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Review on *Campylobacter iosis*

Yosef Deneke Seid Jemal and Tefera Getahun

Jimma University, College of Agriculture and Veterinary Medicine,
P.O. Box: 307, Jimma, Ethiopia

Abstract: Campylobacter is well recognized as the leading cause of bacterial food borne diarrheal disease worldwide. Symptoms can range from mild to serious infections of the children and the elderly and permanent neurological symptoms. The organism is a cytochrome oxidase positive, micro aerophilic, curved Gram-negative rod exhibiting cork screw motility and is carried in the intestine of many wild and domestic animals, particularly avian species including poultry. Intestinal colonization results in healthy animals as carriers. Therefore, the aims of this paper are to review the nature of *Campylobacter* spp. and overview its status as a food born zoonosis. The highest prevalence reported from chicken meats and *C. jejuni* and *C. coli* were the most prevalent *Campylobacter* speciesisolated from both the foods of animal origin and human beings. The disease has significantly reported from different parts of the world, though researches do not seem to cover wider geographic areas. Campylobacteriosis control and prevention strategies should focus on prevention of transmission to human beings by implementing strict hygienic control measures along the food chain to improve the hygienic conditions during handling, slaughtering, storage and commercialization of foods.

Key words: *Campylobacter* Spp. · Food Borne Pathogens · Control and Prevention Measures

INTRODUCTION

Food-borne diseases occur as a result of consumption of contaminated food-stuffs especially from animal products such as meat from infected animals or carcasses contaminated with pathogenic bacteria. The burden of food borne diseases, including *Campylobacter iosis*, is substantial every year almost 1 in 10 people fall ill and 33 million of healthy life years are lost [1, 2]. Food borne diseases can be severe, especially for young children. Diarrheal diseases are the most common illnesses resulting from unsafe food, with 550 million people falling ill yearly (including 220 million children under the age of 5 years). *Campylobacter* is 1 of the 4 key global causes of diarrheal diseases. *Campylobacter* are mainly spiral-shaped, “S”-shaped, or curved, rod-shaped bacteria. Currently, there are 17 species and 6 subspecies assigned to the genus Campylobacter, of which the most frequently reported in human diseases are *C. jejuni* (subspecies jejuni) and *C. coli*. Other species such as *C. lari* and *C. upsaliensis* have also been isolated from patients with diarrheal disease, but are reported less frequently [3].

Campylobacter is one of the major pathogens involved in food-borne illnesses with an estimated 400 million cases per year worldwide [4, 5]. In many countries, the microorganism for *Campylobacteriosis* in humans is characterized by watery or bloody diarrhea, abdominal cramps and nausea [6]. An acute infection can have serious long-term consequences, including the peripheral neuropathies, Guillain–Barreë syndrome (GBS) and Miller Fisher syndrome (MFS) and functional bowel diseases, such as irritable bowel syndrome (IBS) [7, 8].

Cattle and cattle products have been incriminated in relation to outbreaks and sporadic cases, mainly associated with consumption of unpasteurized milk and cattle meat [9]. Prevalence studies of *Campylobacter* spp. as human enteric pathogens in Tanzania reported isolation rates ranging from 9.3 to 18.8% [10, 11]. Several countries have reported the epidemiology of different *Campylobacter* spp. in cattle [12, 13].

The *Campylobacter* bacterial genera contain several species of both public and animal health importance. Among them *Campylobacter jejuni* and *C. coli* are the most common cause of gastroenteritis in humans [14], the bacteria was being isolated 3-4 times more frequently from

Corresponding Author: Tefera Getahun, Jimma University, College of Agriculture and Veterinary Medicine, P.O. Box: 307, Jimma, Ethiopia.

patients with gastrointestinal tract infections than other bacterial enteric pathogens (such as *Salmonella* or *Escherichia coli*) [15, 16]. Children, the elderly and those with weakened immune system (including cancer, HIV/AIDS and transplant patients) being the risk group. Hence, the high incidence of *Campylobacter* spp. diarrhea as well as its duration and possible squeals, makes campylobacteriosis very important from a public health perspective with significant socio-economic impact [17].

Campylobacter spp. are normally carried in the intestinal tracts of many domestic livestock such as poultry, cattle, sheep, pigs, as well as wild animals and birds [5, 18]. Transmission can occur through direct contact with infected animals or from equipment, water or during carcass dressing in a slaughter line [19].

