plan Against *Campylobacter* in Broilers. This provides for the surveillance of live animals, animals at slaughter, and poultry meat products. Ten composite faecal samples are collected on farms 4-8 days prior to slaughter. If these samples are *Campylobacter*-positive, the birds are slaughtered at the end of the day. Carcasses are either heat-treated, or frozen for 5 weeks. There is also follow up action on *Campylobacter*-positive farms. This comprises standardised consultations and the introduction of measures to reduce flock infection, namely the disinfection of drinking water and the introduction of hygiene barriers. There is also a farm-based research programme to identify risk factors for *Campylobacter* infection in flocks.

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

12. The Norwegian poultry industry is only about a tenth the size of the UK industry. Most birds are killed earlier than in the UK (at 32-33 days). In 1991, 18% of broiler flocks (sampled on-farm) were *Campylobacter*-positive. This had fallen to 4% in 1998. The most recent surveillance (2001-2002) produced an on-farm incidence figure of 7.6%. As with human infection, there is a marked seasonality, with around 90% of positive flocks being identified in the summer months.
13. The group visited a typical Norwegian broiler farm, comprising 1 house of 11,000 birds. Access to the house was via an ante-room which had three rooms, each with a door, coming off it. One room served as an office and had a window through which the flock could be observed. Access to the flock was through a door on the other side of the ante-room in which a physical hygiene barrier had been placed. There were dedicated overalls and footwear on the bird side of the barrier. The room also contained a wash hand basin which the farmer used before putting on protective clothing and footwear. **These simple interventions were sufficient to protect birds from *Campylobacter* in spring, autumn and winter and, to some extent, in summer.**
14. The group also visited a poultry processing plant which was typical of most in Europe and employed no devices which were not already in use in the UK. The plant was smaller, and tighter for space than in the UK. Water usage was high. Unlike in the UK, birds were spray-chilled with cold water. Although Norway does not sell "*Campylobacter*-free" poultry at retail, the goal is to reduce the level of *Campylobacter* in broiler chickens at slaughter to as close to zero as possible.
15. The prevalence of *Campylobacter* contamination in fresh poultry products ranged between 4 and 10% over the period 1995-1998. Further fresh product surveys were carried out in 2001 (at production facilities) and 2002 (in shops). Just over 1,000 samples were taken in each survey. *Campylobacter* prevalence was <10% in 2001 and around 2% in 2002.
16. The group felt that Norway provided some useful indications of what could be achieved by targeted on-farm intervention. Hygiene barriers seemed a cheap and effective counter-measure which the UK industry should be pressed to adopt as a matter of urgency. The rather different epidemiology of infection among broilers in Norway, compared with the UK, perhaps indicates a particular source of infection in the summer and the possible involvement of contaminated air in its transmission. The potential for airborne transmission on farms may need further investigation. This could require some quite detailed research.

Overall conclusions from Denmark/Norway visits

17. Our overall conclusions drawn from the group's visits are that :-
 - nothing the group saw in either Denmark or Norway served to undermine the advice I sent you on 26 September 2002 about the feasibility of the on-farm control of *Campylobacter* in chickens;
 - indeed, the Norwegian experience especially offered further encouragement that on-farm control is achievable on a commercial scale;
 - Denmark appears to have established a premium market for *Campylobacter*-free chicken;
 - Norway has succeeded in getting the contamination rate for fresh chicken products in retail outlets down below 10%;
 - the UK broiler industry still has some catching up to do but is, for the most part, on the right track;

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

- however, the UK industry needs to be encouraged to maintain its best endeavours;
- opportunities for collaboration between researchers here and those in Denmark and Norway were identified;
- we need to give some further thought to the efficacy and wider implications of heat treating or freezing *Campylobacter*-positive carcasses.

Sweden

18. As noted earlier, we are actively seeking information about the situation in Sweden which we can incorporate into our final Report, along with a more detailed summary of the Denmark/Norway visits, as part of a Scandinavian overview. In the meantime, if what we obtain about Sweden provides any new insights into how best to tackle *Campylobacter*, I will let you know.

19. I am copying this letter to Andrew Wadge and Judith Hilton.

Yours sincerely

DOUGLAS L GEORGALA

Assured Chicken Production

Introduction

D.1 Assured Chicken Production (ACP) is one of the organisations which gave evidence to the ACMSF *Campylobacter* Working Group. ACP sets nutrition and welfare standards for poultry and verifies compliance with these standards by producers who are members of the Scheme. ACP is also committed to developing standards to achieve high levels of food safety and environmental care.

ACP structure

D.2 In its evidence to the *Campylobacter* Working Group, ACP explained that it is an independent company owning and developing the Assured Chicken Production Scheme standards for poultry. It is a company limited by guarantee. Membership of the company comprises the British Retail Consortium, the British Poultry Council, and the National Farmers' Union of England and Wales.

