Campylobacter Species: Considerations For Controlling A Foodborne Pathogen

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ABSTRACT

Studies in the past decade have demonstrated with convincing evidence that Campylobacter jejuni is an important enteric pathogen of man. The wide distribution of the organism in animal reservoirs, and in foods of animal origin makes control of this foodborne microbe a formidable undertaking. Although the vehicles that are incriminated as sources of infection are broad, most illnesses occur sporadically without a finite determination as to the mode of transmission. The problem is further amplified because an infectious zoonotic disease like Campylobacter enteritis not only occurs frequently, but is almost always unsuspected, and too often unrecognized. Factors that perpetuate the Campylobacter problem are spreading Campylobacter during animal slaughtering and processing, concentrating animals in feedlots and brooding houses, poor food handling and storage practices, environmental contamination from animal wastes and other sources. Campylobacteriosis is a universal problem and an immense challenge to all who work in the arena of food protection. The solutions for control and prevention are demanding. In addition to more needed research, close national and international cooperation is a mandate if progress will be realized in the long-term minimization, and eventual elimination of this pathogen.

INTRODUCTION/HISTORICAL BACKGROUND

Even though campylobacters were first recognized about 70 years ago, their remarkable association with disease in man is only now becoming widely appreciated because these organisms have now been recognized as among the most frequent causes of bacterial diarrhea in man (12). Frequently found in animals, particularly in bovines and ovines, campylobacter for more than 40 years was known exclusively as an animal pathogen. Two veterinarians, McFadyean and Stockman, discovered the organism in 1909 in association with epizootic abortion in ewes (52). In 1913, the same researchers demonstrated that this organism could be observed in infectious abortions, but World War I prevented dissemination of their work to public health workers (52).

Theobald Smith, in 1919, during his investigation of infectious abortions of bovines in the U.S., isolated (apart from the "Bacillus of Bang") another bacterium which he described as a spirillum (73). On completion of his study, Smith became acquainted with the work of McFadyean and Stockman and made an initial assumption that they had been studying the same bacterium. He subsequently confirmed this finding with Taylor, thus, "Vibrio fetus" was proposed as a name (73).

In 1931, Jones et al. (3) described winter dysentery in calves as being caused by a "vibrio" they called Vibrio jejuni. Doyle (19), in 1944, associated a similar organism with swine dysentery. In 1946, Levy (5) reported a milkborne outbreak of acute diarrhea in man, describing organisms in his report resembling Vibrio jejuni in blood cultures from several affected patients. In 1947, Vinzent (85) isolated Vibrio fetus from the blood of three pregnant women, two of whom aborted. Human strains, however, were not extensively studied until 1957, when King (47), working with isolates from human blood cultures, distinguished two groups of organisms (67). One group corresponded closely to the existing description of V. fetus; the second group of organisms King called "related vibrios."

In 1963, Sebald and Veron (70) found that these two groups of vibrios differed biochemically and serologically from the classical cholera and halophilic vibrios since their DNA base-pair ratio (G + C mol %) differed from that of the other vibrios (80). Based on these findings, Sebald and Veron proposed that these species be removed from the genus Vibrio and that they be called Campylobacter or "curved rod" (80).

In 1972, Butzler et al. (11), in Belgium, isolated Campylobacter jejuni from 5% of children with diarrhea. These findings were later confirmed by Skirrow (67). Since that study other workers have reported similar findings and in some laboratories Campylobacter isolations outnumbered those of Salmonella and Shigella together (4,45).

As recent as 20 years ago, fewer than 25% of persons with acute diarrhea had a pathogen identified by stool examination. Today, as many as 65 to 85% of patients have a causative agent identified (13). In addition to better culturing techniques, new organisms have been discovered. Among these, C. jejuni is the most important. Since the organism was first isolated from human diarrheal stool in...
1971, C. jejuni has now been recognized as one of the leading causes of gastroenteritis (78). Finch and Riley (25) conservatively estimated that more than 16,000 people acquired Campylobacter infections in the United States in 1982. It was also determined that diarrhea caused by Campylobacter was as common as Salmonella and more common than Shigella. Since most laboratories did not culture for the organism or report it, the results are significant. Comparative estimates in the United States in 1982 reported C. jejuni infections to have occurred at a rate approximately equal to hepatitis B, and 10 times that of influenza (38).