Furthermore, *Campylobacter* with resistance to antimicrobial agents has been implicated worldwide [4, 13, 20, 21]. The use of antimicrobial agents in food animals has resulted in the emergence and dissemination of antimicrobial-resistant bacteria including anti-microbial resistant *Campylobacter*, which has potentially serious impact on food safety in both animal and human health. The situation seems to deteriorate more rapidly in the developing countries where there is a wide spread and uncontrolled use of different antibiotics [22]. Though scarce, data from low- and middle-income countries (LMIC) suggest that the burden of disease due to *Campylobacter* infection is considerable [16]. In Ethiopia likewise, a few publications have been reported on the occurrence and susceptibility testing of *Campylobacter* strains to antimicrobials on human [13, 23-25], food animals and foods of animal origin [26], abattoir based [27] and antimicrobial susceptibility pattern on sheep carcasses [28].

The review, therefore aimed:

- To highlight campylobacteriosis, review the public health importance of this disease and indicate control and prevention measures

Description of the Organism: The name *Campylobacter* is derived from the Greece ‘campylos’ meaning ‘curved’ and ‘baktron’ meaning ‘rod’ [6]. *Campylobacter species* are Gram-negative, non-spore forming bacteria and are members of the family *Campylobacter aceae*. The genus *Campylobacter* comprises 17 species and 6 subspecies [29]. The continual progress and developments in the criterion of taxonomy may refine the number of *Campylobacter* species. The two species most commonly associated with human disease are *C. jejuni and C. coli. C. jejuni* accounts for more than 80% of *Campylobacter*-related human illness, with *C. coli* accounting for up to 18.6% of human illness. *C. fetus* has also been associated with food borne disease in humans [15].

***Campylobacter* Morphology and Bacterial Characteristics:** *Campylobacter* species are non-spore forming and Gram-negative bacteria. They can be spiral, curved or sometimes can be seen straight rods, with size ranging from 0.2 to 0.8 µm wide and 0.5 µm to 5 µm long. *Campylobacter* may appear as a spiral, S, V, or comma-shaped forms and can also be found in short or occasionally long chains. First *Campylobacter* cells begin to age and then they become coccoid in shape. The cells are highly motile by a kind of single or occasionally multiple flagella at one ends. Rapid movement, darting motility of comma-shaped cells can be seen by a phase contrast microscope [30].

Growth and Survival Characteristics: *Campylobacter* species are fragile organisms. They are sensitive to freezing, heating (pasteurization/cooking), drying, acidic conditions (pickling), salinity, disinfectants and irradiation. They survive poorly at room temperature (21°C) and in general survive better at cooling temperatures [32, 33]. *C. jejuni* grows best at 37°C to 42°C, in a low oxygen environment, such as an atmosphere of 5% O_2, 10% CO_2 and 85% N_2. Requirements for growth in the laboratory also reflect this narrow ecologic niche. Adaptations to an intestinal niche include a single polar flagellum and corkscrew shape (Fig. 1). These traits facilitate motility [34, 35]. In the viscous intestinal mucous Campylobacter species have been shown to enter a viable but non cultivable state when subjected to unfavorable conditions, such as low nutrient availability, elevated temperature, freezing or stationary phase [36]. In this state, cells transform from a motile spiral form to a coccoid form. The nature and role of this coccoid form is uncertain. *C. jejuni* is able to adapt to aerobic conditions due to an ability to produce bio-films [37].

Virulence and Infectivity: *Campylobacter spp*. has four main virulence properties: motility, adherence, invasion and toxin production. The exact nature of how *Campylobacter* spp. adhere to and invade the intestinal epithelial cells is not fully understood [36]. It is thought that the combination of its spiral shape and flagella leads to rapid motility that enables the organisms to penetrate through the intestinal lining unlike conventional bacteria [36, 38].