D.3 ACP is controlled by a Board of Directors responsible for the direction, overall management, and administration of the company. A Technical Advisory Committee monitors and sets the standards for the Scheme. A company operates a certification system on behalf of ACP. This is linked to a Certificate of Approval and the approved scheme mark. The certification system requires the examination of product, the production process, the production environment, and assessment of the quality management system.

D.4 The ACP Scheme covers some 90% of the poultry industry. Any site involved in chicken production is eligible to apply to join the ACP Scheme. Following assessment and acceptance, members' performance is subject to on-going surveillance.

ACP poultry standards³³⁵

D.5 ACP operates very detailed poultry standards applicable in respect of breeder replacement farms, breeder layer farms, and free range chickens for human consumption. The standards cover the farm site and emergency plan; health and hygiene; management and stockmanship; feed and water; the environment; provisions for chicks and breeder layer flocks; records; and depopulation.

D.6 Similar standards apply in relation to hatcheries; and there are detailed provisions covering catching, transport and slaughter.

D.7 Features of the standards include

- health and welfare programmes tailored to the needs of individual units;
- measures covering bird health;
- training to improve stockmanship;
- detailed rules on feed and water, the construction and maintenance of buildings, and lighting, temperature, ventilation, air quality and litter.

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

D.8 Standards stipulate the biosecurity measures which must be employed. ACP Scheme members are required to monitor for *Salmonella* but there are no measures specifically aimed at tackling the problem of *Campylobacter*. In its evidence to the *Campylobacter* Working Group, ACP identified areas where it thought *Campylobacter* could be most effectively addressed on-farm. These were the clothing, equipment and behaviour of stockmen, the sanitation of crates and other equipment, improved biosecurity in poultry houses, and staff education in general. Other areas being closely monitored are vaccine development, competitive exclusion, the use of bacteriophage, and the breeding of genetically resistant birds.

The UK market for extensively-reared poultry

Production and marketing

E.1 Although a growing sector, extensively-reared (ie. organic or free range) chicken comprises a relatively small element of the overall chicken meat market. Approximately 1.2 million tonnes (carcass weight equivalent) of chicken meat is currently produced annually in the UK. Of this, approximately 4% (c. 50,000 tonnes) is produced extensively.³³⁶

E.2 However, there has been a steady increase in sales of organic meat (including poultry meat) in the UK in recent years (see Table E.1).

Table E.1 : Sales of organic meat (including poultry meat) by value, 1996-2001

	Value (£m)	Index	Value (£m) at 1996 prices	Index
1996	26	100	26	100
1997	32	123	32	123
1998	42	162	41	159
1999	53	204	52	199
2000	67	258	66	253
2001 (est)	83	319	81	310

Source: Mintel³³⁷

E.3 Organic poultry meat is estimated to have accounted for 0.54% of the British poultry meat market in 2001, a figure predicted to rise to over 1% by 2008 (see Table E.2).

Table E.2 : The British market for organic poultry meat

Year	Volume (tonnes)	Value (\$ million)	Increase over 1998 value
1998	853	7.3	-
1999	1,200	9.8	34%
2000	1,956	14.7	101%
2001	3,500	25.0	242%
2008 (Forecast)	7,259	50.3	589%

Source : Organic Monitor³³⁸

E.4 One source³³⁸ has organic chicken accounting for more than 95% of organic poultry meat sold in the UK (the only other significant organic poultry meat sold in the UK being organic turkey), and more than one-third of organic poultry meat sold in the UK coming from imports in 2001. France is identified as the major source of these imports, although it is noted that a significant expansion in UK production resulted in a fall in imports in 2002 (when they accounted for only 14% of supplies).

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

E.5 The shares of the principal UK producers of organic poultry meat to the domestic market are shown in Table E.3.

Table E.3 : The British market for organic poultry : market shares of major suppliers : 2001

Company	Production (tonnes)	Market share
Moy Park	1,000	28.6%
Premier Fresh Foods	1,000	28.6%
Lloyd Maunder	400	11.4%
Others	1,100	31.4%
Total	3,500	100.0%

Source : Organic Monitor³³⁸

Consumer perceptions and demand

E.6 Research suggests that consumers are drawn to organic foods for a variety of reasons. A Consumers' Association survey in 2001³³⁹ found that 30% of respondents always, usually or sometimes bought organic. Thirty two per cent of these said the reason was because 'it's healthier/better for you generally'. Twelve per cent bought organic for 'better standards of animal welfare.' The most popular reason given was, however, 'taste' (34%). The results are shown in Table E.4.

