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Campylobacter in Dogs and Cats; Its detection and Public Health Significance: A Review

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Abstract | Campylobacter is becoming more recognised because of its detection in a wide range of hosts and food of animal origin. Campylobacter is considered one of the most common causes of gastro-enteritis in humans and is of public health concern. Several studies have been conducted in developed countries on their occurrence and characterisation in dogs and cats but such studies are lacking in most developing nations. Due to this present scenario, this review will show the prevalance, public health significance of Campylobacter in dogs and cats and to also demonstrate the antibiotic resistance patterns of the isolates and associated risk factors related to its occurrence. Culture based methods are usually employed for the identification and detection of these species. However, molecular techniques such as PCR give a confirmation of the presence of Campylobacter in dogs and cats.

Keywords | Campylobacter, Dogs, Cats, Public health significance, Antibiotic resistance

INTRODUCTION

The genus *Campylobacter* is complex and diverse group of bacteria. Presently, the genus comprised of 25 species, two provisional species and eight subspecies (Man, 2011). The first *Campylobacter* was isolated from human in 1938 from blood samples of diarrhoeic patients (Butzler, 2004). *Campylobacter* were initially classified under the genus *Vibrio* but subsequently they were divided into three different but related genera: *Campylobacter*, *Helicobacter* and *Arcobacter*. They are gram negative, curved, spiral or S- shaped and are members of the order *Campylobacter-*

ales, class *Epsilon* and phylum *Proteobacteria*. *Campylobacter* was differentiated from the genus *Vibrio* because they possessed some features particularly in the DNA base composition, their non-fermentative metabolism and growth under microaerophilic nature (Kersters et al., 2006).

Two veterinary surgeons in 1909, McFadyean and Stockman, surveyed epizootic abortions in ovine and they isolated an unknown bacterium from aborted foetuses which resembled a *Vibrio* (Butzler, 2004). In 1919, a scientist named Smith investigated infectious abortions of bovines in the United States and isolated a bacterium that was de-

scribed as a *Spirillum* (Smith, 1919). After completing the study, Smith became familiar with the study of McFadyean and Stockman, and assumed what they had been studying were on similar bacteria. The first full report of *Campylobacter* enteritis in human was published in 1979, and later in the 1980s it was described that serotyping techniques aided by biotyping, phage typing and genotyping form the backbone of strain typing. *Campylobacter jejuni* was recognised in the mid-1980s as the most frequent cause of bacterial enterocolitis in man (Lior et al., 1982)

The breakthrough in the isolation of *Campylobacter* from faeces occurred in 1972 in a Veterinary research institute in Belgium. This success resulted in further general surveys from which related *Vibrio* were isolated from most children with diarrhoea but less from those without diarrhoea (Dekeyser et al., 1972). In 1931, it was attributed that winter dysentery in calves was due to infection with a 'vibrio' that they called *Vibrio jejuni*, and Doyle described a relevant microbe associated with swine dysentery in 1944 as the present *Campylobacter* (Jones et al., 1931). This advancement led to the development of selective media for the isolation of *Campylobacter* which became a routine in clinical microbiology (Skirrow, 1977). *In 1973,* Véron and Chatelain *published the first taxonomic classification of Campylobacter recognising V. jejuni and V. coli in the system of classification of the genus* (Herbet et al., 1982).

NATURAL RESERVOIRS

Poultry meat is considered as the primary source of *Campylobacter* (Skirrow, 1977). Other studies have indicated that other animals including dogs, cats and also wild birds, pigs, sheep, and cows, among others have been shown to be reservoir host for *Campylobacter* and it has also been isolated from faeces of exotic pets such as turtles, hamsters and monkeys (Blaser er al., 1980; Fox et al., 1983; Harvey and Greenwood, 1985; Simpson et al., 1981; Stern et al., 1992). *Campylobacter* was isolated from beef, rabbit meat and in pork (Little et al., 2008; Wilson et al., 2008). Beetles are also reported as vectors for *Campylobacter* to broiler chickens at rearing facilities (Skov et al., 2004). Certain species of *Campylobacter* are associated with a particular host. Dogs and cats have been shown to be associated with *C. helviticus* and *C. upsaliensis*, while *C. coli*, *C. hyointestinalis*, and *C. mucosalis* are more often isolated from pigs and *C. fetus* subsp. *fetus has been more commonly found in the intestines of sheep and cattle. Campylobacter lanienae has been found in faecal samples of cattle. Most wild birds harbour many species of thermophilic Campylobacter species* (Baker et al., 2008; Blaser et al., 1983; Gebhart et al., 1983; Hatch, 1996; Inglis and Kalischuk, 2003; Kapperud and Rosef, 1983; Manser and Dalziel, 1985; Moore et al., 2002, Pearce et al., 2003).