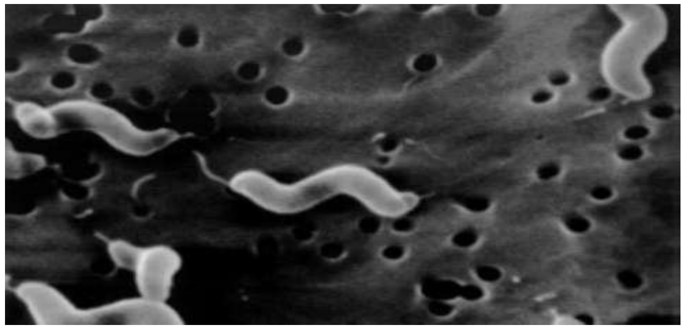

Fig. 1: Scanning electron micrograph of the single polar flagellum and cork screw shape of *Campylobacter Jejuni* [31]

Campylobacter organisms produce two types of toxins: enterotoxin and cytotoxin. The enterotoxin of *C. jejuni* is similar to the *Vibrio cholerae*toxin and the *Escherichia coli* heat-liable toxin. This enterotoxin is produced to a lesser degree by *C. coli*. It has been suggested that enterotoxin produced by *Campylobacter* s*pecies* results in watery diarrhea, as opposed to bloody diarrhea due to cytotoxin production [39].

Rates of infection increased with the ingested dose and rates of illness appeared to increase when in ocula were ingested in a suspension buffered to reduce the acidity of the stomach [40]. In human, 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 food borne illness [33, 34].

Source of Infection and Transmission: The principal route by which *Campylobacter* contaminates the food is through fecal contamination by infected carriers. Mostly human campylobacteriosis are associated with handling of raw poultry, undercooked contaminated meat, cross contamination of raw and cooked foods and poor hygiene [41]. Raw meats and poultry become contaminated during processing when intestinal contents contact the meat surfaces. Feco-oral transmission of infection from person to person has been reported for *C. jejuni*. This uncommon type of transmission can occur when personal hygiene is poor. Humans act as vectors transferring the organism into poultry production area with contaminated clothing and foot wear [42]. It is often difficult to trace sources of exposure to *Campylobacter* because of the sporadic nature of the infection and the important role of cross-contamination The main sources of meat contamination include; animal/carcasses source, on farm factors, transport factors, abattoir and butchers facilities and wild animals, meat van, abattoir and retail meat outlet workers [16].

Animal/Carcasses Source: Fecal matter is a major source of contamination and can reach carcasses through direct deposition as well as by indirect contact through contaminated carcasses, equipment, workers, installations and air [43]. In the case of domesticated animals; bovine, ovine, caprine, swine and especially in case of poultry, the infection can spread due to the slaughter process to raw and finished products. A human can acquire the infection by consumption of raw or decontaminated meat, or by the direct contact of raw products or cross-contamination of raw to cooked foods, swimming in natural waters, contact with contaminated animals or animal carcasses and traveling the disease is communicable when infected animals excrete the bacteria in their feces. People who never took drugs have known to shed these bacteria for as long as seven weeks [44].

On Farm Factors: Body condition may affect the pathogens load. Weak animals lie down more often than healthy ones, thereby increasing the likelihood of contaminating hides. Contacts between animals at auction barns may increase the pathogen load [45]. The exterior of the animals harbours large number and different types of microorganisms from soil, water, feed, manure as well as its natural flora [46].

Transportation of Slaughter Animals: The transport factors such as the type and cleanliness of transport facility, distance travelled and duration of journey, harshness of ride, overpopulation of animals in the conveyance and frequency of stops, may affect and contribute to pathogen load [45].

Abattoir and Butchers Facilities: The abattoir and beef retail outlet environments play important roles in contamination of meat. Site selection and availability of good quality portable water are important factors to consider when selecting site for constructing abattoir or retail meat outlets since it affects the quality of meat.

Meat contamination in abattoirs and retail meat outlets result from the use of contaminated water, unhygienic practices like poor handling, use of contaminated tables to display meat intended for sale and the use of contaminated knives and other equipment0 in cutting operations [47].

The length of time animals are held at the abattoir before slaughter can affect the pathogen load by increasing the probability of exposure and infections. Sanitation of walk ways, pen floor, railings, feed and water affect the pathogen load [45]. Dirt, soil, body discharges and excreta from animals in holding pens or lairages are primary sources of contamination of carcasses in the later stages of the operation. This happens irrespective of whether or not the animals are fit and have passed ante mortem inspection, Adzitey *et al.* [48] reported the possible sources of contaminations arising from cutting knives, intestinal contents, chopping boards, hides, meat handlers, containers, vehicle for transporting carcasses and the meat selling environment. It has been reported by Ali *et al.* [49] that knives, wooden boards and weighing scales from retail shops are sources of bacterial contamination particularly *Staphylococcus aureus* and *Shigella* species. An inadequate slaughtering and disposal facility, in the abattoir becomes a source of infection and pollution, attracting domestic and wild carnivores, rodents and flies, which are vectors of diseases. Refrigerator or freezers are essential storage facilities used to prevent spoilage of meat following prolonged storage at room temperature and hence keep meat safe for long period of time [50].

