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# Control of *Campylobacter* species in the food chain

Microbiology

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# CONTENTS

## SCOPE

This report aims to:

- highlight issues regarding the control and prevention of human exposure to infection with *Campylobacter* species throughout the food chain in Ireland

- summarise existing knowledge and recommend additional measures to reduce the risk of human infection.

# EXECUTIVE SUMMARY

This report aims to summarise existing knowledge regarding the control and prevention of human infection with *Campylobacter* species. in Ireland and to recommend measures to reduce the risk of infection with *Campylobacter* spp. through the food chain. There are many unanswered questions about the biology of *Campylobacter* spp. and the epidemiology of human campylobacteriosis. It is acknowledged that opinions and recommendations will need to be revised as new information becomes available.

Acute gastroenteritis with diarrhoea and/or vomiting are the main features of human infection with *Campylobacter* spp. In most cases the illness is self limiting, but it may be severe and life-threatening in susceptible people. Infection is sometimes complicated by the development of serious post-infection complications, notably a syndrome of damage to the peripheral nerves resulting in temporary paralysis (Guillain-Barré Syndrome). The clinical features of campylobacter gastroenteritis do not permit differentiation from other causes of gastroenteritis and therefore laboratory confirmation is important. Campylobacteriosis is not itself a notifiable disease in Ireland although it may be notified as gastroenteritis. In Ireland, there were 2,085 and 1,613 laboratory confirmed cases of infection with *Campylobacter* spp. in 1999 and 2000, respectively. This represents approximately twice the number of laboratory confirmed cases of infection with *Salmonella enterica*. It is likely that the number of laboratory confirmed cases represents a very small proportion (1% to 10%) of actual cases of infection.

*Campylobacter* spp. are widespread in the intestinal tract of warm-blooded animals used for food production. They may therefore readily contaminate foods of animal origin. Contamination of water may occur through run-off from animal production units. Contamination of vegetables and salads may occur through contact with animal faeces during growing, through contact with contaminated water during harvesting or preparation, or as a result of cross-contamination from raw meat in commercial or domestic kitchens. Although many foods may be contaminated, it is considered by many authorities that poultry and poultry products are of particular importance as a source of human infection. *Campylobacter* spp. does not multiply very effectively in most foods however, it may survive through the food distribution system and because consumption of a small number of organisms (500 or less) may be associated with illness, proliferation in food is not a prerequisite for infection.

Current methods for identifying and typing of *Campylobacter* spp. have technical limitations. Furthermore, many clinical laboratories do not have facilities and resources to identify routine clinical isolates even to species level and there is no national reference laboratory, although a number of laboratories in Ireland are engaged in campylobacter related research. Recognised outbreaks of infection with *Campylobacter* spp. are uncommon and the source of infection in sporadic cases is rarely identified. In order to define sources of infection and routes of transmission, the ability to discriminate precisely between different strains of *Campylobacter* spp. is essential.

There are broadly speaking two approaches to reducing opportunities for human infection with *Campylobacter* spp. elimination or reduction of *Campylobacter* spp. colonisation of animals and contamination of plants during growing and harvesting and treatment of the end product to eliminate *Campylobacter* spp. prior to consumption. These approaches are not mutually exclusive. Interventions intended to achieve campylobacter-free poultry production are underway in some countries and this report includes recommendations to reduce opportunities for campylobacter colonisation of poultry in Ireland. The value of elimination of *Campylobacter* spp. from contaminated food prior to retail sale is well illustrated by the impact of requiring pasteurisation of all milk on rates of infection with *Campylobacter* spp. in Scotland. The potential for similar decontamination of meat by methods such as irradiation is being considered although, it is not clear if more widespread irradiation of food, and specifically irradiation of fresh meat would be acceptable to consumers at the present time. In the absence of measures to ensure campylobacter-free raw meat products food preparation must proceed on the basis that meat, particularly poultry meat, entering the commercial or domestic kitchen is frequently contaminated with *Camplyobacter* spp. and unless properly handled and prepared may act as a direct vehicle of infection and as a source of cross contamination of other foods in preparation. The following key recommendations are made. The recommendations are placed in order of the food chain, from farm to fork and many recommendations have benefits that also extend to control of transmission of other foodborne pathogens.

- Poultry farm managers/operators should comply to the highest possible degree with the biosecurity measures detailed in this report.

- During poultry production, the practice of thinning and point-selling should be avoided, where possible, by completely de-stocking the flock in each house at one time.

- The meat and poultry meat industries should develop and implement evidence-based standard operating procedures, in order to prevent or minimise product contamination with *Campylobacter* spp.

- Food businesses should document and implement a food safety management system based on the principles of HACCP.

- All staff involved in catering and food production generally, should be appropriately trained in food safety to a level commensurate with their work activities.

- A supply of potable water must be available for the preparation of food.

- The Food Safety Authority of Ireland and the relevant official agencies should consider the establishment of monitoring and control strategies for *Campylobacter* spp. in poultry meat production, processing and distribution.

- The Department of Agriculture and Food should put in place systems to monitor imports to ensure that the same standards that are applied to domestically produced food are also applied to imported foods.

- The Food Safety Promotion Board should measure consumer attitudes to interventions, such as irradiation of meat, on an ongoing basis and stimulate dialogue between consumers and scientists in relation to the potential benefits of food irradiation and consumer concerns about perceived hazards.

- A national Campylobacter Reference Laboratory should be established.

- The Food Safety Promotion Board should continue public awareness campaigns which focus on general measures for safe food handling and preparation.

- The Food Safety Authority of Ireland should work with industry to ensure appropriate labelling of raw poultry and other meat products, in order to advise food handlers and consumers that these products may contain harmful bacteria and must therefore be handled, stored and prepared according to the instructions provided.

- The Department of Health and Children should ensure that the health boards can provide an adequate seven-days-a-week public health response to outbreaks of foodborne disease.

- Consumers should practise basic good hygiene when handling food and should cook high-risk raw foods thoroughly.

- There is a need for improved surveillance of human campylobacteriosis and of *Campylobacter* spp. throughout the food chain.

- Funding for research and development related to improved understanding and control of campylobacteriosis merits high priority.

# CHAPTER 1: INTRODUCTION

## 1.1 The Organism and the Disease

In the 1970s, it was established that *Campylobacter jejuni* and to a lesser extent *C. coli* were a major cause of diarrhoeal illness in humans. Campylobacter is therefore a relatively recently recognised human pathogen. There are many unanswered questions about the biology of *Campylobacter* species and the epidemiology of human campylobacteriosis. The control and prevention of human infection with *Campylobacter* spp. is an area of intense research and it is acknowledged that opinions and recommendations may need to be revised as new information becomes available.

In 1997, the incidence rate of infection with *Campylobacter* species exceeded the rate of infection with *Salmonella enterica* in Spain, Sweden, the Netherlands, Scotland, Northern Ireland, and England and Wales [1, 2]. In Ireland, there were 2,085 and 1,613 laboratory confirmed cases of illness due to *Campylobacter* spp. in 1999 and 2000, respectively [3, 4]. This is approximately twice the number of notifications of infection with *Salmonella enterica* for each year, i.e. 965 and 640, respectively.

*Campylobacter* spp. are widespread in the intestinal tract of warm-blooded animals used for food production. They may therefore readily contaminate raw meat, raw milk and raw milk products. *Campylobacter* spp. are also commonly found in the alimentary tract of healthy birds including domestic poultry. This relates to the high optimum growth temperature (42°C) of the microorganism, which approximates the normal body temperature of poultry.

*Campylobacter* spp. are fragile organisms. They are sensitive to freezing, heating (pasteurisation/cooking), drying, acidic conditions (pickling), disinfectants and irradiation. They survive poorly at room temperature (21°C) and in general survive better at cooling temperatures. They can grow on moist foods at temperatures between 37°C and 45°C, with an optimum temperature of 42°C. It has been estimated that consumption of a small number of organisms (500 or less) may be associated with illness. Therefore, the fact that the organism does not multiply very effectively in most foods does not prevent it from causing foodborne illness.

The *Campylobacter* spp. associated with human disease have specific atmospheric requirements, growing best in an atmosphere containing 10% carbon dioxide and 5-6% oxygen. The organisms normally die off quickly in the presence of air and are very sensitive to oxygen breakdown products. Vacuum or gas packaging appears to have little effect on their survival.

The *Campylobacter* spp. associated with gastrointestinal illness in humans include *C. jejuni, C. coli, C. lari, C. fetus* and *C. upsaliensis* [5]. *C. jejuni* and *C. coli* are associated with indistinguishable clinical illness and are the *Campylobacter* spp. most frequently isolated from human specimens. *C. jejuni* represents about 92% of all isolates of *Campylobacter* spp. in England and Wales during the period May 2000-2001 [6]. *C. upsaliensis* is associated with campylobacteriosis in children and is frequently associated with a milder illness [7].

While the sources of *Campylobacter* infection are still unclear, epidemiological studies indicate that campylobacteriosis is primarily a foodborne disease [8]. However, because the majority of human infections are sporadic and the organism may be detected in many foods of animal origin and in water, tracing individual episodes of infection to a specific source has to date been difficult. Meat, milk and water are considered principal sources of sporadic cases of infection, but contact with household pets and foreign travel has also been implicated. On the basis of epidemiological case control studies the consumption and/or handling of poultry meats is now considered a major risk factor for human infections with *C. jejuni* or *C. coli* [1]. However, the relative importance of *Campylobacter* spp. of poultry origin as a cause of human disease has yet to be accurately determined, especially as many domestic and farm animals are also colonised with *Campylobacter spp.* [9]. Evidence from sub-typing data indicates that there are campylobacter strains in poultry which do not infect humans and, conversely, there are strains causing disease in humans which do not appear to originate from poultry.

*Isolation and Typing of Campylobacter spp.*

In Ireland, a number of medical and veterinary microbiology laboratories routinely detect *Campylobacter* spp. in clinical specimens. Likewise, these organisms are recovered from food samples examined at food microbiology laboratories. When *Campylobacter* spp. are isolated, some laboratories will identify the isolates to species level (e.g. *C. jejuni, C. coli*) and may perform a limited range of antimicrobial susceptibility tests, generally by non-standardised susceptibility test methods. These measures are adequate for the management of the individual case of human infection.