From 1980 to 1982, meat and poultry accounted for 4 of 23 outbreaks of foodborne campylobacteriosis reported to the Centers for Disease Control, Atlanta, Georgia, second only to unpasteurized milk as a source of C. jejuni in the United States (53). A recent case control study by the Communicable Disease Control Section of the Seattle-King County Department of Public Health reported that chicken consumption was the predominant risk factor associated with C. jejuni enteritis, and this association was supported by microbiological study of isolates (67).

THE ORGANISM

Campylobacters (71,84) are small, nonsporforming, gram-negative bacteria with a characteristic curved, S-shaped or spiral morphology. The cells may vary from 0.5 to 8 μm in length, and 0.2 to 0.5 μm in width. Virtually all members of the genus are oxygen-sensitive and can grow only under conditions of reduced oxygen tension which vary from almost anaerobic to microaerobic for the different species. An aerotolerant Campylobacter group has recently been described (57). The cells are highly motile with a characteristic rapid, darting, corkscrew-like motility. They have a single polar flagellum at one or both ends of the cell.

Campylobacters grow best in an atmosphere containing 5-10% oxygen and are thus considered microaerophilic. All campylobacters grow at 37°C; however, C. jejuni grows best at 42 to 45°C. (18,44). Because C. jejuni is a very common pathogen of humans, many laboratories use incubation at 42°C for optimal isolation; however, use of this temperature will not allow selection of all species.

Campylobacters tend to multiply slower than the usual enteric flora. Thus they cannot be isolated from fecal specimens without the use of selective techniques. Antibiotic-containing media are the most common isolation methods currently in use. Three such media, Skirrow’s, Butzler’s, and Campy-BAP, or variations of these specific media, are in wide use (44). Butzler’s and Campy-BAP media contain cephalothin, which inhibits Campylobacter fetus and several other Campylobacter sp. but are best suited for isolating C. jejuni.

Campylobacters can be distinguished from other microorganisms on the basis of several standard criteria and can be distinguished from one another on the basis of biochemical testing (35). Visible colonies usually appear on the plating media within 24-48 h. Occasionally growth takes place after 72-96 h of incubation.

The serotypic diversity of C. jejuni is broad, similar to other bacteria whose ecologic niche is the gastrointestinal tract of mammals. More than 60 different serotypes based on somatic (O) antigen and 50 different serotypes based on heat-labile antigens (capsular and flagellar) have been identified (5).

C. jejuni is sensitive to drying or freezing temperatures, characteristics which limit its transmission. The organism, however, survives in milk or water kept at 4°C for several weeks. Concentrations of chlorine commonly used for water disinfection and pasteurization effectively destroy the organism (5).

EPIDEMIOLOGY

Reservoirs

With the emerging knowledge of the significance of C. jejuni as a human pathogen, important advances in our understanding of the epidemiologic characteristics of the infection have occurred, resulting in better diagnosis and treatment. Although many important aspects of the transmission of the organism remain unanswered, considerable progress has been made in our understanding of both the reservoirs and prevalence of infection.

Animal reservoirs

Campylobacters are commonly found as commensals of the gastrointestinal tract of wild or domesticated cattle, sheep, swine, goats, dogs, cats, rodents, and all classes of poultry. Extensive reports in the scientific literature demonstrate the organisms cause infection and disease in humans. Conclusive data from several outbreaks have identified animals or animal products as sources of infection, and many of the Campylobacter serotypes which cause disease in humans have been isolated from animals (6). Animal-transmitted diseases (zoonoses) are remarkable, not only because they occur frequently, but they are almost always unsuspected and unrecognized.

Poultry. The literature and prevailing consensus based on research have implicated the presence of campylobacters in the intestinal flora of commercially raised and wild birds like pigeons, seagulls, crows and raven. Isolations have been made from poultry early in the growing process, but many flocks escape infection. Research work done in Canada has shown that, of 108 chicken samples, C. jejuni could be isolated from 100% (55). Various reports exist on the incidence of positive isolates. While correlating an association of C. jejuni with laying hens, Doyle (20) reported a peak rate of C. jejuni isolation of about 25% occurring in October and in late April to early May. Potential sources for entry of organisms into a flock include infection of newborn chicks from older birds, contaminated feed and water, and wild or game birds. Infection mostly appears to be devoid of clinical manifestations in poultry.