Wild Animals: With inadequate slaughtering and disposal facilities attracting flies, domestic animals, wild carnivores and rodents, abattoir/slaughter houses become among the important sources of microbial contamination [51].

Meat Van: The vehicles used to transport meat from abattoir to retail meat outlets may act as sources of contamination since often lack regular cleanliness and are not well covered leading to contamination by dusts, insects and flies, contamination of meat resulting from other means of transport such as motor-bikes and bicycles due to insufficient vans and trucks. On the other hand, the few transport available were not properly cleaned and thus contained high microbial loads [52].

Abattoir and Retail Meat Outlet Workers: The hygienic condition of the abattoir and retail meat outlet workers has potential to contribute contamination in beef before and after processing. Unclean slaughter men's hands, butcher arms, clothing and equipment used in carcass dressing process accounted for the microbial contamination and also the study revealed that the worker hands and their equipment's were among the main sources of meat contamination [53, 54].

Clinical Features of *Campylobacter iosis*

In Humans: The clinical feature of *Campylobacter* enteritis in humans caused by *C. jejuni* and *C. coli* are indistinguishable from each other and from acute bacterial diarrhea caused by other pathogens like *Salmonella enteritis* [55]. *Campylobacter* may cause mild or severe diarrhea, bloody diarrhea, nausea and stomach pain, often with fever [33].

Abdominal pain can persist for up to 7 days and recurrence of symptoms can occur. The illness may start with cramping abdomen, diarrhea, fever, chills, headache, myalgia and occasionally delirium, with typical more intense long lasting abdominal pain and occasionally blood or mucous in the stool [42]. Extra-intestinal infection and chronic sequel of infection occur in smaller proportion of patients. Bacteremia has been noted in less than 1% of patients with *C. jejuni* infection. Meningitis and endocarditis are rare manifestation of *C. jejuni* infection. There have been infrequent reports of *C. jejuni* infections manifested as septic abortion, acute cholecystitis, pancreatitis and cystitis [56].

*Campylobacter*s have also been linked to some autoimmune diseases such as Reactive Arthritis (RA) and Guillain-Barrè Syndrome (GBS). These two major late onset complications of *Campylobacter*are estimated at one case per 2000 infections [16]. *Campylobacter* infection is recognized as the most commonly identified antecedent event in GBS (40-60% of all cases), also known as post-infective polyneuropathy. The main lesions are acute inflammatory demyelinating poly radiculo-neuropathy that results in a flaccid paralysis [57]. Reactive arthritis occurs in approximately 1% of patients with *Campylobacter* enteritis [58].

In Food or Farm Animals: *Campylobacter* spp., resides in the gut of domesticated warm-blooded animals and birds as part of the intestinal microbiota [59]. *Campylobacter* species cause enteritis, abortions and infertility in various species of animals. The role of *C. jejuni* as primary pathogen in farm animals is uncertain [60]. *C. jejuni* and occasionally *C. coli* cause enteritis in dogs, cats, calves, sheep, mink, poultry and somespecies of laboratory animals. The clinical signs may be more severe in young animals. Calves typically have a thick, mucoid diarrhea with occasional flecks of blood, either with or without fever. *C. fetus* subsp. fetus and *C. jejuni* can cause enzootic abortion that can result in late term abortions, stillbirths and weak lambs in sheep. Infections in sheep are sometimes followed by endometritis and occasionally deaths. Morbidity may be up to 90% in outbreaks in sheep but is usually around 5 to 50%. Morbidity in sheep can result in prolonged lambing and reduction in milk output. Recovery with immunity to re-infection is typical. Sheep can become persistently infected and continue to shed bacteria in the feces [61].

Laboratory Diagnosis: *Campylobacter* is difficult to isolate, grow and identify [16]. Conventional diagnostic methods require that suspected stool specimens, feces or food samples of animals, with favorable transport and storage conditions including use of transport media in the pre-analytical phase, are cultured on selective agar at 42°C under microaerophilic conditions for up to 72 hours before a negative report is issued [59]. Only culture plates with colonies showing the characteristic *Campylobacter* morphology and oxidase positivity are then reported as *Campylobacter* spp. recognition of colonies as *C. jejuni* that are gray/moist flat, glossy, effuse colony with a tendency to spread along the inoculation track having well-spaced colonies resembling droplets of fluid and on moist agar a thin, spreading film and with continued incubation colonies become convex often with a dull surface [62, 63].