In order to define sources of infection and routes of transmission the ability to discriminate precisely between different strains within a species (using typing methods) is essential. No entirely satisfactory method for typing of *Campylobacter* spp. is available at present, although *C. jejuni* and *C. coli* are known to be both phenotypically and genotypically diverse, and several laboratory-based typing methods for *Campylobacter* isolates are being developed. The technical limitations of typing methods for *Campylobacter* spp. contributes substantially to the difficulties in defining the epidemiology of infections involving these organisms As part of its wider food surveillance and monitoring programme, the Food Safety Authority of Ireland (FSAI) is sponsoring the application of methods for typing of *Campylobacter* spp. within Ireland. The Food Safety Promotion Board (FSPB) has commissioned a comparative study of *Campylobacter* isolates of clinical and food origin. A detailed review of current typing techniques was recently published by Wassenaar and Newell [10].

### 1.2 Infection and Clinical Disease

*The Infective Dose*

The number of bacteria of *Campylobacter* spp. that must be ingested to cause disease (the infective dose) is considered to be low, ranging from 500 to 10,000 cells. The infective dose depends on a number of factors including the vehicle in which it is ingested and the susceptibility of the individual. In children, the infective dose may be lower than it is in adults. Compared to other foodborne pathogens with low infective doses, few outbreaks of campylobacteriosis have been identified. Most patients with campylobacteriosis present as sporadic cases, and person-to-person transmission is uncommon [11].

*Clinical Features*

Campylobacteriosis (the illness associated with infection with *Campylobacter* spp.), lacks very specific clinical features therefore it is difficult to distinguish gastrointestinal problems associated with *Campylobacter* spp. from other acute gastrointestinal infections. A definitive diagnosis can be made only by detecting *Campylobacter* spp. in clinical specimens. Clinical disease following infection with *Campylobacter* spp. varies from a mild self-limiting enterocolitis lasting 24 hours to severe illness lasting up to 10 days. Relapse occurs in 10 to 20% of patients and is usually less severe than the original episode of illness[7].

The great majority of persons infected with *Campylobacter* spp. will recover without any specific treatment. Infection may be more common and more severe in HIV-infected patients and in other patients suffering from immunosuppression [12, 13]. In the immunocompromised and in those with more severe illness, antimicrobial agents may be required, and can shorten the duration of symptoms if they are given early in the illness. Mortality is rare.

*Sequelae to Infection*

Complications are relatively rare, but infections have been associated with Guillain-Barré Syndrome (GBS), reactive arthritis, Reiter's syndrome (inflammation of large joints and of the urethra and conjunctiva), haemolytic uraemic syndrome (HUS) and, following septicaemia, localised infection of nearly any organ. Both GBS and reactive arthritis are thought to be autoimmune responses triggered by infection [14]. GBS occurs following approximately 0.1% of cases of campylobacteriosis [15].

*Antimicrobial Resistance*

In the management of human campylobacteriosis, fluid replacement is of primary importance. Antimicrobial therapy is necessary only in a minority of patients with more severe disease and in those who are immunologically compromised.

For the minority of patients who do require treatment, the greatest threat to the continued use of antimicrobial agents for human therapy is the development of antimicrobial resistance among pathogenic microorganisms. Antimicrobial agents are used to prevent and treat infection(s) in animals kept for human food production. Use of antimicrobial agents in animal husbandry contributes to increased antimicrobial resistance in *Campylobacter* spp. and other pathogenic bacteria [16]. In Ireland currently, there are only limited data available to quantify the problems of antimicrobial resistance in *Campylobacter* spp. isolated from humans or animals. As with the methods for typing of *Campylobacter* spp., generation of data on antimicrobial susceptibility has been hampered by limitations of methodology. Such data as are available are in the process of being collated and analysed. Systematic monitoring, on an all-island basis, of antimicrobial resistance in *Campylobacter* spp. and of antimicrobial usage would be valuable in developing suitable strategies to control antimicrobial misuse and monitoring the effectiveness of strategies developed [17, 18].

## 1.3 Epidemiology

Campylobacteriosis is now recognised as an important infectious disease in Ireland. Although not statutorily notifiable by name under the current Infectious Disease Regulations, 1981, cases of the disease are usually notified as "food poisoning (bacteria other than *Salmonella*)". It is not therefore possible on the basis of notifications, to identify the number of food poisoning incidents attributable to infection with *Campylobacter* spp. as opposed to other organisms. In addition, not all infections with *Campylobacter* spp. are due to food poisoning and so information from notification data is limited. Nevertheless, the limited data available suggest that the number of infections with *Campylobacter* spp. notified as "food poisoning (bacteria other than *Salmonella*)" has been steadily increasing over the period 1994-2000 (Figure 1).

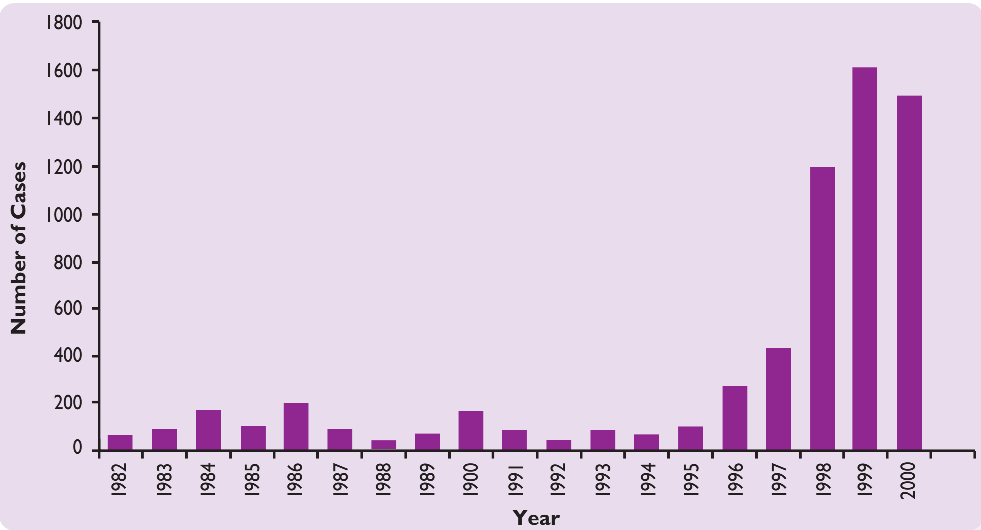


**Figure 1. Food Poisoning Notifications (of Bacteria other than *Salmonella*) in Ireland, 1982-2000**
Source: Department of Health and Children (1982-1999) and National Disease Surveillance Centre (2000).

Information held by laboratories is not currently notifiable however, there are regional laboratory-based data recording systems currently in place in Ireland, such as INFOSCAN and Laboratory Surveillance System (LSS), which provide regional population-based incidence rates of campylobacteriosis. Laboratories are one of the most valuable sources of information on infectious diseases such as campylobacter related illnesses that require public health intervention.

The National Disease Surveillance Centre (NDSC) collated data from clinical laboratories in 1999 and 2000 and established that the crude incidence rate of laboratory confirmed campylobacteriosis was 57.5 cases /100,000 and 44.5 cases/100,000 respectively [3, 4]. Despite the decrease in 2000, *Campylobacter* spp. remain the single most common cause of bacterial gastroenteritis in Ireland. In addition, it is worth noting that these rates are based on laboratory confirmed cases; the true rate of infection is likely to be 10 to 100 times higher than the number of reported cases [19, 20].

The reported incidence rates in the European Union for the year 1999 varied between 9.5 cases/100,000 in Spain and up to 108 cases/100,000 in Scotland [2]. In the United States, 37% of laboratory confirmed cases of bacterial gastroenteritis reported through FoodNet [21] were attributed to infection with *Campylobacter* spp.

In both 1999 and 2000, the highest incidence rates in Ireland were reported in the Western and Southern Health Boards [3, 4]. The extent to which regional differences reflect true differences in incidence, as distinct from differences in ascertainment, is not well defined. The male:female ratio was 1.28:1 and 1.29:1 for 1999 and 2000 respectively. Figure 2 illustrates the characteristic summer peak of cases of campylobacteriosis reported in 2000. In 1999, a peak was seen in Week 25, while a sharp peak in Week 23 occurred in 2000.

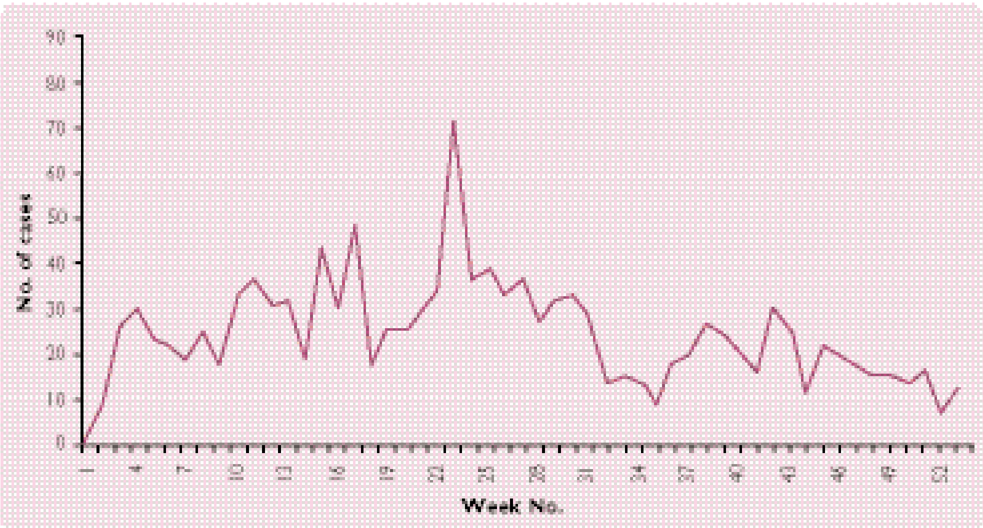


**Figure 2. Total Number of Laboratory Confirmed Cases of Human Campylobacteriosis by Week in Ireland in 2000 [4]**

In developed countries, *Campylobacter* spp. affect people of all ages. Typically, the disease has a bimodal distribution with large peaks of incidence in children under 5 years and a smaller peak in young adults [7;22]. In 1999 in Ireland, the age-standardised rates were highest in children aged 0 to 4 years, with a second peak in early adulthood. A similar age distribution was observed in 2000 (Figure 3). The high rate in young children is attributed in part to susceptibility on first exposure and to the low threshold for seeking medical care for infants [13]. The high incidence among young adults has been attributed by some to poor food preparation skills [23].