During the slaughtering process, C. jejuni from the intestinal contents of processed birds spreads to the carcasses. There also appears to be an inverse relationship between the degree of intestinal carriage and contamination.
C. jejuni was widespread in each of 15 poultry plants evaluated, but on some days the organism was not isolated from any samples (15). Slaughtering of heavily contaminated flocks may result in a contamination rate of up to 100% for end products and seems to be unrelated to the type of slaughtering process (34). A total of 138 samples from two California chicken processing plants were collected from 4 groups of birds (7-12 weeks old) in 11 lots over 6 mornings. Isolation rates for all sites for three scald water temperatures described were 66.7% (60°C), 75.8 and 78.3% (53°C) and 55.1% (49°C). C. jejuni was isolated from all chilling tank samples, 94.6% of feather picker water samples, and from 60-100% of fecal samples. The results demonstrate the chilling and feather picker water were the major sites for cross-contamination (87).

Harris et al. reported a recent case/control study in Seattle (King County), Washington where almost 50% of poultry from the processing plant surveyed were positive for C. jejuni. The highest positive rate occurred during the period July through October. This is substantiated by prior studies in England, Belgium, the U.S. and South Africa that showed a summertime peak of Campylobacter infection (67).

Cattle. C. jejuni appears to be a normal commensal of all bovine classes. Prevaling evidence indicates transmission from adult cattle to calves, but not between adults. At a given time, it is possible for several different serotypes to be present in a herd (6). Carcasses may become contaminated with intestinal contents during slaughter. Five hundred and twenty-five specimens were obtained from 100 slaughter beef cattle and examined for the presence of C. jejuni and C. coli by direct plating and enrichment techniques. Fifty animals were positive for C. jejuni and one was positive for C. coli. The distribution pattern of positively infected animals in decreasing order was steers (57%), bulls (40%), heifers (40%), and cows (22%). Of those animals infected, significantly higher isolation rates were obtained from gallbladders (34%), large intestines (36%), and small intestines (32%) than from liver (12%) or lymph nodes (1.4%) (27).

In Finland, fecal samples from 200 cattle examined bacteriologically showed an incidence rate of infection of 5.5% for C. jejuni (32). Similarly, feces collected from 90 cattle at slaughter in Sweden showed positive isolations from 17 (19%) (77). In a milking herd, the presence of C. jejuni does not necessarily lead to contamination of the milk that is to be consumed, since pasteurization is an effective method of destroying C. jejuni in milk. A community outbreak of gastroenteritis in Vermont was traced to consumption of unpasteurized milk produced at one commercial dairy. Two different testing schemes, showed a C. jejuni isolate from an ill patient and an isolate from a sick cow to be of the same serotype (86).

Swine. Campylobacter sp. contamination of swine carcasses appears more common than that of cattle and sheep/goats. The swine slaughter and dressing procedures tend to have a greater potential for spillage of intestinal contents compared to those of ruminants (cattle, sheep, goats). Thus these dressing procedures contribute to the increased microbial harborage of Campylobacter organisms.

Isolates of C. jejuni from 65 animals in Zaire (29% of the total number examined), showed the highest isolation rates occurred in pigs, with 42 (44%) positive out of 95 examined. In pigs, the youngest animals (weanling pigs of less than 2 months old) were more frequently positive than the older ones; 13 positives of 19 examined for the weanlings and 25 positive of 72 examined for the older group (83). The post-slaughter chilling process tends to suppress Campylobacter replication on the carcasses. This suppression is apparently not caused by low temperatures, but is due to the drying effect of the forced ventilation used in abattoir cooling rooms. Campylobacters appear to be sensitive to drying (59). A Canadian study of 118 pig isolates showed 115 positive for C. coli (56). Samples collected from 300 normal slaughtered pigs during epidemiological studies done at six different slaughter houses were examined for the presence of C. fetus jejuni. One hundred and eighty-two or 60.7% were positive (60).

Sheep. Sheep have had a long relationship with campylobacters dating back to 1909 when they were identified as a cause of epizootic abortion in ewes. C. jejuni exists in many sheep herds as an intestinal commensal, and surveys have proven the organism to be a common isolate. However, C. jejuni has not been found in sheep as often as in other animals used for food production.