However, further identification to the species level requires other tests including growth temperature preferences, antibiotic sensitivity to cephalothin and nalidixic acid and biochemical tests, mainly hippurate test [59]. The first report on the application of polymerase chain reaction (PCR) in the diagnosis of *Campylobacter* was described by Oyofo in 1992 [64]. Application of multiplex PCR for the detection and speciation of this pathogen; however, these protocols have been optimized for isolates obtained from pure cultures and artificially spiked stool specimens [64, 65].

Treatment and Antibiotic Resistance: Most cases of *Campylobacter* enteritis are self-limiting, symptomatic treatment of campylobacteriosis with rehydration solutions is recommended in affected children but is of questionable benefit in otherwise healthy adults with adequate fluid intake [66]. In situations where antibiotic therapy is indicated either erythromycin or ciprofloxacin are the usual drugs of choice. However, recent data indicates an upward trend of *Campylobacter* resistance to antibiotics with varying patterns being seen in different countries and regions [67]. In addition, there is growing concern that the widespread use of antibiotics such as erythromycin, ciprofloxacin and tetracycline in veterinary medical practice and as additives to animal feeds (particularly poultry) can select for resistant *Campylobacter* spp. which may be transmitted to humans through the food chain [18, 67].

Public Health Significance of *Campylobacter*: According to the Centre for Disease Control (CDC) report, *Campylobacter* infections accounted for approximately one-third of laboratory confirmed food borne illness that occurred globally in food net surveillance areas [14].

Reported Incidence of *Campylobacter iosis*: The true incidence of gastroenteritis due to *Campylobacter* spp. is poorly known, particularly in LMIC; studies in high-income countries have estimated the annual incidence between 4.4 and 9.3 per 1000 population [16]. Generally, developing countries do not have national surveillance programs for campylobacteriosis; therefore, incidence values in terms of number of cases for a population do not exist. Most estimates of incidence in developing countries are from laboratory-based surveillance of pathogens responsible for diarrhea. *Campylobacter* isolation rates in developing countries range from 5 to 20% (Table 1) (Revise with Table 1 [68].

Food Born Implications of *Campylobacter*: Food-acquired *Campylobacter*iosis accounts for up to 74 to 85% of total cases, with poultry being the number one contributing vehicle [33]. *Campylobacter*-contaminated foods as the result of poor sanitation are an important potential source of infection in humans (Table 2 and 3). For example, *Campylobacter*s were isolated from 40 and 77% of retail poultry meat sold in Bangkok, Thailand and Nairobi, Kenya, respectively [70]. The serotypes of the organisms isolated in Thailand were similar to those of organisms isolated from humans. In Mexico City, a survey of ready-to-eat roasted chickens showed that they were contaminated with *Campylobacter*s [71]. In developed countries, risk factors associated with foods include occupational exposure to farm animals, consumption of raw milk or milk products and unhygienic food preparation practices [70].

Estimates of Impact of Human Campylobacteriosis in Developing Countries: The Disability Adjusted Life Year (DALY) is the basic unit used in Burden of Disease (BoD) methodology to quantify the impact of disease n a population. DALYs have been applied in the Dutch

Table 1: Isolation of Campylobacter from diarrhea specimens from < 5 year olds in selected developing countries

WHO region and country	Isolation rate (%)
Africa	
Algeria	17.7
Cameroon	7.7
Ethiopia	13.8
Nigeria	16.5
Tanzania	18.0
Zimbabwe	9.3
Americas	
Brazil	9.9
Guatemala	12.1

Source: Coker *et al.* [69].

Table 2: Selected major food born outbreaks associated with Campylobacter Spp (> 50 cases and/or >1 fatality)

Year	No. of Cases (fatalities)	Food	Country
2008	98	Raw peas	US
2007	68	Cheese	US
2005	79	Chicken salad	Denmark
2005	86	Chicken liver pate	Scotland
2003	81	Custard prepared from UHT milk	Spain
1998	79	Tuna salad	US
1995	78	Cucumber	South Australia

Source: Anne [66].