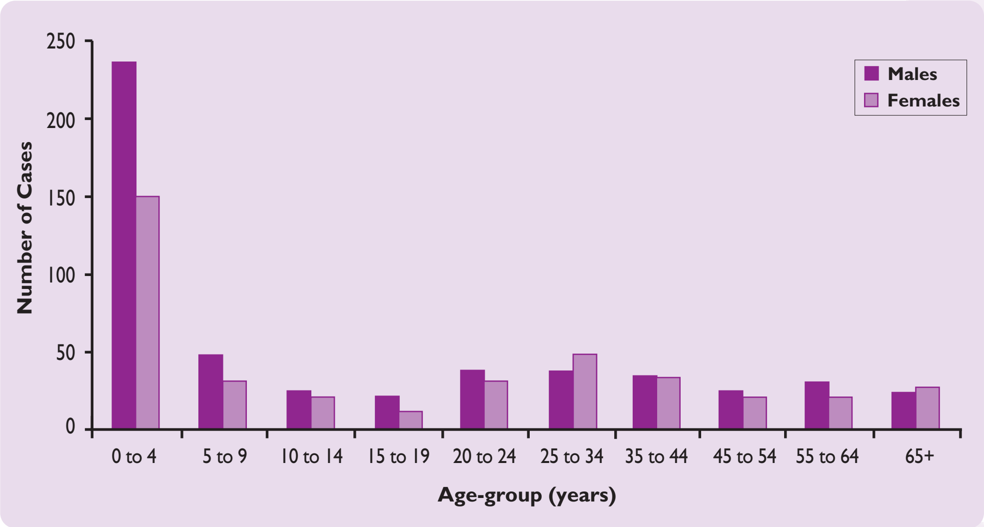


**Figure 3. Age-Gender Adjusted Incidence of Laboratory Confirmed Cases of Human Campylobacteriosis according to Age Group in Ireland in 2000 [4]**

*Outbreaks*

Unlike many of the other foodborne pathogens, *Campylobacter* spp. are not frequently associated with conspicuous outbreaks of human disease. For example, only 0.04% of cases reported in England and Wales in 1995 and 1996 were associated with identified outbreaks and the cause of most of these outbreaks was not found [24]. The FSAI's database on infectious intestinal outbreaks (1998-2000) contains no reports of *Campylobacter* spp. outbreaks in Ireland in that period. The first documented Irish outbreak occurred in July 2001. This was classified as a foodborne point source outbreak. Generally, it is acknowledged that outbreaks may go undetected, one contributing factor being the absence of suitable techniques for typing of *Campylobacter* spp.

Outbreaks, when they occur, have epidemiological characteristics that are different from those of sporadic infections. The seasonality for common-source outbreaks is bimodal, with peaks in May and October. They are most commonly associated with the consumption of raw milk or untreated water, while other sources have also been identified, as shown in Table 1 [25, 26, 27].

**Table 1. Foodborne and Waterborne Outbreaks of Campylobacter spp. Infections Reported in the US by Vehicle, 1978 to 1996 (Adapted from Friedman *et al.*, 2000) [28]**

| Origin | Number of Outbreaks | Number of implicated associated cases |
|---|---|---|
| **Foodborne** | | |
| Milk | 30 | 1,212 |
| Chicken | 2 | 16 |
| Turkey | 1 | 11 |
| Beef | 1 | 24 |
| Other meat | 2 | 30 |
| Eggs | 1 | 26 |
| Fruits | 4 | 227 |
| Other foods | 4 | 251 |
| Multiple foods | 10 | 411 |
| Unknown food | 42 | 2,775 |
| **Waterborne** | | |
| Community water supply | 8 | 5,068 |
| Other water supply | 4 | 104 |
| **Total** | **111** | **10,155** |

*Risk Factors*

The EU Scientific Committee on Veterinary Measures Relating to Public Health recently expressed an opinion on the basis of zoonoses control policies [1]. When examining the risk factors associated with *Campylobacter* spp., the Committee reviewed the literature relating to (a) sporadic cases of infection and (b) outbreaks.

**Table 2. Risk factors Associated with Sporadic Illness due to *Campylobacter* spp. Adapted from Opinion of the Scientific Committee on Veterinary Measures relating to Public Health on Foodborne Zoonoses [1].**

- eating undercooked poultry
- handling raw poultry
- frequent contact with (diarrhoeic) dogs or cats, particularly young pets such as kittens and puppies
- drinking non-potable water
- drinking unpasteurised milk or dairy products made from non heat-treated milk
- drinking doorstep-delivered milk with caps damaged by birds
- eating barbequed poultry, pork or sausages
- eating poultry liver
- journeys abroad

(a) They found that in several case-control studies the most frequently identified risk factors for sporadic *Campylobacter* spp. infections were those shown in Table 2.

In 2000, the FSAI in a survey of health board public health specialists found that the information available on risk factors in sporadic cases was inadequate. Two health boards had aggregated data for a subset of cases which were investigated and for whom a food/risk factor history was obtained. The Southern Health Board (SHB) examined 40 cases and the South Eastern Health Board (SEHB) examined 48 case histories. In both groups, the morbidity was high, *viz.* 12/40 patients in the SHB and 32/48 in the SEHB, were hospitalised. A high proportion of cases (40%) had contact with animals. Drinking water from a private well or group water scheme was a factor in approximately a third of cases in both health board areas. Foreign travel was a factor in one case in the SHB and in four of the SEHB cases. There were insufficient data to identify suspect foods.

In England and Wales [29], analysis of the first year of a sentinel surveillance scheme revealed the following:

- 20% of cases reported travel abroad in the two weeks prior to the onset of symptoms and 14% had travelled within the United Kingdom (1% of cases did both).
- Raw milk was consumed by 9% of cases and 1% reported drinking from a bottle that had been pecked by birds.
- 7% reported drinking water from a private water supply and 3% had consumed river, stream, or spring water.
- Animal contact was reported by over half (57%) of the cases and 10% of cases reported visiting a farm.

(b) The risk factors that have usually been associated with outbreaks of campylobacteriosis are consumption of unpasteurised milk, untreated surface water, and food, particularly poultry meat [1].

## Sources and modes of transmission

Poultry, including chickens, turkey, ducks, pheasants and guinea fowl have all been found to have high rates of colonisation by *C. jejuni.* Wild birds are considered to be an important reservoir of infection for domestic and food animals. In addition to birds, *Campylobacter* spp. have been found in cattle, sheep, pigs, goats and domestic pets, as well as in rodents, flies and other insects [9]. *C. coli* is particularly associated with pigs [13]. Due to the fact that *Campylobacter* spp. are ubiquitous in animals, no animal can be excluded as a potential source of human infection.

• *Milk*

*Campylobacter* spp. are found commonly in dairy cows and may, therefore, be present in raw milk as a result of faecal contamination. While reported contamination levels of milk are usually low, often less than 1 cell/ml, it is considered that the high fat content of this product may serve to protect *Campylobacter* spp. from gastric acidity and permit low numbers of cells to cause infection. In Scotland, it has been illegal to sell unpasteurised milk since August 1983. Since then, there have been no reports of milk-borne outbreaks of infection with *Campylobacter* spp. in that country. In Ireland, the sale of raw cow's milk has been prohibited since July 1997. However, on-farm consumption of raw milk is common [30]. The consumption of pasteurised milk from bottles where the tops have been pecked by either magpies or jackdaws has been implicated in cases in the UK [31].

• *Poultry Meat*

A high proportion of retail chicken sold worldwide is contaminated with *C. jejuni*, with isolation rates as high as 98% being reported (Table 3). In a recent Irish study, 60-70% of broilers were found to be faecal culture positive when sampled at the farm of origin [32]. Also, when neck-skin flaps of freshly dressed carcases were examined at the processing plant, an isolation rate of 90-100% was recorded. Some 80-90% of these isolates were identified as *C. jejuni* [32]. Meanwhile the Department of Agriculture (DAF) in association with the FSAI commenced sampling of poultry for campylobacter isolation in September 1999. Of over 7,000 samples analysed the average isolation rate is 55%. This ranges from 27-60% depending on the species of bird examined (approximately 56%, 58% and 47% of chicken, turkey and duck samples respectively) and the type of sample (approximately 60% of carcases and 27% of skinless fillets).

Further insight into the role of poultry meat products in the dissemination of *Campylobacter* spp. among the human population was provided by studies undertaken in Belgium following the dioxin crisis in 1999 [33]. Chickens and eggs produced in Belgium were withdrawn from the markets in that country in June of that year when it was realised that some locally produced products might contain dioxin. Imported poultry meat products continued to be available. Using a model based upon the numbers of reported cases in the period, 1994 – 1998, it was calculated that there was a 40% drop in the incidence of human campylobacteriosis in the months immediately following the withdrawal of Belgian poultry meat products in 1999. When the dioxin crisis was over, and the ban on Belgian poultry meat was withdrawn, the incidence of campylobacteriosis returned to a level comparable to that seen before the crisis in a matter of weeks.

Given these results, it is not surprising that poultry meat is considered to account for the majority of *Campylobacter* spp. infections in humans. Even if a broiler is not infected on the farm, there are many opportunities for cross-contamination of carcases to occur during the slaughtering process.

• *Other Foods*

*Campylobacter* spp. are widespread in warm-blooded animals used for food production and the resulting food products may easily become contaminated. Meats such as pork, lamb and beef are sometimes contaminated (Table 3). While this information highlights the ubiquity of the organism in the food supply, direct comparison of the findings of different studies relating to the frequency and level of contamination of different animal species is not possible, as the sampling methods and laboratory procedures used varied between laboratories.

As a consequence of the transient existence of *Campylobacter* spp. in the marine environment, different types of seafood can sometimes become contaminated. Relatively few studies have been carried out on the prevalence of *Campylobacter* spp. contamination in vegetables, although these products can be contaminated by several routes such as the application of contaminated fertilisers, the droppings of wild birds or animals, or by contaminated surface water.