E.7 Data from the annual TGI survey looking at food safety in 2001, and drawn from a nationally-representative sample of 25,000 adults, found that 32.8% agreed with the statement 'I buy free-range products wherever I can'. This was down slightly on the 2000 figure of 34.9%. This survey also found that 20% of those surveyed felt that it was worth paying more for organic foods. This rose to 25% in the 25-44 age group, and 29% for socio-economic group ABs. Therefore, while this is still a limited sector, many consumers are now choosing organic and free range poultry products. Both of these terms are defined within EU regulations which apply across the Community.

Table E.4 : Reasons for buying organic

Prefer the taste	34%
Less use of pesticides	32%
It's healthier/better for you generally	32%
It's a more natural process	24%
Less use of drugs in animals	17%
It's better for the environment	14%
Concern about GM	14%
It has more vitamins and minerals	12%
Better standards of animal welfare	12%
Prefer the texture/appearance	7%
My family/friends prefer it	5%
Lower risk of BSE	4%
Lower risk of food poisoning	3%
Don't know	8%

(Base: 482 - all buy organic food at some time)

Source: Consumers' Association

Organic production standards

E.8 Organic poultry production is based on the rigorous application of a range of production and welfare considerations. The term 'organic', when applied to agricultural products and

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

foodstuffs, is controlled by the Organic Products Regulations 2001 which implement the requirements of EC Council Regulation 2092/91. Standards for organic livestock production came into effect from August 2000, following an amendment to the legislation.

E.9 Disease prevention in organic livestock is based on the following principles :-

- the selection of appropriate breeds;
- the application of animal husbandry practices appropriate to the requirements of each species, encouraging strong resistance to disease and the prevention of infections;
- the use of high quality feed, together with regular exercise and access to pasturage, having the effect of encouraging the natural immunological defence of the animal;
- ensuring an appropriate density of livestock, thus avoiding over-stocking and any resultant animal health problems;
- prohibition on the use of substances to promote growth or production (including antibiotics, coccidiostats and other artificial aids for growth promotion purposes);
- prohibition on the use of chemically-synthesised allopathic veterinary medicinal products or antibiotics for preventive treatments;^(a)
- an 81 day minimum age for slaughter of poultry (except in the case of slow growing breeds);
- specific provisions for transport aimed at minimising stress. For example, during transit each bird should have sufficient space to rest and stand up without restriction, and birds should be protected from undue fluctuations in temperature, humidity or air pressure, and sheltered from extremes of weather;
- full inspection of the production unit at least once a year, and the possibility of unannounced inspection visits by the inspection body.

Free range standards

E.10 While organic poultry must be free-range,^(b) poultry labelled as 'free range' will not necessarily be organic. The criteria for stocking densities also differ between the two categories - with stricter criteria for organic production. The term 'free-range' is defined within EC Council Regulations 1906/90 and 1538/91 which lay down certain marketing standards for poultry meat.

E.11 'Free range' may only be used where the stocking rate in the house is 13 birds (not more than 27.5 kg liveweight) per square metre and where the birds are slaughtered at 56 days or later. In addition, the birds must have continuous daytime access to open-air runs comprising an area mainly covered by vegetation of not less than 1m² per chicken. The feed formula used in the fattening stage must contain at least 70% of cereals. The poultry house must be provided with pop holes of a combined length of at least equal to 4m per 100m² surface of the house.

^(a) the prohibition on preventative treatment does not mean that veterinary medicines cannot be used (albeit with increased withdrawal periods) if the health of the stock warrants it. This could include action where there were indications of *Campylobacter* infection.

^(b) In practice, standards for organic poultry are slightly less onerous than for birds officially designated as 'free range'. Free range birds must have continuous day time access to the open air. Organic birds on the other hand must have access to an open air run whenever weather conditions permit and, where possible, must have access for at least one-third of their lives.

***Campylobacter* control measures**

E.12 As noted in Chapter 4, we think that extensively-reared chickens are likely to come into more frequent contact with *Campylobacter* which is ubiquitous in the environment. We also believe that it will be very difficult to maintain high levels of biosecurity in the extensive production setting. Given the fact that an important reason why consumers buy organic is because they consider organic produce to be healthier and better for you,³³⁹ it is important that consumers are aware of this risk. This question is addressed in Chapter 4. Given consumer interest in this sector – for a variety of reasons, including animal welfare – it is also important that more research is undertaken into both the prevalence of *Campylobacter* in extensively-reared birds and how this could be more effectively controlled.