Table 3: Prevalence of Campylobacter in food of animal source, Addis Ababa

Sample type	Abattoir	Butcher shops	Supermarket	Total
Beef	9/138 (6.5)	4/69 (5.8)	1/20 (5.0)	14/227(6.2)
Mutton	11/93 (11.8)	1/10 (10.0)	0/11 (0)	12/114 (10.5
Goat	6/67 (9.0)	1/11 (9.0)	0/14 (0)	7/92 (7.6)
Pork	3/30 (10.0)	-	1/17 (5.9)	4/47 (8.5)
Chicken	8/30 (26.7)	-	5/30 (16.7)	13/60 (21.7)
Total	37/358	6/90(6.7)	7/92 (7.6)	50/540 (9.3)

Source: Dadi and Asrat [26]

population to measure the mean health burden of *Campylobacter*-associated illness in the period 1990-1995. The mean estimate was 1, 400 DALYs per year; the main determinants of health burden were acute gastroenteritis (440 DALYs), gastroenteritis-related mortality (310 DALYs) and residual symptoms of GBS (340 DALYs) [72].

Although data on DALYs due to campylobacteriosis in developing countries are not available, diarrhea, which is a clinical manifestation of campylobacteriosis, was one of the top three causes of death and disease in developing countries in 1990. The disease is projected globally to remain one of the top 10 by 2020. (The burden of campylobacteriosis in developing countries may increase by 2020 because HIV is projected to move up to the 10th position from 28th by 2020). Considering the higher incidence of campylobacteriosis in developing countries, DALYs for the disease in developing countries will likely be higher than those of the Dutch population [70].

Factors Influencing Campylobacteriosis Epidemiology

Age: Campylobacteriosis is often a pediatric disease especially in developing countries. This is because of multiple reasons; as age increases, level of antibody tends to increase. Higher risk of campylobacteriosis in young children was also associated with ownership of pet chickens [34].

Season: In developed countries epidemics occur in summer and autumn. Isolation peaks vary from one country to another and also within countries; in contrast, in developing countries, *Campylobacter* enteritis has no seasonal preference. The lack of seasonal preference may be due to lack of extreme temperature variation as well as lack of adequate surveillance for epidemics [70].

Travel and Food Trade: Foreign travel is a commonly reported risk factor for campylobacteriosis. In Sweden, where *Campylobacter* contamination of poultry meat is uncommon, international travel has traditionally accounted for approximately 75% of human *Campylobacter* infections. In the United States, it is estimated that between 20 and 25% of *Campylobacter* infections are acquired during international travel. Campylobacteriosis was the most frequently reported enteric bacterial infection in Austrian tourists returning from southern Europe and Asia. In England, travel to South Africa was associated with *C. coli* infection. The causal exposures for travel-associated infections remain to be determined [34, 66].

Strain Variation: Although a diverse group of strains is associated with Guillain-Barré syndrome (GBS), the syndrome is strongly linked to a few strains of *C. jejuni* (eg. Heat stable or Penner serotype HS: 19 and HS: 41). *Campylobacter* strains contain sialic acid linkages to lip oligosaccharides resembling sialic acid moieties on the gangliosides of peripheral nerve tissues. Patients with GBS develop antibodies against these gangliosides, resulting in autoimmune targeting of peripheral nerve sites. Complement-mediated damage and blockage of neurotransmission are suspected to affect GBS pathogenesis [34].

Host Immunity: Acquired immunity is generally accepted to be an important factor in the epidemiology of campylobacteriosis [17]. Prior exposure to *Campylobacter* may result in at least partial protective immunity. Since immunity may be strain specific, time-limited and/or inadequate in the presence of large challenge doses, repeated or chronic exposure to a variety of *Campylobacter* strains may be required to produce protective immunity [66]. In developing countries, healthy children and adults are constantly exposed to *Campylobacter* antigens in the environment. As a consequence, the levels of antibodies tend to be much higher than those in children in the developed world such as in the United States [70].

Economic Significance of *Campylobacter iosis*: Campylobacteriosis cause severe economic loses both in the public health and food industry sector. Campylobacteriosis has an enormous economic impact in terms of treatment costs, loss of production and human welfare. In livestock, particularly sheep and cattle, *Campylobacter* species are the cause of important economic losses associated with infertility problems and abortion [73].