**Table 3. Isolation of *Campylobacter* spp. from food. Adapted from Jacobs-Reitsma, 2000 [8]**

| Product | Stage of process | Sample type | Total number | % of positive samples | Country | Year |
|---|---|---|---|---|---|---|
| **Raw milk** | | | | | | |
| Raw cows' milk | 12 farm bulk tanks | N/A | 153 | 5.9 | UK | 1988 |
| Raw cows' milk | Bulk tank at 15 sites | N/A | 237 | 0.4 | USA | 1987 |
| Raw cows' milk | 292 farm bulk tanks | N/A | 292 | 12.3 | USA | 1992 |
| Raw cows' milk | 1,720 farm bulk tanks | N/A | 1,720 | 0.5 | Canada | 1997 |
| Raw goats' milk | Various sources | N/A | 2,477 | 0.4 | UK | 1985 |
| Raw goats' milk | Individual samples | N/A | 1,078 | 0 | Germany | 1992 |
| **Poultry** | | | | | | |
| Chicken carcase | Before chilling | Swab | 203 | 80 | USA | 1990 |
| Chicken carcase | After chilling | Carcase rinse | 80 | 86 | USA | 1995 |
| Chicken carcase | At retail | Carcase rinse | 330 | 69 | USA | 1997 |
| Chicken carcase | At retail, frozen | Carcase rinse | 199 | 14 | Finland | 1989 |
| Chicken breast | At retail | Swabs | 616 | 58 | France | 1996 |
| Chicken breast | At retail | Swabs | 607 | 23 | Netherlands | 1996 |
| Chicken wings | At retail | Whole wings | 153 | 65 | N. Ireland | 1994 |
| Chicken products | At retail | Meat (10g) | 120 | 38 | N. Ireland | 1998 |
| Chicken | At retail | Meat (10g) | 60 | 65 | Ireland | 2001* |
| Chicken | At retail, frozen | Meat (10g) | 20 | 0 | Ireland | 2001* |
| Chicken livers | At retail, frozen | Exuded liquid | 126 | 93 | Chile | 1996 |
| Turkey carcase | Before chilling | Swabs | 236 | 3 | USA | 1990 |
| Turkey breast | At retail | Meat (25g) | 30 | 20 | Italy | 1996 |
| Turkey | At retail | Meat (10g) | 20 | 0 | Ireland | 2001* |
| Duck carcase | Before chilling | Swabs | 200 | 48 | USA | 1990 |

**Table 3. Contd.**

| Product | Stage of process | Sample type | Total number | % of positive samples | Country | Year |
|---|---|---|---|---|---|---|
| **Other meats** | | | | | | |
| Beef carcase | Before chilling | N/A | 114 | 0.9 | USA | 1990 |
| Beef carcase | After chilling | N/A | 657 | 0.3 | Australia | 1998 |
| Beef meat | At retail | N/A | 127 | 23.6 | UK | 1989 |
| Beef meat | At retail | N/A | 50 | 0 | N. Ireland | 1998 |
| Minced beef | At retail | N/A | 20 | 4 | Ireland | 2001* |
| Pork carcases | Before chilling | N/A | 105 | 2.9 | USA | 1990 |
| Pork | At retail | N/A | 158 | 18.4 | UK | 1989 |
| Pork meat | At retail | N/A | 50 | 0 | N. Ireland | 1998 |
| Pig liver | At slaughter | N/A | 400 | 6 | N. Ireland | 1998 |
| Lamb | After processing | N/A | 100 | 0 | N. Ireland | 1998 |
| Lamb | At retail | N/A | 103 | 15.5 | UK | 1989 |
| Offal | At retail | N/A | 689 | 47 | UK | 1989 |
| Offal | At retail | N/A | 20 | 12 | Ireland | 2001* |
| Raw meat products | At retail | N/A | 2,330 | 0.6 | UK | 1998 |
| Cooked meats | At retail | N/A | 2,192 | 0 | UK | 1998 |
| **Other foods** | | | | | | |
| Mussels | 59 batches | N/A | 59 | 69 | Netherlands | 1997 |
| Oysters | 41 batches | N/A | 41 | 27 | Netherlands | 1997 |
| Shellfish | Retail | N/A | 146 | 0 | Denmark | 1998 |
| Cockles, Mussels & Scallops | Shortly post harvest | N/A | 337 | 47 | UK | 1996 |
| Vegetables (mix of 10 types) | Fresh samples at retail (market & supermarket) | N/A | 1,031 | 0 | Canada | 1992 |

* The asterisk indicates data from Cloak *et al.* (2001) [34], all other data are taken from a review by Jacobs-Reitsma (2000) [8]

N/A means not applicable

• *Water*

Both drinking water, whether natural or processed, and recreational water, can become contaminated with *Campylobacter* spp. and may act as a vehicle of infection. *Campylobacter* spp. have been isolated from surface waters, rivers and lakes and can survive for months in water at temperatures below 15°C. The sources of contamination for surface water most frequently quoted are faecal contamination by wild birds, domestic animals or sewage effluent [8]. Overflow of waste from farms and meat plants, entering rivers, has the potential to contaminate public water supplies.

(a) Drinking (potable) water

Properly treated drinking water (e.g. chlorinated) should be free of *Campylobacter* spp. However, subsequent contamination with faecal material can impair the disinfecting capabilities of the residual chlorine. *Campylobacter* spp. have been associated with waterborne outbreaks, many of which have been linked to defective chlorination systems. Waterborne outbreaks have also been traced to both surface and ground water sources. Contamination of a municipal ground water supply with sewage led to a prolonged 6-week outbreak in a Danish town [35]. In a recent Canadian outbreak related to contaminated drinking water, both *E. coli* O157 and *Campylobacter* spp. were isolated from clinical samples [36].

In Ireland, drinking water is obtained either from (i) a public water supply, (ii) one of 5,500 group water schemes, or (iii) from small private supplies (wells). The presence of *E. coli* in drinking water is accepted as one of the most reliable microbiological indicators that a water supply is unfit for human consumption. The Environmental Protection Agency (EPA) publication, *The Quality of Drinking Water in Ireland: A Report for the Year 2000* [37] reported that for public water supplies (serving 92.8% of the population) there was a 96.7% compliance with the standard of absence of *E. coli* from 100ml. For group water schemes, the same standard was achieved in only 70.8% of schemes and the figure was as low as 44.4% in some counties. In many rural areas of Ireland, which are supplied by group water schemes or small private supplies, chlorination is frequently not practised, or may not be practised consistently. The frequency of positive results on testing for *E. coli* confirms that such supplies are liable to contamination from sources such as improperly sited septic tanks and /or animal slurry pits. There is clearly potential for serious risks of campylobacteriosis associated with consumption of water from such supplies.

• *Occupational Exposure*

People in contact with infected animals are likely to be at an increased risk of exposure to *Campylobacter* spp. This includes farmers, veterinarians and abattoir workers, as well as persons exposed to domestic pets. Such an outbreak among farm workers was reported in Canada in 1995 [38]. In the middle of June 1980, an explosive outbreak of campylobacteriosis occurred among the staff of a poultry abattoir in southern Sweden [39]. In all, 37 cases of acute gastroenteritis originating from the abattoir were reported and

*Campylobacter jejuni* was isolated from the stools in 24 of these cases. When the outbreak occurred, a large proportion of the ordinary staff had been replaced by inexperienced teenagers working during their holidays. Furthermore, an exceptionally large kill had taken place during the same week as these inexperienced workers had started. The replacement workers contracted the disease to a greater extent (71%) than the ordinary staff (29%). An overall screening revealed a further five asymptomatic carriers among the ordinary staff. In three cases, secondary spread was found.

• *Environment*

*Campylobacter* spp. have been found in sand from bathing beaches and have also been isolated from mud and sewage [40]. Shedding of the bacterium in the faeces of wild animals, particularly birds may be an important source of such environmental contamination.

• *Human sources*

Human beings are a relatively minor source of infection, although person-to-person spread has been documented among young children [19, 41].

## 1.4. Economic Costs of Disease

The cost of human illness, due to infection with foodborne pathogens, has been assessed extensively in the United States. Buzby and Roberts selected seven foodborne pathogens (*Campylobacter jejuni, Clostridium perfringens, E. coli* O157*, Listeria monocytogenes, Salmonella enterica, Staphylococcus aureus* and *Toxoplasma gondii)* for analysis and estimated that their costs in human illness were between US$6.5 and US$34.9 billion annually [42]. In 1995, Withington and Chambers estimated the cost of campylobacteriosis in New Zealand at NZ$4.48 million [43]. Cost of illness estimates for the pathogens were developed based on the estimated number of acute illnesses, deaths and secondary complications. Most people with foodborne illness only miss 1 to 2 days of work however, the serious sequelae that occur in a minority of those infected, e.g. Guillain-Barré Syndrome (GBS), have a significant economic impact. Buzby *et al.* concluded in 1997 that the economic losses associated with new cases of GBS, triggered by *Campylobacter* spp. infection, are US$0.2-US$1.8 billion annually for the United States [44]. Sentinel surveillance of *Campylobacter* spp. infections in England and Wales conducted during the first six months of 2000, revealed that 2,118 people reported a total of 16,443 days of illness, 236 people were admitted to hospital for a total of 946 days and 17,325 days were lost from work [45].

# CHAPTER 2: CONTROL OF THE TRANSMISSION OF *CAMPYLOBACTER* SPP. IN THE FOOD CHAIN

## 2.1 Overview

Control of *Campylobacter* spp. throughout the food chain requires implementation of food safety management systems based on well established principles such as those of the Hazard Analysis Critical Control Point (HACCP) system. HACCP is an internationally recognised food safety management system, the principles of which are now enshrined in European and Irish legislation. It is a structured systematic approach to achieving food safety which involves identifying potential hazards and measures for their control. A HACCP based system is a legal requirement in the food processing, retail and catering sectors as defined in the European Communities (Hygiene of Foodstuffs) Regulations, 2000 (S.I. No. 165 of 2000). However, in the interests of control HACCP based principles should be applied by all sectors of the food industry.

Two different approaches to reduction or elimination of *Campylobacter* spp. from the food chain may be considered. On the one hand are primary prevention efforts aimed at reducing or eliminating colonisation of live animals with *Campylobacter* spp. on the farm, while on the other are measures to eliminate or reduce *Campylobacter* spp. from the finished product (decontamination). These approaches are not mutually exclusive.

Colonisation of most animal species with *Campylobacter* spp. of public health significance does not represent an animal health/welfare issue and is not considered to significantly impact on the weight gain/feed conversion rates on farms. There would therefore be little rationale for very vigorous and expensive on-farm control of *Campylobacter* spp. colonisation if effective and acceptable end-product de-contamination measures were in place. It is far from clear at this point that the objective of campylobacter-free meat is realisable through "on-farm" control and there is considerable concern as to the impact of on-farm campylobacter control measures on the economics of meat production. In this context it is appropriate to consider that, although the biology of *Salmonella enterica* is much better understood than is the biology of *Campylobacter* spp., consistent production of poultry free of salmonellae has not to-date been widely achieved under normal commercial conditions.

However, carefully controlled end-product decontamination, e.g. pasteurisation of milk, is an effective and affordable public health intervention. Measures that are effective and affordable for end product decontamination of meat are available in the form of irradiation, steam cleaning, chemical cleaning and disinfection [46, 47]. However, it is not clear that such methods are acceptable at present to the EU authorities and the European consumer. These issues are complex and policy must be formulated against a background of considerable uncertainty. In the following sections, these issues are considered in detail.