Isolations of Campylobacter sp. were made from 16 of 197 (8.1%) of sheep fecal samples examined in Norway (65). Stomach contents and heart blood were collected from 10% of lambs from 25 farms for survey of C. fetus. C. fetus infection was found in 102 of the 762 lambs examined (31).

Dogs and cats. Several epidemiological findings of C. jejuni and other Campylobacter sp. in pets, such as dogs and cats, are now clear: (a) C. jejuni may be isolated from both healthy and diarrheal dogs; (b) isolation rates are higher in puppies and kittens than in adult dogs and cats; and (c) isolation rates are higher in kennel populations for both dogs and cats compared to those raised within households. C. jejuni C. coli are isolated from 45% of 56 clinically normal cats, the high rate of isolation possibly being due to scavenging of contaminated food from a poultry processing plant. Campylobacters were isolated from 49% of 144 stray dogs and 39% of 38 clinically normal puppies, and 38% of 42 diarrheic puppies seen in a veterinary practice (9). In a breeding kennel, C. jejuni was isolated from the feces of 4 of 47 healthy adult dogs, 7 of 71 healthy puppies, 10 of 31 puppies with blood stained diarrhea, and from the intestines of a puppy that had died from hemorrhagic enteritis (15). Prevalence of campylobacters in normal dogs and cats show a wide range. It is highest (49% dogs, 45% cats) in immature animals, particularly strays or those living in kennels, and lowest (less than 1.6% of dogs and cats) in adult animals living in households (69).

Humans as reservoirs. Fecal-oral person-to-person infection has been reported for C. jejuni. As with other enteric pathogens, those in contact with excreta of infected people are themselves at risk. Transmission from asymptomatic infected food handlers is uncommon (5). Interesting reports of human-to-human contact spread occasionally appear in
the published literature implicating the role of food handlers as sources of the organism, and the rationale for their exclusion from the work environment when affected, as well as during the period of carriage of the organism (41).

A temporary food handler was the most probable source of an outbreak of acute gastroenteritis due to *C. jejuni* that occurred in a military base in Israel. Stool cultures were taken from 17 clinically affected as well as from 23 asymptomatic soldiers. In 6 of the 17 patients with enteritis (35%), *C. jejuni* serotype ii was isolated, while the stool cultures of all the asymptomatic soldiers was negative. The temporary food handler had suffered from symptoms of acute gastroenteritis before the outbreak, but had not reported them. He was found to harbor the same serotype as the affected patients (14).

**Inanimate reservoirs. (a) Water.** Outbreaks of water-borne campylobacteriosis in the United States have traditionally been associated with the drinking of spring water during outdoor recreational activities, or other contaminated water not meant for drinking. An outbreak in May of 1983 in Florida involved 871 cases in which a community water system was contaminated by wild birds (82). Domestic and/or wild animals and birds potentially are significant sources of *Campylobacter* organisms found in polluted water. Studies have shown that backcountry thinly settled rural areas) surface water can be an important source of *C. jejuni* and that infection should be considered as a cause of diarrhea in those who have recently returned from wilderness areas (79).

In nature, *C. jejuni* has been isolated from stream and river water, from the effluent of poultry processing plants and even from samples of seawater. Campylobacters were isolated from 50.4% of 540 water samples (riverine) from the Southampton area in England (6).

Survival studies of thermophilic campylobacters in water done in Norway demonstrated the following points:

1. All organisms survived better at 4oC than at 12 or 20oC in all media tested. Briefest survival was obtained at 20oC; no viable bacteria could be detected after 2 d at this temperature in any of the media.

2. Maximum viability was 21 d for *C. jejuni* in physiological saline solution kept at 4oC. *C. coli* and *C. laridis* survived for only 5 d in this medium (12°C).

3. All strains remained viable for 15 d in unchlorinated tap water at 4°C (10 d at 12°C). Chlorination (0.1 mg of Cl per liter) drastically reduced the survival of all three strains examined; *C. coli* and NARTC died within 1 d in chlorinated tap water, whereas *C. jejuni* remained viable for 4 d at 4°C (3 d at 12°C).

4. All strains survived for 10-15 d in polluted river water at 4°C (6-12 d at 12°C). Removal of interspecific competition by sterile filtration did not significantly enhance survival” (29).

(b) **Soil.** Isolations of campylobacters have been made from both mud and sewage sludge in the U.S. (58), and under adequate conditions for replication, fecal contamination of soil could be a viable source of infection.