A study, estimating the disease burden and the cost-of-illness, in Netherland indicated that cost-of-illness has direct health-care costs (e.g. doctors' consultations, hospitalization, rehabilitation), direct non-health-care costs (e.g. travel costs of patients, co-payments by patients) and indirect non-health-care costs (productivity losses), using cost estimates for a year 2000. The results, costs-of-illness were estimated to total _ 21 million per year with a 90% confidence interval of between _ 11 million and _ 36 million per year. Concluding, *Campylobacter* infections pose an important public health problem for the Netherlands and incur substantial costs [72].

Control of the Transmission of *Campylobacter* Species in the Food Chain

Overview: The complex epidemiology of *Campylobacter*, a multi-tiered approach to control is needed, taking into consideration the different reservoirs, pathways, exposures and risk factors (Fig. 2) [16, 33]. Control of *Campylobacter* s*pp*. 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. That is a structured systematic approach to achieving food safety which involves identifying potential hazards and measures for their control. However, in the interests of control HACCP based principles should be applied by all sectors of the food industry [74].

On-Farm Control: The interventions that have consistently been shown to be effective at pre-harvest are the application of strict bio-security and good animal husbandry and health measures [16]. Control of *Campylobacter* contamination on the farm may reduce contamination of carcasses, poultry and red meat products at the retail level. Epidemiologic studies indicate that strict hygiene reduces intestinal carriage in food producing animals [75]. In field studies, poultry flocks that drank chlorinated water had lower intestinal poultry that drank unchlorinated water [76]. Recent studies undergone to develop methods such as treatment of chickens with commensal bacteria other than *Campylobacter*, which is called competitive exclusion regimens and flock vaccination [77].

The Abattoir: the Post-harvest Phase Control: Good hygienic practices and the application of control measures based on HACCP principles are also critical for successful

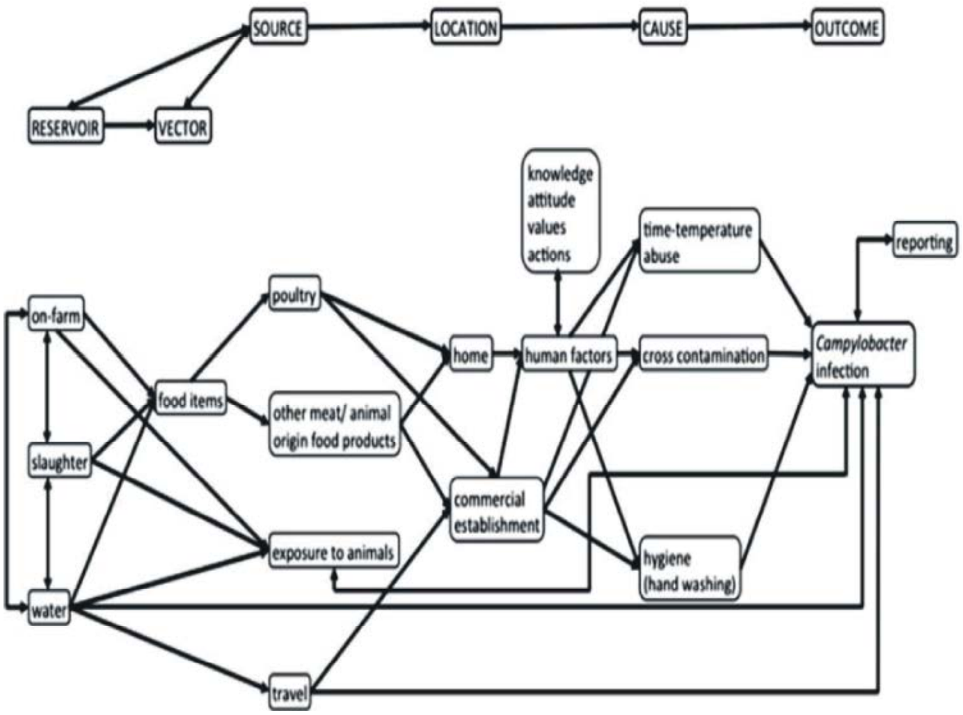

Fig. 2: Diagram shows Campylobacteriosis risk factor, the source of Campylobacter Organisms and the locations where people are exposed [33]

post-harvest control and decontamination of the carcass by physical or chemical means [16]. Bacterial counts on carcasses can increase during slaughter and processing steps. In one study, up to a 1, 000-fold increase in bacterial counts on carcasses was reported during transportation to slaughter. HACCP studies of the slaughter process show specific areas where contamination occurs [33].