*Food Safety Standards and Procedures*

There is worldwide recognition that food safety management systems are required to control food safety hazards, such as *Campylobacter* spp., throughout the food chain. The Codex Alimentarius Commission (i.e. the body responsible for developing international food standards and codes of practice and guidelines on behalf of the Food and Agriculture Organization (FAO) and the World Health Organization (WHO)) has endorsed the use of a food safety management system such as HACCP as an addition to a basic quality assurance programme. The latter is achieved through good agricultural practices (GAP) and good manufacturing practices (GMP). The objectives are as follows:

- to control changes in food materials so as to consistently achieve the desired qualities in the finished product
- to ensure food is safe to eat, and
- to stop or slow down any deterioration in the food.

GAP/GMP involves understanding, analysis and control of the food production process.

## 2.2 On-Farm Control

*Campylobacter* spp. of public health concern, notably *C. jejuni* and *C. coli*, are widespread in the intestinal tract of domestic animals including food animals and household pets. The prevalence of intestinal colonisation with *Campylobacter* spp. varies from time to time in any group of animals and is a function of a number of factors including the general health of the individual animal and the extent of exposure to *Campylobacter* spp. posed by the animal's environment.

*Farm animals*

Infection with *C. jejuni* and *C. coli* rarely causes clinical disease in animals[*] . A variable proportion of animals in populations of cattle, sheep and pigs, as well as poultry, are carriers of these organisms. Therefore, in terms of risk management, it is reasonable to proceed on the basis that all flocks and herds contain animals that are likely to be colonised with and excreting considerable numbers of, *C. jejuni, C. coli* and other *Campylobacter* spp. of public health importance. As the identification of such animals, on an individual level, is unrealistic, the management of risk in relation to such populations must be undertaken on a whole herd/flock basis at all stages of production, processing and distribution.

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[*]Clinical campylobacteriosis associated with *C. fetus* var. *venerealis* in cattle results in infertility and abortion, while *C. fetus* subsp. fetus infection in sheep may lead to enzootic abortion. *C. jejuni* and *C. hyointestinalis* have been occasionally associated with enteritis in calves and older cattle. Such cases are relatively more prevalent in the autumn months. In general, other campylobacters, along with *C. jejuni*, are not regarded as primary animal pathogens and have been regarded as components of the normal flora of the intestinal tract of healthy food animals including poultry [48].

In beef and dairy production units, and in pig production, the housing together of animals from different sources at various stages of production represents a significant risk of introduction and spread of *Campylobacter* spp. There are well-defined risk factors associated with this practice, not least of which are the stressful effects of transport and their impact upon the density of colonisation within the alimentary tract of the newly introduced animals and the high numbers of *C. jejuni* and *C. coli* excreted in the course of transportation. At the same time, the indigenous animals also undergo stress, the result of which is further excretion and resulting contamination of their surroundings.

These factors also come into play when food animals are subjected to stress for other reasons. Animals going to or coming from sales yards or marts are likely to exhibit signs of alimentary distress resulting in the passage of unformed faeces, leading to a high level of environmental contamination and cross-infection of other animals. This is particularly the case when food animals, *viz.* cattle, sheep and pigs, as well as poultry [49; 50] are assembled and sent for slaughter. The level of stress associated with this period is well documented, as is the extent of the changes that the enteric flora undergoes at this time. As a result, not alone is there an increased risk of cross-contamination of live animals but also a consequential higher risk of contamination of these and other carcases in the course of carcase dressing, often conducted under less than ideal conditions.

*Poultry*

Once exposed, the bird's alimentary tract is rapidly colonised by *Campylobacter* spp. and other microorganisms, and within a relatively short period following initial exposure, a high proportion of the flock become lifelong excreters of large numbers of these microorganisms.

The source of colonisation is not always clear. Introduction of the organisms by way of contaminated boots and clothing are commonly implicated [51]. Contaminated water supplies, infected vermin and insects have also been implicated, while feed has not been identified as a primary source of infection. Depletion of poultry houses in three or four phases (i.e. thinning) represents a clear opportunity for farm-to-farm spread of *Campylobacter* spp. This practice results in access by individuals and their equipment to multiple poultry houses and farms in the course of a single working period for the purpose of removing a proportion of the flock for slaughter (thinning) while the remainder of the flock is grown to large size.

The possibility of vertical transmission (i.e. from breeder flocks to progeny) has been suggested [52], but is not widely accepted [53]. Meanwhile, a Danish study concluded that neither vertical transmission nor horizontal transmission via the hatchery were significant transmission routes of *C. jejuni* to broiler chickens under Danish conditions [54]. Consequently, the control of this zoonotic agent within the poultry industry may be more complex than is at present believed.

*Current Control Measures*

The essential elements of hygiene and biosecurity required to protect poultry flocks from exposure to *Campylobacter* spp. include the following measures:

**A. Structural and General Measures**

- An all-in, all-out policy regarding the movement of stock into and out of houses and preferably, into and out of individual sites, should be practised.
- In all cases, the poultry houses should be sound in structure and capable of being cleaned and disinfected.
- The poultry houses should be vermin-proof and rodents should be controlled by systematic baiting in the surrounds.
- The site should be maintained in a tidy state and the growth of grass and vegetative cover (including shrubs, trees) should be controlled.
- Entrances into poultry houses should have a well drained, concreted surround.
- Where there are exit points for the air ducts at the side of the poultry house, the surrounding area should be concreted and be maintained in a tidy state at all times.
- Each poultry house should have a separate lobby inside the entrance that is suitably equipped so as to facilitate changing of protective clothing and footwear and hand washing.
- Litter removal and disposal points outside the houses should be located in well drained, concreted areas, be clearly marked and be maintained in a clean and tidy state at all times.
- Spillage from feed bins should be removed promptly.
- Straw and shavings storage facilities should be kept tidy and be rodent-, bird- and pet-proof.
- The water supply to poultry houses should meet bacteriological standards comparable to those required of potable water under the Council Directive 80/778/EEC.

**B. Operational Measures During Production**

- Cleaning and disinfection facilities for footwear should be provided at the entry point(s) into each house and be kept replenished along with a requirement that personnel follow a strict procedure of cleaning and disinfection each time before entering and leaving.
- Separate protective clothing and footwear should be worn when entering each poultry house.
- Personnel should use the hand washing facility each time when entering and leaving poultry houses.

- The number of visitors entering poultry houses should be minimised.

- Visitors should be provided with protective clothing and footwear and be required to follow the same procedures as staff when entering poultry houses in all cases.

- As the practices of thinning and point-selling during production represent serious risks of introducing *Campylobacter* spp. to the flock, industry should consider the practicality of de-stocking the entire flock in each house at one time.

- All animal waste, dead birds and unused feed should be removed from houses and be disposed of hygienically.

- Pets should not be allowed to enter poultry houses at any time.

**C. Operational Measures on each Occasion when the Site is Entirely De-Stocked**

- All animal wastes and leftover feed should be removed and disposed of hygienically.

- The interior of the houses, including all water and feed distribution equipment, should be thoroughly cleaned.

- The concreted areas at personnel entry points, litter removal points and around side extraction air ducts should be cleaned and disinfected.

- All gross debris should be removed and disposed of hygienically and these areas should then be cleaned and disinfected.

- The use of a suitable insecticide prior to or following cleaning and disinfection should be considered.

- In cases where the flock in question has been found to have been infected with *Campylobacter* spp., the house(s) should be examined using drag swabs or by other means, in order to assess the efficacy of the cleaning and disinfection procedures followed.

- Following cleaning and disinfection, each house should be allowed to dry before re-stocking is commenced.

- In all cases the time and details of the sanitation programme as applied, together with the names of the personnel involved, should be recorded.

- Conformation with terms of a written sanitation programme, as agreed with the personnel concerned, should be the subject of an audit and the outcome of such audits, including site inspections, should be made known to the management of the integrated production/processing operation before re-stocking is allowed to commence.

The primary intervention strategy adopted to date for control of *Campylobacter* spp. in poultry has been to enhance biosecurity (outlined above) in an attempt to prevent the entrance of the organism in to the broiler house from the environment. The "thinning" procedure as outlined earlier represents a risk period with the potential to undermine efforts at biosecurity taken earlier in the production cycle.

Studies on the effectiveness of biosecurity measures, such as those outlined above, have been reported to have resulted in a significant reduction in campylobacter infection in broilers in the Netherlands and UK(55) . Some success in this regard has already been achieved on a number of poultry production units in Ireland as a result of the adoption of improved biosecurity measures on an integrated basis. The efficiency of implementation of the approved control measures as standard operating procedures (SOPs) must be consistently high at all stages and at all times if elimination of *Campylobacter* spp. is to be effective. However, the possibility of introducing *Campylobacter* spp. at any stage is very real. It is vital that this point is communicated to all personnel throughout the entire production chain as a matter of priority. These measures are unlikely to be applicable to free-range poultry, which may be expected to have regular contact with wild birds and other animals' droppings.

Provided it is properly protected from contamination at the point of consumption, animal feed is generally not regarded as a primary source of infection. This is because *Campylobacter* spp. are relatively susceptible to the effects of heat, do not multiply in, and survive poorly in animal feedstuffs, and generally have a low tolerance for aerobic conditions. However, the animal's food and water supply may become contaminated shortly before consumption by droppings from infected rodents, birds, and other animals and may also contain infected insects in which case transmission of *Campylobacter* spp. may ensue.

*Food Animals Other than Poultry*

Most poultry production in Ireland is based on integrated all-in all-out systems of intensive production with housing of the poultry in an environment which can be relatively rigorously controlled. Most other animal production occurs in an environment that is much less amenable to control, in many cases on open grassland. For these reasons on-farm control or elimination of *Campylobacter* spp. in food animals other than poultry is likely to be even more challenging.

*Other Control Measures*

Competitive exclusion exploits the principle of competition between microorganisms for similar ecological niches. The technique has been applied as a component of a successful strategy for the control of some bacterial infections, including salmonellosis in poultry (56). It involves the oral administration of a mixture of unspecified saprophytic bacteria to the chickens which will effectively inhibit colonisation by *Campylobacter* spp. To date, this approach has been unsuccessful. However, some competitive exclusion experiments have been shown to reduce the numbers of campylobacters in the caeca of treated birds [57]. At present, the use of proprietary competitive exclusion agents for this purpose is not permitted in Ireland, based on animal health grounds.

Effective vaccine strategies directed against infection with *Campylobacter* spp. in broiler chickens have yet to be developed.