Drinking water has also been incriminated as a source for the transmission of *Campylobacter* in cows (Hanninen et al., 1998).

PHENOTYPIC AND BIOCHEMICAL PROPERTIES

Phenotypically, *Campylobacter* are slender, curved or spiral-rod shaped bacteria under phase contrast microscopy and measure 0.2-0.5mm wide and 0.5-8mm long with a single polar flagellum at one end that gives them the unique "cork screw" motility (Corry et al., 2001). They can be found in pairs or in chains, appearing as S- shaped or gull winged and may form coccoid or spherical bodies in aged cultures, usually more than 48 hours old. The gull wing gives them a darting motility (Vandamme et al., 1991). The optimum growth requirement for this organism is under microaerophilic conditions of 3% to 15% O_2 and 3% to 10% CO_2 and incubation is most suitable at 42^{0}C, however non-thermophilic species are isolated at 37^{0}C (Weese, 2011). Thermophilic *Campylobacter* such as *C. jejuni, C. lari, C.upsaliensis* and *C. coli* are able to grow between 37^{0}C and 42^{0}C, but incapable of growth below 30°C with an optimum temperature of 41.5°C. While non-thermophillic *Campylobacter* such as *C. hyointestinalis, C. helviticus, C. mucosalis* and *C. gracilis.* (Bester et al., 2016).

When subjected to oxidase test, all species of *Campylobacter* are positive with the exception of *C. gracilis* and non-spore forming *Campylobacter*. The G+C content of DNA of members of this genus is relatively low ranging from 29 – 46 mol% (Harvey and Greenwood, 1985). The members are also indole negative and the activities of catalase and nitrate reduction vary with the species involved (Ursing et al., 1983).

Catalase activity on *C. upsaliensis* is either negative or weakly positive and has the ability to reduce nitrates to nitrites. However, hippurate and urea are not hydrolyzed and therefore there is no production of H_2S in iron/metabisulphite medium or triple sugar iron agar. Most *Campylobacter* grow in 1% glycine and 1% bile and majority are capable of anaerobic growth in the presence of 0.1% trimethylamine N-oxide hydrochloride.

METHODS OF IDENTIFICATION AND DETECTION

CULTURE BASED METHODS FOR *CAMPYLOBACTER*

The isolation of *Campylobacter* from faecal samples is difficult because the plates are easily overgrown by commensals of the flora of the faeces and by the fact that *Campylobacter* are fastidious (Kulkarni et al., 2002). Enrichment broths are commonly used rather than direct plating and may increase the rate of detection by 30% compared to *Campylobacter* Blood Free Selective Agar (CCDA) alone (Baker et al., 1999; Maher et al., 2003; Acke et al., 2009). However, isolation using an enrichment procedure also has its shortcomings as it is known to result in a higher bacterial load

Table 1: Phenotypic and biochemical properties of Campylobacter species

Species	Catalase	Oxidase	Growth at:		Urease	Hydrolysis of:	
			25°C	42°C		Hippurate	Indoxyl acetate
C. coli	+	+	–	+	–	–	+
C. concisus	–	–	–	V	–	–	–
C. curvus	–	V	–	V	–	V	V
C. fetus subsp. fetus	+	+	+	V	–	–	–
C. gracilis	V	–	–	V	–	–	V
C. helviticus	–	V	–	+	–	–	+
C. hyointestinalis subsp. hyointestinalis	+	V	V	+	–	–	–
C. jejuni subsp doyley	V	+	–	–	–	+	+
C. jejuni subsp. Jejuni	+	+	–	+	–	+	+
C. lari	+	+	–	+	V	–	–
C. mucosalis	–	–	–	+	–	–	–
C. sputorum	V	V	–	+	V	–	–
C. upsaliensis	–	+	–	V	–	–	+

+: positive reaction; –: negative reaction; V: variable reaction
Sources: (On, 1996; Yamazaki-Matsune et al., 2007)

flora which can contaminate the plates and also prolong the incubation time (Fleming, 1983).

There is no standard method for the isolation of the *Campylobacter* species based on culture methods and techniques employed differ among laboratories. In 1972, Butzler used the membrane filtration technique for the isolation of the organism from faeces (Dekeyser et al., 1972). Isolation of the organism became easier when Skirrow in 1977 introduced a selective medium for the isolation of *C. jejuni* and *C. coli* which are the main causes of *Campylobacter* gastroenteritis (Skirrow, 1977).