ACMSF SECOND REPORT ON *CAMPYLOBACTER*

IMPLEMENTATION OF RECOMMENDATIONS

Recommendation	Response
<p>(2.37) We recommend that the Government should instigate a primary care-based sentinel surveillance system, aimed at measuring directly the incidence and economic cost of long-term <i>sequelae</i> among cases of <i>Campylobacter</i> infectious intestinal disease. (Priority B)</p>	<ul style="list-style-type: none"> • Possible FSA research requirement in 2005-06. • The Agency is currently considering funding for a second Infectious Intestinal Disease (IID) study to provide updated information on the burden of illness including campylobacteriosis but this will not include the long-term <i>sequelae</i>. Due consideration will be given to this recommendation and mechanisms of funding once the proposed second IID study has been progressed.
<p>(2.38) We recommend that serological markers for recent infection and prior immunity be developed and tested through structured, epidemiologically robust, population-based studies. This should assist with estimating the prevalence of asymptomatic infection in the population (and hence estimating more accurately the magnitude of <i>Campylobacter</i>-associated <i>sequelae</i>). (Priority C)</p>	<ul style="list-style-type: none"> • Possible FSA research requirement in 2005-06. • The FSA is already funding work using serological markers to look for evidence of VTEC O157 infection using non-invasive samples (e.g. saliva). Further work is needed to develop robust markers for <i>Campylobacter</i> before such tools can be applied in population-based studies to identify patterns and trends.
<p>(3.30) The contribution of foodborne transmission (as opposed to other transmission modes) to the human toll of <i>Campylobacter</i> needs to be better defined and we note that the FSA has already funded a research project designed so to do. We support this course of action. (Priority A)</p>	<ul style="list-style-type: none"> • The Agency is funding several research projects including a case control study of risk factors for <i>Campylobacter</i> infectious intestinal disease in England and Wales, and work on the burden of environmental and waterborne sources of <i>Campylobacter</i>, and will take stock when this programme of research completed.
<p>(3.31) We recommend that population studies to investigate the seasonality of <i>Campylobacter</i> infection be undertaken. An approach combining epidemiological, microbiological, environmental and veterinary expertise is likely to be needed. (Priority A)</p>	<ul style="list-style-type: none"> • The Agency is planning a meeting of key groups to be held in 2005 to look at the feasibility of linking studies on <i>Campylobacter</i> in human illness, animals, and the environment to the rolling surveillance of food. • Current surveillance of retail chicken in Wales is already providing information on seasonality of contamination and more extensive sentinel surveillance is to be initiated by LACORS/HPA/FSA in November 2004. This study will also include a Local Authority administered follow-up questionnaire for laboratory confirmed sporadic cases of campylobacteriosis and salmonellosis to enable the HPA to identify outbreaks and

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

Recommendation	Response
	<p>common factors linked to infections.</p> <ul style="list-style-type: none"> • FSA are also funding work in NW England looking at the role of environmental factors such as water.
<p>(3.32) We recommend that population studies to investigate cultural/behavioural risk factors for <i>Campylobacter</i> be undertaken. (Priority B)</p>	<ul style="list-style-type: none"> • To await outcome of study on cross-contamination in 2004-05. • The Agency will be funding a review of studies on cross-contamination in the home and this may assist in identifying specific gaps where population studies could be undertaken. • Some information is also likely to arise from the <i>Campylobacter</i> epidemiology studies being put in place. In addition to the LACORS/HPA/FSA sentinel surveillance of poultry meat, LAs will be gathering information on sporadic cases of campylobacteriosis and salmonellosis to enable the HPA to identify outbreaks and common factors linked to infections.
<p>(3.33) We recommend that more extensive data are gathered on the levels of <i>Campylobacter</i> spp. in specific foods (e.g. water, dairy products, vegetables, poultry and red meat) as well as in food-producing animals and companion animals. These are all potential sources of exposure for humans. We recommend that consideration be given to on-going surveillance as well as to “snap-shots” which tend to be the norm. It is very important that the microbiological methods employed allow meaningful comparisons to be made across the food chain. (Priority A)</p>	<ul style="list-style-type: none"> • Surveillance of chicken to continue for at least the next 3 years probably on rolling basis. The Agency will review this as a basis for considering roll-out surveillance to other types of food. A sentinel LA based sampling program has been established by LACORS/HPA/FSA to provide data on <i>Salmonella</i> and <i>Campylobacter</i> contamination of raw chicken on an ongoing basis. Sampling under this new initiative is expected to start in November 2004. A Defra-funded abattoir survey has been carried out by the VLA. • The Agency also tries to make sure <i>Campylobacter</i> is included in current and future HPA/LACORS surveys, where appropriate. Collation of this survey data by the Epidemiology of Foodborne Infections Group (which reports to the ACMSF) will help identification of priorities for further work.
<p>(4.65) Our principal recommendation is that the Food Standards Agency utilises the conclusions we have drawn to intensify its work with the poultry industry and other stakeholders to achieve wider acceptance that <i>Campylobacter</i> control of housed birds is now possible. A primary aim should be to develop an industry-wide programme to spread the “good farming” practices and biosecurity measures which lie at the heart of the matter. (Priority A)</p>	<ul style="list-style-type: none"> • The Agency launched the second stage of the biosecurity campaign in October 2004. • Initial stage of biosecurity campaign to educate and train poultry farmers in best practice was launched on 19 January 2004. • Stage 2 of the campaign, launched on 4 October, involves face-to-face communication to farmers of the basic biosecurity messages,