*Conclusion*

Overall, the pre-harvest conditions, i.e. on-farm management practices and transport conditions, to which the slaughter animal is subjected in the period immediately preceding slaughter have a profound effect in increasing the risk of in-carriage and/or in-lairage cross-contamination of other animals including poultry, and later, of cross-contamination of carcases and equipment. There are, therefore, opportunities to reduce such contamination, provided sound animal husbandry and management practices aimed at achieving an effective level of biosecurity, are put in place on the farm, during transport and within the lairage of the receiving meat or poultry meat plant. In this respect, the current code of practice in regard to the acceptance of cattle and other food animals for slaughter only on the basis of their freedom from gross faecal contamination at their arrival at the plant, has merit in regard to reducing, to some extent at least, the risk of transmission of campylobacters to the consumer. It is far from clear if sustained campylobacter-free status can be achieved on poultry farms under commercial conditions, with even the most intensive level of biosecurity that is practicable. However, if this can be achieved, birds from flocks shown to be campylobacter-free should be transported under strict hygienic conditions to the poultry meat plant and slaughtered separately from birds from other flocks. Such a procedure is feasible and can lead to reductions in contamination rates in the dressed carcases.

### 2.3 The Abattoir: The Post-Harvest Phase

Abattoirs are food businesses and as such are required to give the same attention to food safety as any other food business [1]. The risk of contamination of meat by *Campylobacter* spp. originating from the skin, hides or alimentary tract of carrier animals cannot be eliminated under current slaughtering procedures. However, implementation of GMP and identification of hazards and potential points for their control may help to minimise such contamination. Prevention of gross carcase contamination with faeces is an obvious priority. However, general operational and structural hygiene should not be overlooked. Likewise, the possibility of contamination originating from workers and food handlers clinically infected with *Campylobacter* spp. should be considered.

*Poultry*

The pre-slaughter management of poultry has a considerable effect in determining the extent of contamination of the skin and feathers, and the density of colonisation of the bird's intestinal tract. Both these factors in turn contribute to the risk of contamination of the raw poultry meat.

Numerous studies both in Ireland and elsewhere have demonstrated that the measures currently adopted by the industry and, specifically, by equipment manufacturers, have not been effective in preventing such occurrences. In effect, the process of scalding, plucking and eviscerating poultry carcases from different sources in the course of the same work period inevitably leads to cross-contamination, with the result that 80% or more of carcases carry varying numbers of *Campylobacter* spp., principally *C. jejuni* and *C. coli*, on their skins and on their internal surfaces as they move into the cold-line and distribution chain [32].

*Other Animals*

*(a) Other Food Animals*

In regard to the slaughter of pigs and pork carcase dressing, there are greater opportunities for carcase contamination than is the case with cattle or sheep. Pig carcases undergo a communal scalding process in the early stages of processing. The skin remains on the carcase as it enters the food chain, and automated equipment is increasingly used in the course of carcase dressing which results in a high rate of intestinal rupture and escape of contents onto the interior of the carcase. The avoidance of such cross-contamination is rendered more difficult by the high line speeds used.

The opportunity for cross-contamination is considerably less in the case of red meat production. Cattle and sheep are slaughtered and dressed on an animal-by-animal basis, with little or no carcase-to-carcase contact occurring throughout the process. Thus, good butchering technique that in particular avoids contamination of the carcase through contact with the hide or wool and puncture of the gastrointestinal tract, along with personnel hygiene and sanitation of equipment such as knives, saws and moving surfaces with which the carcase comes into contact, offer a reasonable means of reducing contamination of carcases to a minimum. Nevertheless, *Campylobacter* spp. can be found on beef and sheep carcases as they leave the slaughter hall and enter the cold line and distribution chain.

In all cases, the absolute numbers of microorganisms present on the surfaces of contaminated carcases reduce considerably in the course of chilling and distribution within the cold chain. This reduction, however, is not complete, as campylobacters can be recovered from the surfaces of chilled carcases, but in lower numbers than from unchilled carcases.

*(b) Contact with Animals -Livestock and Animals on Pet Farms*

There have been a number of reported vero-toxigenic *Escherichia coli* O157 outbreaks among children following visits to pet farms/open farms [58, 59]. In the case of *Campylobacter* spp., the infective dose is also low and therefore *Campylobacter* spp. may present a risk for visitors to farms if good hygiene is not observed. This issue is very important in the case of young children who do not understand the importance of hygiene and are prone to putting their hands in their mouths or sucking their fingers. The UK Health and Safety Executive (HSE) recently published revised guidelines [60] for open farms including recommendations regarding farm layout, animal contact, eating areas, washing facilities, information and signs, training and supervision, livestock management, and manure and compost heaps. In addition, the HSE also produced a supplement to these guidelines specifically for teachers [61]. In Ireland, the Cork Zoonoses Committee has published a guide to good practice on open farms [62].

*(c) Household Pets*

There is ample evidence of the potential risk posed in the home by clinically healthy but infected dogs and cats as a source of *C. jejuni, C. coli* and other campylobacters for the human population. Hald and Madsen (1997) concluded that infected young pups and kittens were potential transmitters of campylobacter to their owners [63]. Torre and Tello (1993) associated dog-related biotypes of *C. jejuni* with cases of human enteritis [64]. Consumers need to be made aware that pets may be a source of such infection and that they should not handle food after handling pets without first washing their hands. Young children in particular should be encouraged to wash their hands between handling pets and eating.

*Conclusion*

Such measures as are currently employed to prevent or control contamination of meat by *Campylobacter* spp. during slaughter and carcase dressing are unlikely to be successful in isolation. Additional measures either at the earlier phase of production (as outlined above) or after carcass dressing (end product decontamination) are likely to be required to achieve campylobacter-free meat.

At present, chemical sanitation of carcases is not allowed under EU rules, although the use of chlorinated water is allowed within specified limits of chlorine concentration that ensure the potability of the water, for commercial purposes. Elsewhere, decontamination of poultry carcase is permitted using organic acids and tri-sodium phosphate preparations [47] and by means of ionising radiation [46]. These methods have been found to reduce the extent and density of contamination with Campylobacter spp. Meanwhile, steam pasteurisation of beef carcases in the final stages of processing is now practised in some countries including Ireland, with encouraging results [65].

## 2.4 Specific Foods

- *Unpasteurised Milk and Products*
  Unpasteurised milk and unpasteurised milk products may be contaminated with *Campylobacter* spp. (Table 3). These foods are best avoided by those with impaired immunological function, e.g. the very young, the very old, pregnant women, and patients at increased risk of infection for whatever reason. On-farm consumption of unpasteurised milk is common. In 1998, the FSAI launched a campaign to alert people to the possible dangers of drinking untreated milk and to encourage the use of home pasteurisation kits.

- *Meat*
  Raw chicken and other raw meat should be handled and stored carefully in order to avoid cross-contamination of cooked or ready-to-eat foods. As *Campylobacter* spp. are sensitive to heat, thorough cooking of raw chicken and other meats provides protection against foodborne campylobacteriosis.

- *Seafoods*
  *Campylobacter* spp. may be found transiently in marine environments. As a consequence, shellfish may become contaminated. Possible sources of contamination include sewage effluent, farmland run-offs and waterfowl reservoirs. Depuration of oysters is not fully effective in eliminating pathogens such as *Campylobacter* spp. therefore, people with impaired immunological function should avoid consumption of uncooked shellfish.

- *Vegetables and Salads*
  There have been relatively few studies on the presence of *Campylobacter* spp. in vegetable foods. Isolation rates from published studies are extremely low [(66)]. There have been some reported outbreaks linked to sources of raw foods such as lettuce or salads, but it has been suggested that these foods were not the original source but rather the vehicle, which became contaminated during preparation [(8)].

## 2.5 Food Processing, Catering and Retail Outlets

- *Introduction*
  *Campylobacter* spp. are frequently present in a variety of foods, raw poultry meat and other raw meats in particular (Table 3). The processing, retail and catering sectors need to be aware that such foods must be processed in a manner that will destroy the contaminating pathogen and ensure that at all times the handling and storage of such foods does not result in the contamination of ready-to-eat foods. Simple precautions are needed, viz. – use of normal cooking temperatures that will kill this pathogen and the employment of good hygiene practices that prevent contamination of ready-to-eat foods. Meat should be cooked thoroughly until it is no longer pink and the juices run clear. Particular care should be taken with chicken and other poultry to ensure that they are fully cooked before serving.

- *Legislative Control*

  All food businesses are required by law European Communities (Hygiene of Foodstuffs) Regulations, 2000 (S.I. No. 165 of 2000) to ensure that the food they produce is safe. The legislation requires that employees are suitably trained and that a food safety management system, based on the principles of Hazard Analysis Critical Control Point (HACCP) system, is implemented.

- *Training*

*'Food business operators shall ensure that food handlers are supervised and instructed and/or trained in food hygiene matters commensurate with their work activity.'*

Training initiatives for staff are crucial to ensuring the production of safe food, in addition to being a legal requirement. Recently the FSAI has published two guides in a series of three planned national guides that aim to improve industry standards, for the ultimate benefit of providing safer food for consumers. *Guide to Food Safety Training - Level One* outlines the minimum staff training standards at induction level that food businesses must meet to comply with the law. *Guide to Food Safety Training - Level Two* outlines standards which must be demonstrated by all food handlers within a specified period of time after commencing employment.

These guides were devised in consultation with the FSAI's Food Safety Training Council following research by the FSAI which showed that during the period 1998-2000, of the 100 outbreaks reported to the FSAI, inadequately trained staff was one of the contributory factors. This research suggests that outbreaks of foodborne disease could be reduced by enhanced staff training in basic food hygiene practices.

- *HACCP*

*'The proprietor of a food business shall ensure that any step in the activities of his/her food business which is critical to ensuring food safety is identified and that adequate safety procedures are identified, implemented, maintained and reviewed on the basis of the following principles used to develop the system of HACCP (Hazard Analysis and Critical Control Points) …'*

HACCP is a systematic approach to identifying and controlling hazards (biological, chemical and physical) that could pose a threat to the production of safe food - in simple terms, it involves identifying what could go wrong and planning to prevent it.

It is essential that everyone within a food business, irrespective of the scale of the business, appreciates the importance of HACCP and has a sense of ownership of the system. HACCP should not be viewed as the sole responsibility of the technical staff. Proprietors and senior management must recognise the need to properly resource the HACCP system, while all food handlers should understand the vital role they play in making the system work. Before a food business can benefit from implementing a HACCP system, it must already be operating to standards of good hygienic practice/good manufacturing practice (GHP/GMP). The so-called prerequisite hygiene programme includes such things as structural, operational and personal hygiene; product labelling, traceability, release, and recall; and calibration and maintenance of equipment. HACCP is additional to and dependent on the prerequisite programme and allows a food business to focus resources on ensuring that steps crucial to achieving food safety objectives are properly executed and monitored.