Basically two methods are often used for the isolation of *Campylobacter* from culture based methods which are culture on a selective agar after a filtration step and culture without filtration. A 0.45μm pore sized cellulose triacetate membrane filter is used for the culture method using membrane filtration as described by (Steel and Mc Dermott, 1984). Samples are prepared as suspension using *Brucella* broth or normal saline. Few drops of the suspension are then placed on the surface of the membrane filter which is placed on the blood agar media and allowed to filter passively through the membrane filter for 20-30 minutes. The pores of the membrane filter allow only the passage of *Campylobacter* which are relatively slender in size while other bacteria and facultative anaerobes are excluded (Modolo and Giuffrida, 2004). No antibiotic is used on the blood agar which facilitates the growth of cultivatable *Campylobacter* in the sample. The inoculated plates are then incubated at 37°C for non-thermophilic and 42°C for thermophilic *Campylobacter* under microaerophilic conditions

for 48h. Suspected *Campylobacter* colonies are subcultured on selective media. On the contrary, some studies found that membrane filtration has the limitation that it could not detect co-infection of *Campylobacter* species because smaller sized organisms can be filtered through (Goossens et al., 1990; Koene et al., 2004).

For the culture of *Campylobacter* on selective media without filtration, faecal samples are streaked directly onto a selective blood free agar (such as charcoal cefoperazone deoxycholate agar CCDA) supplemented with antibiotics and incubated under microaerophilic conditions at 42°C for 48h. After incubation, suspected colonies are cultured on blood agar filter and isolates are identified by Gram stain, motility and biochemical tests as shown in Table 1 (Chon et al., 2014).

The Capetown protocol is employed to detect the presence of non-jejuni and non-coli *Campylobacter*. In this method, it combines procedures of culturing the sample on antibiotic free blood agar using the membrane filtration and incubation under microaerophilic environment. In 1977 in South Africa, the adoption of this method increased the rate of isolation of *Campylobacter* from 7.1% to 21.8% (Coker et al., 2002). The incubation period for the isolation of *Campylobacter* is significant because certain species like *C. jejuni* can be grown in 48 h while *C. upsaliensis* requires 96h to grow (Jamie et al., 2002). This effect was shown by (Hald et al., 2004) who found higher occurrence of *C.jejuni* when compared to *C. upsaliensis* and later found *C. upsaliensis* higher in occurrence than *C. jejuni* when the incubation period was extended to 96h although the different popu-

lation sampled may also be a factor for the variation in the results (Hald et al., 2004). Temperature too has a vital role in the detection of *Campylobacter* species which ranges between 37⁰C and 42⁰C equivalent to the body temperature of humans and chicken respectively (Engvall et al., 2003).

Molecular Detection of Campylobacter

Several studies conducted on the detection of the presence of *Campylobacter* are cumbersome culture-based methods that are known to have low recovery yields and to potentially underestimate the number of species in a given sample because of their fastidious growth requirements. Biochemical test depend on biochemical pathways and their disruption can lead to product failure leading to false result. These results give unclear prevalence and densities of *Campylobacter* species (Yamazaki-Matsune et al., 2007). Hippurate hydrolysis is the most popular phenotypic characterisation test that is used to distinguish between *C. jejuni* and the other *Campylobacter* species including *C. coli* however the test could provide false negative responses (Van Dyke et al., 2010).

In the recent years a rapid, simple and practical molecular assay for the identification of *Campylobacter* species has been sought. This is important due to their low cost and potential application in large scale screening programs. (Denis et al., 1999) observed that biochemical test provide only 34% efficiency compared to 100% with the PCR. This approach has significantly increased the detection frequency of *C. jejuni* (8.1% versus 5.3%) and recovery rates of *C. jejuni* were significantly increased with the molecular screening approach-guided culture in comparison to conventional culture (Humphries and Linscott, 2015).

Different PCR assays have been developed and designed using single primer sets to detect and identify *Campylobacter* species (Inglis and Kalischuk, 2003; Wang et al., 2002; Klena et al., 2004) developed two multiplex PCR assay that are sophisticated approach in the simultaneous detection and identification of *Campylobacter* that were effectively used. The findings of the various studies showed PCR techniques to be effective, precise and quick in the diagnosis of *Campylobacter* (Vilardo et al., 2006).

(Steinbruecker et al., 2001) compared three different methods for *Campylobacter* identification which included normal biochemical techniques, Gas Liquid Chromatography (GLC) and PCR, and noted PCR techniques to be the most sensitive method. PCR tests have been developed for the detection and identification directly from pathological and food sample (Abu-Halaweh et al., 2005). This method is accurate, automated and robust like all other real-time PCR. In addition, it is more cost-effective compared to the two-tube real-time assay, which is also a time consuming assay.