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

Recommendation	Response
	<p>why they are important, and the evidence that they are effective in reducing <i>Campylobacter</i>. The campaign messages will continue to be communicated at Growers meetings over the autumn, with follow-up seminars in spring 2005.</p>
<p>(4.66) We recommend that the FSA, in collaboration with Defra, as appropriate, should explore with industry the options for modifying thinning practices to reduce the threat to the biosecurity of broiler farms. If the necessary improvements cannot be made, the FSA and Defra should explore with industry the conditions which would allow the practice of thinning to be discontinued, notwithstanding the economic pressures to which industry has drawn attention. (Priority A)</p>	<ul style="list-style-type: none"> • The Agency has commissioned research to provide detailed and practical information on best practice, which will enable publication of a code of best practice on thinning for the UK poultry industry.
<p>(4.67) If thinning is to continue, crate washing and other biosecurity measures (including clothing and footwear) need urgent improvement. We recommend that the FSA pursues this with stakeholders. (Priority A)</p>	<ul style="list-style-type: none"> • As per 4.66. • The Agency will work with stakeholders to identify improvements in other biosecurity measures and promote these in the next stage of the biosecurity campaign. • Output from FSA project MO1023 will identify the best operating regime for existing crate washing systems, identify simple improvements which can be made to the equipment now, and propose measures which can be incorporated in future designs. Best practice information developed within this project will be communicated to the poultry processing industry during Autumn 2004 as part of the Agency's <i>Campylobacter</i> biosecurity campaign.
<p>(4.68) In order to facilitate evaluation of the effectiveness of <i>Campylobacter</i> reduction measures, and to improve controls at slaughter, we recommend that Defra carries out surveillance of <i>Campylobacter</i> in broiler flocks. We also recommend that the FSA continues to perform routine surveillance of <i>Campylobacter</i> in retail chicken. (Priority A)</p>	<ul style="list-style-type: none"> • Surveillance of chicken to continue for at least the next 3 years, probably on rolling basis. • The Agency has been working with LACORS/HPA to develop a rolling survey approach to monitor the prevalence of <i>Campylobacter</i> in raw chicken. The survey is expected to start in November 2004. • FSA are currently discussing options for funding <i>Campylobacter</i> flock surveillance as an add-on to flock surveillance for <i>Salmonella</i> carried out by Defra under the Zoonoses Directive.

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

Recommendation	Response
<p>(4.69) Extensive chicken production is a minor but nevertheless important feature of the UK market. We believe that consumers would benefit from knowing more about the <i>Campylobacter</i> status of this type of product. We therefore recommend surveillance :-</p> <ul style="list-style-type: none"> • by Defra to determine the prevalence of <i>Campylobacter</i> in extensively-reared flocks and the <i>Campylobacter</i> spp. involved; (Priority B) • by the FSA to determine the <i>Campylobacter</i> status of free range, organic and other extensively-produced chicken meat on retail sale in the UK. (Priority B) 	<ul style="list-style-type: none"> • The Agency has been working with LACORS/HPA to develop a rolling survey approach for <i>Campylobacter</i> in raw chicken. The survey is expected to start towards the end of 2004 and will include chickens of different production types. The number of extensively produced chicken samples will be small reflecting market share although any differences in <i>Campylobacter</i> prevalence should be reflected in the longer term. However, differences between production types (if any) are likely to be masked by contamination arising during slaughter and processing. • As per 4.68. • Defra is currently funding an epidemiological study with the aim of developing an effective farm to fork Quantitative Risk Assessment model that identifies practical control measures for <i>Campylobacter</i> in broiler flocks, and part of the study will also consider prevalence in extensively reared flocks as a potential source of infection.
<p>(4.70) We also recommend further research into how <i>Campylobacter</i> can be more effectively controlled in extensively-reared chickens. We note that the FSA is already considering funding research in this area and welcome the fact that the Agency has invited Expressions of Interest from researchers. (Priority B)</p>	<ul style="list-style-type: none"> • Research on the control of <i>Campylobacter</i> in extensively reared flocks will begin in November 2004. • Research projects will consider the use of plant extracts, probiotic bacteria, and dietary manipulation to control <i>Campylobacter</i>. • Under the Government Partnership Awards scheme, the Agency will part-fund a BBSRC project investigating bacteriophage therapy as an option for controlling <i>Campylobacter</i> in poultry.
<p>(6.60) We recommend that, in addition to the work it is doing on chicken meat, the FSA carries out surveillance to establish the <i>Campylobacter</i> status of other types of poultry meat on retail sale in the UK. (Priority A)</p>	<ul style="list-style-type: none"> • Await outcome of HPA/LACORS survey for data on turkey and other poultry meats in 2004-5. The Agency will consider this once the UK findings from the 2004 EC Co-ordinated sampling programme on poultry meat (including turkey) are known.