**Occurrence and Survival in Foods of Animal Origin**

Transfer of *C. jejuni* to carcasses and to other meat/
between 42°-45°C (88). (c). The organism is favored by a roughly neutral pH (6.5-7.5) (88). (d). The organism survives better in foods at refrigeration temperature than at room temperature.

Modes of Transmission

Transmission can be defined as the pathway by which a pathogen spreads from its source to the host. It may occur through one or more of four different routes: (a) contact, (b) common-vehicle, (c) airborne, and (d) vectorborne. (22). Campylobacter may be transmitted by direct contact with contaminated animals or animal carcasses, through ingestion of contaminated food and water, person-to-person from excreters with active infections, perinatal and childhood transmission. Most Campylobacter infections appear to occur sporadically without a clear determination as to the mode of transmission. The vehicles that are incriminated as sources of infection include poultry intended for human consumption, uncooked or poorly cooked meat and poultry products, unpasteurized dairy products, and uncooked foods subjected to possible cross contaminated by meat and poultry products or with untreated sewage.

An outbreak of Campylobacter enteritis occurred in 1982 in Colorado among 11 of 15 people attending a party. The illness was associated with eating undercooked barbecued chicken. Two ill persons had stool specimens positive for C. jejuni. Eight of 10 ill persons tested had immunoglobulin-M-specific indirect fluorescent antibody (FA) titers to C. jejuni (39).

An epidemiological study on C. jejuni enterocolitis involving 55 patients in an urban Swedish community during a 6-month period showed 41 of the patients (75%) were infected outside Sweden. Patients infected in Sweden had eaten chicken significantly more than a corresponding control group (58).

Eighty chicken handlers in a market in Lima, Peru were studied bacteriologically for C. jejuni. The same number of non-chicken handlers from the same market were sampled as controls. Results showed 15 persons (19%) positive for C. jejuni among handlers and none positive among the control group (30). Raw hamburger was implicated in an outbreak that occurred in the Netherlands (61). Raw clams were described as the vehicle in an outbreak in New Jersey. Sewage contamination was the probable cause (7).

Milk is an important and frequent source in the transmission of Campylobacter enteritis. A community outbreak of Campylobacter enteritis was associated with consumption of untreated milk, apparently contaminated by two cows with campylobacter mastitis (36). A New Zealand report implicated raw milk as the cause of gastrointestinal illness among children in two different camp sites. C. jejuni was isolated from 50 of the 88 affected children (8). A drink prepared with raw milk was associated with an outbreak of C. jejuni enteritis in Switzerland involving more than 500 participants at a jogging rally, with an attack rate of over 75% (74). A milkborne outbreak of C. jejuni enteritis followed consumption of unpasteurized milk and an attack rate around 50%. Cases occurred in all age groups but were maximal in the 1-10 age group (63). C. coli was isolated from a 9-year-old British boy with persistent diarrhea and whose family had consumed raw goats' milk from a local farm. C. jejuni and C. coli were found in feces of goats from the farm, and C. jejuni was identified in samples of bulk milk (37). In addition to fecal contamination, a Swedish researcher has associated C. jejuni with mastitis in milk, even though no cases of Campylobacter mastitis have been reported except those induced experimentally (66). Some 2500 English school children between the ages of 2-7 became acutely ill after drinking free school milk. Strains of C. jejuni were isolated (43).

It is important to remember that many zoonotic infections are acquired by contamination of human food either by infected animal feces or from diseased animal tissues. Under normal processing procedures it is extremely difficult, if not impossible, to produce meat and poultry carcasses that are bacteria-free. The entire slaughter-processing environment has the potential to perpetuate contamination, because of the close contact of the tissues in the slaughterhouse with animal and poultry feces. Therefore, it is inevitable that some of these contaminating bacteria will be campylobacters (1). The same basic factors apply to raw or inadequately heat-treated milk contaminated by feces at the time of milking. Fortunately, most milk consumed in this country is pasteurized and devoid of harmful pathogens.

The cycle of actual or potential contamination does not always end at the processing establishments. Clean meat and poultry can be contaminated at retail outlets if hygiene of the facility is poor or insufficient attention is paid to the sanitizing and cleanliness of operational equipment like knives, cutting blocks, and slicing machines.

CLINICAL MANIFESTATIONS/INFECTION IN MAN

Campylobacter can be found in virtually every country and is now recognized as one of the most common causes of bacterial diarrhea.