In studies of chickens and turkeys at slaughter, bacterial counts increased by approximately 10- to 100-fold during de feathering and reached the highest level after evisceration. However, bacterial counts on carcasses decline during other slaughter and processing steps such as: Forced-air chilling of swine carcasses caused a 100-fold reduction in carcass contamination. In turkey plants, scalding reduced carcass counts to near or below detectable levels [17]. Adding sodium chloride or trisodium phosphate to the chiller water in the presence of an electrical current reduced *C. jejuni* contamination of chiller water by 2l to 10 units. Use of chlorinated sprays and maintenance of clean working surfaces resulted in a 10 to 100-fold decrease in carcass contamination. In another study, lactic acid spraying of swine carcasses reduced counts by at least 50% to often undetectable levels [31].

However, some consumers report that the color and texture of chicken fillets are altered by irradiation. Competitive exclusion products have also been proposed to reduce broiler colonization. Various products containing defined poultry isolates of *C. jejuni,* Lactobacillus and undefined cultures are reported to reduce colonization under experimental conditions. Diet may also alter intestinal carbohydrates that affect the colonization potential of *Campylobacters* [34].

At Home: At home, the consumer is the last link in the food chain and has to deal with residual pathogens in food. The measures required in the kitchen to minimize risk of infection with *Campylobacter* spp. consist of the application of the basic principles of safe food preparation. 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 carcasses in the kitchen sink is unnecessary and increases the risk of contamination [74].

Proper and hygienic preparation of food, avoidance or heating of unpasteurized dairy products, avoidance of eating raw meat, travel to underdeveloped countries (hyper-endemic *Campylobacter* transmission area) and exposure to animals such as pet animal with diarrhea (particularly puppies and kittens) should be avoided [58].

Water: Untreated water has been identified as an important source of *Campylobacter* infections in humans. The presence of *Campylobacter* in surface water and shallow wells is likely the result of contamination by wild bird feces, manure run-off from dairy or poultry farms, or human sewage [66]. The chlorination of carcass wash water, an important component of the HACCP programs in processing plants contributed to the decline in human *Campylobacter iosis* [34]. Therefore, the use of chlorinated water in the farm as well as in abattoir or processing industries is crucial, as piped waters prevent fecal contamination from farm run offs.

Disease Surveillance and Public Awareness: Surveillance of enteric diseases, including campylobacteriosis, is common in high-income countries; it is rarely attempted in other parts of the world. Nevertheless, a well-designed surveillance program for campylobacteriosis can provide information to inform national decision-making by: determining the relative importance of campylobacteriosis compared with other enteric infections; showing which animals are the primary reservoirs for infection; and helping to identify the most common pathways of transmission [16]. Educating farmers on improved disease prevention measures and hygiene may lead to a lower prevalence of *Campylobacter* [78].

Prevention: Vaccination against *Campylobacter* is used commonly and considered the best method of control [79]. The effectiveness of vaccination has been demonstrated in several experimental and field studies in sheep and experimental studies in guinea pigs. However, vaccination is complicated by the fact that abortion can be caused by two or more different species (*C. fetus* subsp. *fetus, C. jejuni*, *C. coli*), multiple strains of a species may be involved in the disease and there is limited cross-protection between strains/species Thus, vaccination may not provide complete protection, even following the use of polyvalent vaccines [80].

CONCLUSIONS

The review demonstrated that Human campylobacteriosis caused by thermo-tolerant *Campylobacter* spp. continued to be one of the major commonly reported zoonotic diseases, which results in a serious consequence of diarrheal in human and severe economic losses worldwide. Fecal matter is a major source of contamination and transmits the diseases to other. Through the use of both traditional microbiological methods and molecular genomic technologies in conjunction with animal models, considerable progress has been made in understanding the etiology, transmission, epidemiology, pathogenesis and control measures of the disease conditions. Various measures should be put in place to minimize the possibility of fecal material being transferred from the gut or the skin to the carcass during the slaughter process. The importance of proper handling and cooking of foods of animal origin are very important in preventing Campylobacter and other potential pathogens. Coordinated actions are needed to reduce or eliminate the risks posed by these pathogens at various stages in the food chain. More epidemiological studies are needed in order to determine the possible role of bovine as a source of reservoir of the pathogen. Public education is crucial not to eat raw meat or any undercooked animal origin foods. Integrated control strategies of ante mortem control (clean livestock policy), hygiene control during slaughter, implementation of HACCP and regular microbiological testing on the abattoir as well as farms should be implemented.

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