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

Recommendation	Response
<p>(7.25) In view of the variations in the data for the prevalence of <i>Campylobacter</i> in retail meat samples, and in order to obtain a clearer picture of the risk if any to public health from such products, we recommend that the Food Standards Agency should undertake UK wide, large-scale, structured surveillance of the prevalence of <i>Campylobacter</i> in red meat on retail sale. (Priority A) We note that the Agency has recently requested pilot work in this area.</p>	<ul style="list-style-type: none"> FSA will also take into account the findings from the ongoing surveillance of meats by the HPA/LACORS before undertaking any national meat surveillance. The Agency expects to commission pilot work in 2005-6 to develop methodology for a meat survey.
<p>(8.24) We strongly recommend the proper use in catering of meat thermometers, as a means of ensuring the effective cooking of raw poultry products in particular. The use of such devices in the home may also yield benefits and we recommend that the Food Standards Agency (FSA) considers communicating the benefits of the use of cooking thermometers for domestic and catering settings. We also recommend that, as part of its review of HACCP implementation in the catering sector, the FSA considers whether documentary evidence of effective temperature checks should be required to be kept. (Priority A)</p>	<ul style="list-style-type: none"> The Agency has, since 2002, published information on how to use probe thermometers and minimum cooking times for meat, as part of its Food Hygiene Campaign initiatives targeted at caterers and food business: The Agency is considering what documentation and record keeping is appropriate for catering businesses of different types and sizes.
<p>(8.25) We recommend that industry guidance is produced through trade associations, to ensure a consistent approach to the generation of on-pack cooking instructions. In addition, where guidance is provided, this should feature prominently on the packaging. (Priority A)</p>	<ul style="list-style-type: none"> Labelling rules already require instructions for use to be given if it would be difficult to make appropriate use of the food without them, and that where such instructions are given, they should be sufficiently detailed to enable appropriate preparation to be made of the food. The ACMSF has previously advised on the provision of appropriate cooking instructions for raw beef and poultry products, which are currently appended to our food labelling guidance. The Agency will consider incorporating this and the new recommendations into best practice advice on labelling of meat and meat products, which would be developed in consultation with industry. The ACMSF is currently revisiting its advice on the time/temperature requirements for safe cooking of burgers and other minced meat products.
<p>(8.26) In the case of meat which is not pre-packed, we recommend that the industry examines the feasibility of providing cooking guidance on all raw meat and poultry</p>	<ul style="list-style-type: none"> As above

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

Recommendations	Response
products, including those sold from service counters, butchers and other similar outlets. (Priority A)	
(8.27) We believe that the practice of washing raw meat and poultry is likely to lead to increased risk of spread of <i>Campylobacter</i> in the kitchen through splashes, droplets and aerosols, given the high levels which may be present on raw chicken. We recommend that this practice be actively discouraged by the FSA and industry. If necessary, consumers should be advised only to wipe down a chicken with a disposable paper towel. (Priority A)	<ul style="list-style-type: none"> • The Agency highlighted the risks of cross contamination from chicken in its hygiene campaign for consumers which included information on meat handling/washing. • Some retailers are considering including a note on poultry labelling about not washing chickens.
(8.28) Whilst it is understood that the consumer does not always read such advice, we recommend, in the public interest, that all producers and retailers of foods, where enteric pathogens such as <i>Campylobacter</i> may be present, should provide advice on the key food safety steps which should be taken to prevent infection. This should, as a minimum, be applied to all raw poultry products, as the levels of the organism are known to be high. Advice should include measures for effective cooking and for the avoidance of cross-contamination from the raw food to ready-to-eat food (through separation of foods and utensils, and through hand washing). (Priority A)	<ul style="list-style-type: none"> • FSA will take forward in parallel with the Food Hygiene Campaign. Campaign activities to date include use of TV advertising and web based activity to promote good hygiene practices and messages on safe cooking and how to avoid cross contamination. • FSA is aware that some retailers already provide food safety advice on their products although there is a need for more consistency in the advice that is given. • A number of retailers added advice on hygiene in connection with barbecuing to charcoal packaging in the summer of 2003, which has been retained in 2004. • The British Retail Consortium will be asked to bring this recommendation to the attention of their members.
(8.29) We are aware of previous activity by the FSA to provide targeted advice to consumers regarding improved cooking/hygiene practices when barbecuing and we recommend that this approach be repeated prior to each summer period. (Priority A)	<ul style="list-style-type: none"> • Prior to each summer period, the Agency will continue to issue advice on summer eating and barbecue cooking (supported by long-lead media activity). • The Summer Eating and barbecue campaign (including television and radio advertising, leaflet and website publicity) was launched in summer 2002. During summer 2003 and 2004, targeted advice relating to summer eating and barbecuing was repeated in leaflets and on the web site. Advice and leaflets are also promoted at publicity events.
(8.30) We recommend that the industry provides food safety/hygiene advice on the packaging of foods for barbecues, particularly raw meats, and especially poultry. (Priority A)	<ul style="list-style-type: none"> • See recommendations 8.25 and 8.26.