Acute enteritis is the most common feature of C. jejuni infection, symptoms appearing from 1 d to 1 week or longer. A prodromal phase with fever, headache, myalgia, and malaise usually lasts 12-24 h, but may last for up to 48 h, before the onset of intestinal symptoms. The most common symptoms with campylobacter infection are diarrhea, malaise, fever and abdominal pain. The diarrheic pattern can vary from loose stools to profuse, bloody, slimy and/or foul smelling stools (5,50). In some patients abdominal pain can be cramping, typically periumbilical, and the predominant manifestation of illness (5).

Vomiting may occur, but is rarely a marked feature. The illness is frequently self-limited within 1 to 4 d and usually lasts no more than 10 d, occasionally relapsing (3). Twenty-five percent of patients tend to have a recurrence of symptoms, often characterized by abdominal pain, and varying from a relatively mild gastroenteritis to an enterocolitis with bloody diarrhea and accompanying abdominal pain lasting for several weeks (50).

As with other intestinal pathogens, the clinical picture of C. jejuni infection varies from symptomless excretion to severe disease. Although it is normally a self-limiting dis-
ease, complications such as cholecystitis, peritonitis, septicemia and meningitis have been reported. The small intestine is thought to be the main site of infection, but the colon is often involved (10).

Recently, two fatalities were reported with *C. jejuni* infections in the Denver metropolitan area. The first case was in a previously healthy 26-year-old woman who died following a 2-d diarrheal illness. The second case was in a 69-year-old diabetic woman who died 19 h after developing a gastrointestinal tract illness 1 d following hospital discharge for an orthopedic procedure (72).

Clinically, new types of *Campylobacter* and *Campylobacter*-like organisms (CLO) have recently been noted and described.

Australian researchers have reported on the colonization of the stomach antrum of patients with peptic ulceration and gastritis by spiral bacteria. They were found in 100% of patients with duodenal ulcer, 80% of patients with gastric ulcer and 95% of patients with "active chronic gastritis" (51).

Fennel and co-workers from the University of Washington in Seattle described new campylobacter-like organisms (CLOs) in association with proctitis in homosexual men. The organism was isolated from 28 of 181 symptomatic homosexual men compared with 7 of 77 asymptomatic homosexual men and none of 150 normal heterosexual men and women (24).

Archer (2) reviewed the role of foodborne enteric pathogens (including *C. jejuni*) in the development of three seronegative spondarthropathies (ankylosing spondylitis, Reiter's disease and reactive arthritis), following gastrointestinal infections with gram-negative enteric bacteria.

**STRATEGIES FOR PREVENTION AND CONTROL**

Prevention and control of most zoonotic diseases is difficult at best, but assumes greater importance and significance when the causative agent, *C. jejuni*, is so widely distributed among animal reservoirs and the environment. It should be recognized that even a comprehensive, conscientious approach might not result in complete elimination of the organism. Also, resources are not available to carry out an unlimited effort against a particular foodborne pathogen like *Campylobacter*, and not include a number of other bacteria of concern, sometimes referred to as emerging pathogens, including *Yersinia*, *Aeromonas* and *Listeria*. Therefore, assurance that any raw meat and poultry will be completely free of *Campylobacter* cannot be made.

Control measures are facilitated by the fact that *C. jejuni* is not a hardy survivor outside of its host's environment, and does not survive well in foods, since it is sensitive to (a) drying, (b) 21% oxygen, (c) storage at 25°C, (d) acidic conditions, and (e) heat (28).

Preventive and control measures must include the use of existing resources to reduce the level of infection in animals and subsequently in man. The joint endeavor must include the full cooperation and the concerted effort of the livestock farming sector, food processors, veterinarians, physicians, public health officials, regulatory agencies, food chains (distributors and retailers), consumers and research scientists.