• *Codes of Practice*

To assist food businesses in the interpretation of and compliance with the legislation the National Standards Authority of Ireland (NSAI) has developed a number of codes of practice specifically tailored for the manufacturing, catering and retail sectors, i.e. I.S. 342, I.S. 340 and I.S. 341, respectively. The codes for the three different sectors detail the general hygiene and other requirements (i.e. "pre-requisite programme") that must be met to ensure food safety. These include personal hygiene, zoning (i.e. to prevent cross-contamination), cleaning/sanitation, pest control, premises and structures, plant and equipment, maintenance, services (e.g. water, ventilation etc.), storage distribution, transport, and waste management. In addition, the NSAI has published a general standard, I.S. 343, which outlines a food safety management system based on the principles of HACCP.

• *Control at Processing*

The following approaches can be used to control *Campylobacter* spp. and other pathogens in food production:

1. avoid initial contamination of raw materials and subsequent contamination of the product;
2. prevent multiplication/growth during the processing and storage, and
3. ensure death of the pathogen where possible.

In order to select the appropriate control measure(s) the following factors need to be considered:

- the initial level of contamination of the raw materials, since a wide range of foods may be contaminated with *Campylobacter* spp. (Table 3).
- the characteristics of the pathogenic agents - e.g. *Campylobacter* spp. multiply best at 42-43°C, with a minimum temperature for growth of 32°C. *Campylobacter* spp. are killed by normal cooking temperatures.
- the characteristics of the food that may influence the potential for growth of the pathogen under various conditions – *Campylobacter* spp. are acid sensitive and will not grow below pH 4.9. *Campylobacter* spp. are very sensitive to salt (2.0% salt is sufficient to inhibit growth), even under otherwise optimum growth conditions. They grow best in moist foods (with a minimum water activity of ~0.98) and are sensitive to oxygen.
- the effect of the production, processing, handling, distribution steps and preparation by the final consumer on the microbial agent.
- the level of hygiene practiced at each stage and the potential for (re)contamination of the food.

Contaminated water used as an ingredient or in the preparation of food can be a potential source of *Campylobacter* spp. (see section 2.7)

• *Control at Catering and Retail Outlets*

To manage the risks posed by bacteria, such as *Campylobacter* spp., food handlers in restaurants, cafés, canteens, supermarkets and corner shops etc, must (i) deal with residual contamination from the earlier parts of the food chain and (ii) prevent contaminated food from entering this stage of the chain by applying the following simple control measures:

- prevention of contamination of the food by contaminated water, unhygienic premises, unhygienic food handler/food handling practices
- prevention of cross-contamination between raw and ready-to-eat foods
- prevention of bacterial multiplication, through appropriate storage and cooling
- killing pathogens by cooking or other treatments of the food.

The retail sector contributes to lowering the residual risks in the food chain by providing consumers with advice on how to safely prepare the food.

Caterers and retailers should be aware that contaminated water used as an ingredient or in the preparation of food can be a potential source of *Campylobacter* spp. (see section 2.7)

## 2.6 Control in the Home

• *Food*

At home, the consumer is the last link in the food chain and has to deal with residual pathogens in food. A comparison of the 1998 and 2000 surveys on *Public Knowledge and Attitudes to Food Safety in Ireland* conducted by FSAI and the Food Safety Promotion Board (FSPB), respectively, revealed a promising increase in consumer awareness of food safety issues and knowledge of safe handling practices [67, 68]. However, both surveys identified the continued need for public awareness campaigns and new consumer education strategies. In 1998, 41% of respondents were unlikely to wash utensils and chopping boards between preparing raw meat and cooked food; this number was halved in the 2000 survey.

Cogan *et al.* (1999) examined 13 sites in each of 60 domestic kitchens for the presence of *Salmonella enterica* and *Campylobacter* spp. following the preparation of a chicken for cooking with the application of different hygiene regimes [69]. During food preparation bacteria became widely disseminated to hand and food contact surfaces. Cleaning with detergent and hot water did not result in any significant decrease in surface contamination. By contrast, the additional use of hypochlorite resulted in a significant reduction in the number of contaminated sites observed. The study suggests that there is a need for better understanding of and application of effective hygiene procedures for the domestic kitchen.

Consumers need to be reminded that as raw foods are not sterile they may contain bacteria, including pathogenic bacteria such as *Campylobacter* spp. (Table 3). The measures required in the kitchen to minimise risk of infection with *Campylobacter* spp. consist of the application of the basic principles of safe food preparation. In public awareness campaigns, the emphasis should be consistently placed on these basic principles rather than on the details of individual gastrointestinal pathogens. In addition to awareness of basic measures such as hand washing and separation of ready-to-eat and raw food, some traditional food preparation practices should be discouraged. For example, the practice of washing dressed poultry carcases in the kitchen sink is unnecessary and increases the risk of contamination.

Barbecues are becoming increasingly popular in Ireland. Some 30% and 34% of those surveyed in 1998 and 2000, respectively, said they had cooked food using a barbecue. Whether cooking outdoors or in a well-equipped kitchen, people need to observe the highest standards of hygiene and in particular, (a) prevent cross-contamination between raw and ready-to-eat foods (as a result of using the same utensils for handling the raw and cooked food) and (b) cook food thoroughly. The summer 2001 awareness campaign and leaflet *Eating Outdoors - How to Stay Safe for Summer*, published by the FSPB, is an extremely valuable and necessary guide for the consumer.

### 2.7 Water

The findings of the 2000 Environmental Protection Agency (EPA) report entitled *The Quality of Drinking Water in Ireland: A Report for the Year 2000 with a review of the period 1998-2000*[37], highlight the potential for a proportion of the Irish water supply (in particular group water schemes and small private supplies) to become contaminated with faecal organisms such as *Campylobacter* spp. [70]. Those in charge of maintaining these supplies should ensure that they are protected from faecal contamination, that all such schemes are suitably treated, that treatment processes are properly supervised and maintained, and that water supplies are checked routinely for microbial contamination. The unsatisfactory level of contamination of drinking water serving a significant percentage of consumers in the country, as outlined, is a major public health concern and efforts to improve drinking water safety must be of a high priority to Government and consumers alike.

With reference to the European Communities (Hygiene of Foodstuffs) Regulations, 2000 (S.I. No. 165 of 2000), food businesses are now required:

- to have an adequate supply of potable water,
- when appropriate, to make ice from potable water. Ice must be made, handled and stored under conditions which protect it from all contamination,

- to ensure that steam that is likely to come directly in contact with food must not contain any substance which presents a hazard to health or is likely to contaminate the product, and

- to ensure that water unfit for drinking used for the generation of steam, refrigeration, fire control and other similar purposes not relating to food, must be conducted in separate systems, readily identifiable and having no connection with, nor any possibility of reflux into, the potable water systems.

## 2.8 Control and Surveillance in the Human Population

- *Vulnerable Groups*

The young, the old and the immunocompromised are likely to have more severe disease as a result of infection with *Campylobacter* spp. than the general population. The incidence of campylobacteriosis among HIV-infected patients is higher than in the general population and common complications such as recurrent infection and infection with antimicrobial-resistant strains tend to occur among these patients [12, 13].

The consequences of infection with *Campylobacter* spp. for vulnerable patients can be very serious and, with increasing numbers of vulnerable people in modern society in Ireland, it is important that human exposure to infection with *Campylobacter* spp. in Ireland is prevented and controlled.

Increased collaboration between clinicians and public health physicians is necessary to heighten awareness concerning high-risk groups, the need to observe precautions against cross-infection in those with diarrhoeal disease and the importance of submitting stool samples for microbiological investigation. Culture of stools for *Campylobacter* spp. should form a routine part of the microbiological investigation of community-acquired acute diarrhoea.

- *Sporadic Cases*

Most cases of campylobacteriosis are sporadic and are mainly foodborne [24, 25]. Sporadic cases are those with no known epidemiological link to another case. Studies of sporadic cases have failed to explain the majority of causes, although some risks have been identified [24]. Sporadic illness peaks in the summer and is generally associated with mishandling and consumption of undercooked poultry or cross-contamination of ready-to-eat products [7, 13].

- *Local Level*

For a person with campylobacteriosis who seeks medical attention, the first point of contact is usually with their general practitioner (GP). More seriously ill patients may require hospitalisation. Harmonisation of data collected and of criteria for the submission of specimens for laboratory investigation from those with acute gastrointestinal disease may be valuable for surveillance purposes.

Campylobacteriosis may be notified to the Medical Officer of Health, in the health board where the patient resides, as "food poisoning other than *Salmonella*" however, specific notification of campylobacteriosis is not compulsory at present. Direct reporting of campylobacteriosis from the laboratory may improve data quality and may be supported by forthcoming developments in computerised infectious disease reporting and changes in legislation relating to the process of notification.

The following groups are considered most at risk of infection with *Campylobacter* spp. (i.e. they are high risk groups)

- food handlers
- staff of healthcare facilities who may have direct contact or contact through serving food, with susceptible patients or persons
- children less than 5 years old, who attend crèches, nursery schools, playgroups or other similar groups
- older children or adults who may find it difficult to implement good standards of personal hygiene e.g. those with learning difficulties or special needs
- immunocompromised patients
- poultry processors, abattoir workers and veterinarians.

• *Health Board Level*

Information collected at health board level is important in detecting outbreaks, monitoring trends and ensuring that control measures are implemented. On receipt of a notification to the Director of Public Health the minimum dataset, as outlined below, should be assembled and notified to the National Disease Surveillance Centre (NDSC). Appropriate public health measures to minimise the risk of spread of infection should be instituted, in particular relating to exclusion of patients with diarrhoea from contact with high-risk groups, or from food preparation, until 48 hours after the first normal stool. Laboratory confirmation of clearance of infection is not required.

The minimum public health dataset for regional/district surveillance should include the following:

- patient name
- gender
- age
- residence
- occupation
- date of onset of illness
- date of diagnosis
- species

• *National Level*

At national level, data are aggregated, analysed and compared within and between countries by the NDSC. A Sub-committee of the Scientific Committee of the NDSC has produced a document entitled *A Review of the Notifiable Diseases and the Process of Notification 2000*[70]. *Campylobacter* spp. infection will be statutorily notifiable under the new system which is proposed in the notification process.

• *Outbreak Management*

The objective of outbreak management is to prevent further cases, in the particular outbreak under investigation, and to highlight contributing factors so as to prevent similar outbreaks occurring in the future. The investigation of an outbreak of campylobacteriosis should follow the format of general outbreak investigation. This involves the collection of epidemiological, microbiological, environmental and veterinary information. Effective communication between the professionals involved is essential for a thorough outbreak investigation and should be fostered continually at local and national level.

Investigation of outbreaks offers a unique opportunity for identifying the origin of the infection, the most likely routes of transmission and the most effective means of control and prevention.