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

Recommendation	Response
(8.31) We recommend that attention is drawn to the potential risks associated with carriage of <i>Campylobacter</i> in domestic pets, and to the hygiene precautions applicable to them. (Priority A)	<ul style="list-style-type: none"> This will be considered where food safety advice is being developed or revised.
(8.32) We recommend that further measures are taken to embed food hygiene and safety principles into the education of primary and secondary school children. (Priority C)	<p>The Agency is working with the DfES and Devolved Administrations to raise the profile of food hygiene in the national curriculum. A number of measures have been launched including:</p> <ul style="list-style-type: none"> A "Cooking Bus" in November 2003 with the aim of delivering healthy eating and food safety messages to school children around the country. The Agency's Bad Food Live video with full supporting teacher's pack has been made available to all primary and secondary schools across England and Wales. The video is aimed at 10-14 year olds and aims to highlight basic food hygiene messages and raise hygiene awareness. The Agency will be supporting the roll out of 'Mission Possible!', which won the FoodLink National Food Safety Communications award in 2003. The scheme is aimed at primary school children aged 8-10 and is expected to reach 10,000 in this age category in 2005. The Agency's website includes resources aimed at raising awareness of food hygiene issues amongst children and the material is due to be updated in 2004-05. Several of the 2004-05 Local Authority food hygiene grants include initiatives relevant to raising hygiene awareness amongst children. The Agency is funding research at Surrey University looking at the ways of getting hygiene messages into schools. The Agency is also working with the Scout association to look at opportunities to raise food hygiene awareness amongst children and developing hygiene competencies in the DfES Getting to Grips with Grub scheme.
(8.33) In light of the fact that basic precautions may not be sufficient to prevent <i>Campylobacter</i> cross-contamination from highly contaminated foods such as raw chicken, we recommend that the FSA considers what measures can be taken to highlight to caterers and consumers the heightened risks associated with certain foods such as raw poultry. (Priority A)	<ul style="list-style-type: none"> FSA launched a high profile TV campaign in 2004 aimed at consumers to promote good hygiene practices and messages on how to avoid cross contamination from foods such as chicken. The FSA supported the FDF's FoodLink Food Safety week which also featured cross contamination.

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter

Recommendations	Response
<p>(9.32) As with all typing methods for food poisoning pathogens, different laboratories will take different approaches, and agreement will be difficult to reach. We therefore believe that the Food Standards Agency needs to take a firm initiative in bringing together laboratories capable of applying MLST so that investigative programmes can be designed to improve our epidemiological understanding in the next few years. We so recommend. (Priority A)</p>	<ul style="list-style-type: none"> • The Agency will initiate a programme of work in 2005 to bring together the key human, food and veterinary laboratories to examine the scope and resources required to undertake this work on a routine basis. • There is a new head of the HPA's <i>Campylobacter</i> Reference Unit and it will be important to establish links to identify the likely direction of future typing work. Preliminary discussions suggest that HPA will be considering implementing MLST and possibly other molecular-based typing tools. • The Agency is already funding work where MLST and other molecular based approaches are being applied to gain a better understanding of <i>Campylobacter</i> epidemiology. • We would also aim to explore the potential for using this approach in characterising <i>Campylobacter</i> isolates from the ongoing surveillance of retail chicken. • The Agency will explore the options for a longer-term archiving resource so that isolates collected as part of surveys and research are available for future comparisons using the most appropriate typing tools.
<p>(9.33) We want to be very clear that this is in no way a recommendation that, at this stage, the FSA should be funding large research programmes on typing methods. Rather, it is a recommendation that advantage is taken of the opportunity to get the most out of MLST in the shorter-term and set in place the technology to adopt universal sequence-based techniques as they become available.</p>	<ul style="list-style-type: none"> • If the key laboratories decide to put MLST in place as a front line typing tool then there may be scope for a ring trial/quality assurance exercise to assess performance. This is unlikely to be needed until 2005-2006