The food processor and distributor can (a) use wholesome food products; (b) use mandatory HACCP (Hazard Analysis Critical Control Point) system in their food protection program which include elements such as: (i) Animal production - wholesomeness and safety of meat and poultry are based in part on the health of live animals, their feed, and the environment under which they are raised; (ii) slaughtering/dressing - sanitary conditions during transport, slaughtering, and dressing; the rate of carcass cooling; and time-temperature conditions of storage and distribution of the carcasses; (iii) processed products - minimize cross-contamination of raw meat from dirty workers, hands, cutting boards, knives, saws and maintain the sanitation of utensils and other equipment; (iv) raw (eviscerated, ready-to-cook) poultry - use of microbiological guidelines to periodically evaluate equipment surfaces and processing practices by examination of freshly processed carcasses (53). (c) educate employees to observe and follow proper personal hygiene practices; (d) have effective rodent and insect control; (e) limit to a minimum non-essential traffic in all food-processing areas; (f) employ managers and supervisors who are technically competent and conscientious as well as committed to the principles of food hygiene.

The consumer can: (a) be conscious of basic sanitation and health practices, especially hand washing, and the use of clean equipment and cutting boards; (b) use proper methods in storing, preparing and serving food; and (c) have an awareness of potential microbial contaminants of raw meat/poultry.

The veterinarian can: (a) help farmers maintain disease-free animals and clean environments in which to raise them, (b) seek laboratory confirmation of suspected cases of campylobacteriosis in animals and report positive cases, (c) conduct sanitation inspection of the slaughter environment and product inspection to ensure an acceptable level of compliance with established standards of hygiene, (d) assist in the education of food processing management and employees on proper sanitation practices, (e) assist in the education of the public regarding the basic principles of food hygiene and the attributes of personal cleanliness in the prevention/control of foodborne diseases.

The physician can: (a) seek laboratory confirmation of suspected cases of campylobacteriosis in humans, (b) report all infections of *Campylobacter* spp. to the proper health authorities and assist in the epidemiology when applicable, (c) inform patients of needed precautions to preclude the spread of the organism especially to family and close contacts, (d) assist in the education of the public at large when the contributing causes are foodborne diseases, including preventive measures.

The public health official can: (a) keep local physicians informed of suspected outbreaks of campylobacteriosis, (b) follow up reported cases and investigate/coordinate outbreaks, (c) take special care to obtain proper specimens for laboratory examination, (d) impress upon food processors the need for proper sanitation control, (e) create public
awareness of campylobacteriosis, and (f) promote campylobacter prevention and control measures (64).

The research scientist can: (a) maintain a close liaison with clinicians and epidemiologists, (b) keep abreast of the state of the art information/knowledge applicable to Campylobacter spp., (c) assist in the adoption of acceptable standardized methods for isolating campylobacters, (d) keep current with new or improved techniques for their isolation, (e) handle all cultures of campylobacters with the necessary precautions to prevent spread from the laboratory, and (f) serotype all isolates and be a resource for information sharing to collaborators and other researchers.

Aside from the cooperative inputs described above to assist in the prevention/control of this challenging organism, other innovative technological advances have played a significant role in the potential to minimize or eliminate the problem. Irradiation of food is an innovation that offers some benefits to campylobacter control.

Considerable interest has recently been generated on the role of food irradiation in the control of bacteria which cause food poisoning. One major study found that a medium dose of 250 Krad, combined with a handling-environment temperature of 1.6°C (34.9°F), resulted in a product essentially resistant to spoilage by various fungal diseases. Changes in temperature of 1.6°C (34.9°F), resulted in a product essentially wholesome and safe for human consumption, requiring no safety testing to market (23). This could be an excellent adjunctive factor in the control of microbial pathogens in food.

The use of irradiation on fresh products, however, can also cause changes which are deemed undesirable. Irradiation can affect metabolic food processes, making food less resistant to spoilage by various fungal diseases. Changes in flavor or texture of irradiated food may be unacceptable to some consumers (17).

In summation, prevailing research indicates that irradiated foods are safe, can extend a product’s shelf life, and reduce the number of microorganisms spoiling food (18).

Current and future research endeavors are attempting to evaluate the use of acetic acid or lactic acid in chilled water atmosphere, and grows poorly in food. These factors contribute to minimize the transmission epidemiologically.

The principles of animal husbandry will play a significant role in the control of this ubiquitous organism. By using Campylobacter-free parent animals and raising Campylobacter-free animals for slaughter the consumer will be faced with less likelihood of infection from food sources. This will require the strictest standards of livestock hygiene and management.

Hygienic slaughter and processing procedures will preclude cross-contamination while adequate cooling and aeration will cause a decrease in the microbial load. As an adjunct, thorough cooking of meat and poultry products followed by proper storage should assist in maintaining food integrity and less contamination.

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