• *Sentinel Surveillance*

In order to provide more extensive epidemiological data on campylobacteriosis in Ireland, a sentinel enhanced surveillance scheme is required. This would involve collection of extensive epidemiological data on patients in certain areas or selected sites in Ireland. These data would then be matched with detailed laboratory data on strain characterisation which would, in turn, require a reference laboratory for confirmation of identification and detailed typing.

## 2.9 Zoonoses Directive

The EU Council Directive 92/117/EEC (the "Zoonoses Directive") provides for yearly reporting from all Member States on the epidemiology of various zoonoses, including campylobacteriosis. In a recent review of foodborne zoonoses the Scientific Committee on Veterinary Measures Relating to Public Health identified campylobacteriosis, along with six other zoonotic agents of significance within the EU, which warranted focused surveillance [1]. A zoonosis group at national level has been formed to coordinate the submission of national zoonosis data to Europe under the Zoonoses Directive, with representatives from DAF, NDSC and FSAI.

Zoonoses Committees, supported by FSAI, which have now been established in the regional health boards provide an appropriate forum to enhance communication and collaboration between medical, veterinary, public health and environmental personnel, should continue to be fostered at regional level.

## 2.10 Public Awareness and Labelling of Food

The likelihood that certain foods, notably raw meat and poultry meat and non-heat-treated milk and dairy products, may carry variable numbers of potentially harmful microorganisms is a matter that requires the attention of consumers and the food industry alike. The need to take reasonable precautions against foodborne infections such as salmonellosis and campylobacteriosis is being addressed by bodies such as the FSPB and the FSAI. There is a role here for labelling of individual packs of foods such as those mentioned earlier so as to advise customers at the point of sale of the potential hazards that readily may be transferred from the commodity in question to themselves or to family members through the mishandling of such products in the kitchen or elsewhere. Such an approach has been implemented successfully in the United States, with the cooperation of the marketing agencies, for some time and to the benefit of the consuming public. In general, the provision of information on proper handling of the food at both the domestic and retail (including catering) levels, in the form of a label carrying an explicit cautionary statement readily understood by the reader, is an effective preventive measure that can be implemented with limited cost. The provision of additional and complementary information by other means, including the education of the young on matters of food hygiene, would ensure a heightened awareness of the need for due care when preparing such foods for human consumption.

# CHAPTER 3: RECOMMENDATIONS

## 3.1 Introduction

Contamination of food with *Campylobacter* spp. represents an excellent paradigm of a divergence of views between many food safety and public health authorities and many members of the general public. There is clear evidence that end product decontamination of food, by means of heat treatment, chemical treatment or irradiation of food, for example, is effective in reducing/eliminating *Campylobacter* spp. and other foodborne pathogens. In particular, end product decontamination by means of irradiation, as carried out under conditions of Good Manufacturing Practice (GMP), is considered a safe and effective food processing method that can reduce the risk of foodborne disease. Irradiation is permitted in Ireland for herbs and spices, and in other countries for a greater range of food products. It appears however that there is considerable public anxiety related to irradiation of fresh meat and that irradiation of meat products may not be widely acceptable at the present time. Public policy must take account of the premise that a product can only serve as food if the majority of those in the community find it palatable and otherwise acceptable.

In presenting the recommendations that follow, due account is taken of these concerns. The recommendations are presented in the knowledge that some of the measures specified, in particular in relation to animal production, have a considerable cost and are in some cases of uncertain effectiveness as an alternative to end product decontamination. Improved measurement of consumer concerns and more effective dialogue between scientists, consumers and policy makers is essential to strengthen the acceptance of science as a basis for food safety policy.

## 3.2 Recommendations

### 1 Farm Level

1.1 Poultry farm managers/operators should comply to the highest possible degree with the biosecurity measures detailed in this report.

1.2 During poultry production, the practice of thinning and point-selling should be avoided, where possible, by completely de-stocking the flock in each house at one time.

1.3 Farm managers/operators should adopt methods to control exposure of visitors to *Campylobacter* spp. Of particular concern are pet/open farms where visitors, especially children, may be exposed to *Campylobacter* spp. through the consumption of contaminated raw milk and through contact with healthy but infected animals, followed by the consumption of food without proper hand-washing.

1.4 Animal waste from poultry farms should be managed in such a way as to minimise the risk of contamination of the environment with *Campylobacter* spp.

1.5 In the case of all farmed animals, pre-slaughter stress at collection, transport and lairaging should be minimised.

## 2 Abattoir and Poultry Plant Level

2.1 The meat and poultry meat industries should develop and implement evidence-based standard operating procedures, in order to prevent or minimise product contamination with *Campylobacter* spp.

2.2 As a component of a possible future quality assurance scheme for poultry meat production, on-farm monitoring programmes could be used to identify campylobacter-free flocks and slaughter these at the start of the day's kill.

2.3 Waste from poultry plants and abattoirs should be managed in such a way as to minimise the risk of contamination of the environment (in particular water sources) with *Campylobacter* spp.

## 3 Retail and Catering Level

3.1 Businesses should document and implement a food safety management system based on the principles of HACCP.

3.2 All staff should be appropriately trained in food safety to a level commensurate with their work activities.

3.3 Constant attention should be given to proper hand hygiene before and after handling food in the kitchen, particularly after handling raw poultry products.

3.4 Measures to reduce cross-contamination should be strengthened, e.g. by providing leak-proof bags, and by ensuring effective separation of raw and cooked meat products, and by effective supervision and control of 'in-store' cooking.

3.5 A supply of potable water must be available for the preparation of food. In the event that a premises is not linked to a public water supply, the business should monitor the quality of the water supply to ensure it is consistently of potable quality.

3.6 Procedures should be in place to ensure that staff members report symptoms of gastroenteritis and that affected staff are excluded from food handling until 48 hours after the last symptom of the condition, in accordance with the Public Health Laboratory Service (PHLS) UK, and forthcoming Irish guidelines.

## 4 Statutory/Regulatory Authorities Level

4.1 The Food Safety Authority of Ireland and the relevant official agencies should consider the establishment and enforcement of monitoring and control strategies for *Campylobacter* spp. in poultry meat production, processing and distribution.

4.2 The Department of Agriculture and Food should put in place systems to monitor imports to ensure that the same standards that are applied to domestically produced food are also applied to imported foods.

4.3 The Food Safety Authority of Ireland and the Department of Agriculture and Food should initiate a campaign, directed in the first instance, towards poultry producers and processors, to increase awareness of the hazards posed by *Campylobacter* spp.

4.4 A national *Campylobacter* Reference Laboratory should be established with facilities for phenotypic and genotypic characterisation of human, food and animal isolates, and recording and analysis of antimicrobial resistance patterns.

4.5 Sentinel-based surveillance should be introduced at health board level in order to elicit sources and routes of transmission of *Campylobacter* spp. in Ireland.

4.6 The Food Safety Authority of Ireland and the health boards should ensure that food businesses are aware of the statutory requirement to have available and to use a supply of potable water for the preparation of food.

4.7 The Food Safety Promotion Board should continue public awareness campaigns which focus on general measures for safe food handling and preparation, such as the need for proper refrigeration and separation of raw and cooked foods in the kitchen and when cooking out-of doors.

4.8 The Food Safety Promotion Board should measure consumer attitudes to interventions, such as irradiation of meat on an ongoing basis and stimulate dialogue between consumers and scientists in relation to the potential benefits of food irradiation and consumer concerns about perceived hazards.

4.9 The health boards should be appropriately resourced to ensure that they can adopt and implement the National Disease Surveillance Centre recommendations regarding surveillance, including the establishment of a minimum national dataset and co ordination and standardisation of laboratory reporting of cases in keeping with Computerised Infectious Disease Reporting (CIDR) procedures.

4.10 The Food Safety Authority of Ireland should work with industry to ensure appropriate labelling of raw poultry and other meat products, in order to advise food handlers and consumers that these products may contain harmful bacteria and must therefore be handled, stored and prepared according to the instructions provided.

4.11 The Food Safety Authority of Ireland and the official agencies should ensure that the legislation regarding training of staff and implementation of food safety management systems based on the principles of HACCP is enforced.

4.12 Relevant professional bodies should develop guidance on indications for collection of, and laboratory examination of stool samples. Laboratory examination should include culture of stools for *Campylobacter* spp. as a routine part of the microbiological examination of community-acquired acute diarrhoea.

4.13 The Department of Health and Children should ensure that the health boards can provide an adequate seven days a week public health response to outbreaks of foodborne disease.

4.14 Those persons preparing food for vulnerable groups should be made aware of the hazard that foodborne pathogens, and in particular *Campylobacter* spp. with their low infective dose, represents for members of the most vulnerable groups in our society.

4.15 In view of the wide implication of the consumption of raw milk in particular and raw milk products as a means of transference of *Campylobacter* spp., and other foodborne pathogens to consumers, clear information should be developed on the risks such products are likely to represent. This information should continue to be distributed to farming families and their visitors, and at the point-of-sale and/or distribution in restaurants and other food outlets.

## 5 Consumer Level

5.1 Consumers should practise basic good hygiene when handling food and should cook high-risk raw foods thoroughly.

5.2 Consumers should avoid washing the inside of whole "oven ready" chickens or turkeys prior to cooking, as this practice may serve to spread bacteria from the cavity of the bird around the kitchen.

5.3 In the home, consumers should practise basic good hygiene, such as hand-washing, to protect food from direct or indirect contamination with pathogenic organisms, such as *Campylobacter* spp., from non-food sources including household pets.

5.4 Given the importance of water quality in food preparation, consumers should inform themselves of the source of their water supply and, where necessary, should be assisted in ensuring access to a water supply of acceptable quality.

## 6 Surveillance and Research Level

6.1 More data is required relating to the levels of *Campylobacter* spp. in specific foods, including water, dairy products (especially unpasteurised milk and dairy products made therefrom), vegetables, poultry meat, lamb, pork and beef products, as well as in food animals, domestic pets and other sources of *Campylobacter* spp.

6.2 Research on the mechanisms of virulence in *Campylobacter* spp. strains should be undertaken in order to elucidate the relative public health significance of different strains of this microorganism as recovered from various sources.

6.3 An investigation of the efficacy and feasibility of using (i) competitive exclusion and (ii) vaccination in reducing levels of *Campylobacter* spp. in poultry in Ireland should be undertaken.

6.4 An extensive investigation should be undertaken of the efficacy, feasibility and public acceptability of additional specified methods of carcase/food decontamination, including chemical treatment of carcases (e.g. organic acids, tri-sodium phosphates and physical treatments such as pasteurisation) with other forms of thermal or sonic treatment and ionising radiation.

6.5 Further research should be undertaken to assist the development of evidence based protocols for control procedures for use in the different stages of poultry production and processing, to prevent and/or reduce cross-contamination of poultry and poultry meat by *Campylobacter* spp.

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