GLOSSARY

including acronyms

Aetiology	The cause or origin of a disease.
Aetiological agent	The organism causing an infectious disease.
Antigen	A substance which elicits an immune response when introduced into an individual.
ATP	Adenosine 5'-triphosphate.
Case-control study	A study comparing a group of people with a particular disease (the cases) with a group of people free from the disease (the controls) to determine whether the cases have been exposed more or less often than the controls to a specific factor.
Chemotaxis	A taxis (see below) in which the stimulus is a concentration gradient of a particular chemical.
Cloaca	Common, faecal, urinary and oviduct outlet.
CLP	Clean Livestock Policy.
Coccioid cells	Spherical (or near-spherical) bacterial cells.
CSSS	<i>Campylobacter</i> Sentinel Surveillance Scheme.
Cytoplasm	The protoplasm (ie. the living contents) of a cell contained within the cell membrane, but excluding the nucleus.
DNA	Deoxyribonucleic acid, the genetic material of humans, bacteria, some viruses, etc. It is a polymer of nucleotides connected by sugars.
Enrichment	The process of increasing the proportion of a particular microorganism in a mixed population.
Epidemiology	The study of the occurrence, transmission and control of epidemic disease.
Epithelial cells	Cells which form the layer (the epithelium) lining the inner surface of the intestines.
<i>fla</i> typing	Flagellin gene restriction fragment length polymorphism.
Flagella-mediated motility	Bacterial locomotion through the action of flagella on cell surfaces.
Flagellin	The protein sub-unit of the filament of a bacterial flagellum.

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

Flagellum	A thread-like appendage on the surface of a cell whose movement is used for cellular locomotion.
Fomites	Objects or materials which have been associated with infected persons or animals and which potentially harbour pathogenic microorganisms.
FSA	Food Standards Agency.
GBS	Guillain-Barré syndrome : a disorder characterised by acute, bilateral ascending paralysis.
Gene clusters	A cluster of functionally-related genes.
Genome	The genetic material of an organism (e. the DNA – see above – or RNA – see below – of a virus).
Global regulators	These subject genes and operons with diverse functions and independent control to a coordinated and overriding system of regulation.
Genotyping	Distinguishing and grouping organisms by their content of genetic information.
HPA	Health Protection Agency.
IFD	Indigenous foodborne disease.
IID	Infectious intestinal disease.
Insertion sequence	A small bacterial transposon (see below) which carries only the genes needed for its own transposition (see below).
Microarray	DNA microarrays are specially-treated microscope slides which carry an ordered mosaic of sequences representing most or all of the genes of an organism. DNA microarrays offer the ability to genotype or to monitor the expression of all genes in an organism at once (e. they provide a snapshot of all the genes that are active in a cell at a particular time).
Microaerophilic	Describes a gaseous environment in which oxygen is present but at a concentration significantly lower than in air (partial pressure). A microaerophilic organism prefers, or can only survive in, such an environment.
MFS	Miller Fisher syndrome.
MLST	Multilocus sequence typing.
Operon	A group of contiguous structural genes which are transcribed as a single transcription unit from a common promoter and can thereby be subject to coordinated regulation.
Passage	The transfer of a pathogen from one to another of a succession of animals, tissues, etc, growth of the

Advisory Committee on the Microbiological Safety of Food : Second Report on *Campylobacter*

	pathogen occurring before each transfer.
PFGE	Pulse field gel electrophoresis.
Phagocytosis	The process in which particulate matter is ingested (and may be subsequently digested) by certain types of cell or microorganism.
Phenotyping	Distinguishing and grouping organisms by their appearance and/or physiological (functional) properties.
RAPD	Random amplification of polymorphic DNA.
ReA	Reactive arthritis : a non-infective arthritis which may be secondary to an episode of infection elsewhere in the body.
Risk factor	A factor known, on the basis of epidemiological evidence, to be associated with a particular disease.
RNA	Ribonucleic acid, a nucleic acid consisting of ribonucleotides each of which contains one of the bases adenine, guanine, cytosine or uracil or, in some RNAs, a modified form of one of these bases.
Sequelae	Conditions which follow the occurrence of a disease eg. late complications or long-term or permanent ill effects.
Serotyping	A method of distinguishing types of bacteria (serotypes) within a single species by defining their antigenic properties (see antigen) on the basis of their reaction to known antisera.
Taxis	A locomotive response to an external stimulus exhibited by certain motile cells or organisms.
Thermophilic	Thermophilic campylobacters are those which grow well at 42°C and 37°C, but not at 25°C.
Transposition	The translocation of a discrete DNA segment from one site to another (target) site.
Transposon	A genetic element which, in addition to encoding functions necessary for its transposition, also carries genes with functions unrelated to transposition (eg. genes for resistance to antibiotics).
Vacuole	Any of the membrane-delimited compartments within a cell.
VNC :	Viable Non-Culturable.

Advisory Committee on the Microbiological Safety of Food : Second Report on
Campylobacter