Identification of *Campylobacter* species is important for epidemiological and antibiotic resistance surveillance purposes (Steinbrueckner et al., 2001). Several methodologies have been documented for identification of *Campylobacter* thatinclude using rRNA gene sequences multiplex PCR with *gyr*A and *pfl*A genes or the *cad*F and *ceu*E gene (Nayak et al., 2005; Gorkiewicz et al., 2003). Multiplex real-time PCR has been used for rapid detection and identification of *C. coli* and *C. jejuni* from other *Campylobacter* species, employing a TaqMan probe targeting three different genes, *orfA*, *hipO*, and 16S rRNA respectively. 23S rRNA, *ceu*E, and *map*A are frequently used genes for PCR confirmation of *C. jejuni and C.coli* (Gonzalez et al., 2000).

A colony multiplex PCR was developed and optimized to simultaneous identify the 23S rRNA from *Campylobacter* spp.; the *hip*O gene (hippuricase) from *C. jejuni* subsp. *jejuni*; the *gly*A gene (serine hydroxymethyltransferase) from *C. coli, C. lari,* and *C. upsaliensis*; and the *sap*B2 gene (surface layer protein) from *C. fetus* subsp. *fetus*. The multiplex PCR protocol was capable of detecting the type strains and clinical isolates from all five species with a high degree of specificity (Wang et al., 2002). *Campylobacter* species can be detected by PCR assays using single primer (monoplex PCR) set that have been developed and also using multiple primers (multiplex PCR) for detecting several species (Yamazaki-Matsune et al., 2007; Inglis and Kalischuk, 2003).

EPIDEMIOLOGY

Prevalence of Campylobacter

Campylobacter is now regarded as the most frequent cause of food poisoning in humans and these bacteria are found in the digestive tract of most domestic animals. They are ubiquitous and can be found in various places and habitats including farms, urbanised areas, slaughter houses, companion animals, water, wild birds, mammals and farm production animals. The prevalence can be high in cattle, swine and poultry exceeding 80% from faecal samples (Economou et al., 2015; Aung et al., 2015: Stanley and Jones, 2003).

Household pets are known to be carriers of *Campylobacter* spp. in their guts, with incidences as high as 92% in stool samples when analyzed either through culturing or molecular methods such as PCR and PFGE (Hald et al., 2004; Waldenstrom et al., 2002). The carriage rate in stray dogs was higher (23.8%) than the pet dogs (2.7%) with *C. jejuni* (86.8%)most commonly isolated followed by *C. upsaliensis* (9.3%) then *C. coli* (3.9%) in a study done in Taiwan (Tsai et al., 2007). Studies conducted in Denmark and Spain on canine species showed carriage rates of *C. jejuni* at 20.1% and 35.2% respectively while *C. upsaliensis* constituted the majority of the isolates at 75% and 58.8%

Table 2: Prevalence rate of Campylobacter species across the globe from different studies

Author	Prevalence	Species isolated	Country
Baker *et al.*, 1999	Dogs 43% (43/289) Cats 7.6 % (15/195)	Dogs: *C. upsaliensis, C. jejuni* and *C. coli* Cats: *C. jejuni* and *C. upsaliensis*	Australia
Steinhauserova *et al.*, 2000	15.1% (19/126)	*C. upsaliensis, C. jejuni* and *C. coli*	Czech Rep.
Workman *et al.*, 2005	Dogs 46.9% (61/130) Cats 37.3% (19/51)	Dogs: *C. jejuni, C. coli* and *C. helviticus* Cats: *C. upsaliensis* and *C.helviticus*	Barbados
Carbonero *et al.*, 2012	102/290 (35.2%)	*C. jejuni* and *C.upsaliensis*	Spain
Parsons *et al.*, 2010	38% (96/249)	*C. jejuni* and *C.upsaliensis*	UK
Engvall, 2003	45/84 (53.6%)		Sweden
Hald, 2004	278/366 (76.0%)		Denmark
Tsai, 2007	2.8% (27/928)	*C. upsaliensis, C. jejuni* and *C. coli*	China
Stavisky, 2011	42.9% (63/147)		UK
Rossi, 2008	19/63 (30.2%)	Dogs: *C. upsaliensis, C. jejuni, C. helveticus* and *C. lari* Cats: *C. helveticus, C. jejuni* and *C. upsaliensis*	Italy
Kumar, 2012	51% (50/100)		India
Rodrigues *et al.*, 2015	Dogs 19.4% (20/103) Cats 11.7% (2/17)	Dogs: *C. jejuni* and *C. coli* Cats: *C. coli*	Brazil
Karshima, 2016	81/341 (23.8%)	*C. jejuni* and *C. coli*	Nigeria
Bojanić *et al.*, 2016	Dogs 36% Cats 16%	Dogs: *C. jejuni, C. upsaliensis, C. lari* and *Campylobacter helveticus* Cats: *C. jejuni, C. upsaliensis,* and *C. helveticus*	New Zealand
Mohammed *et al.*, 2016	Dogs: 14.8% (15/101) Cats: 23.2% (20/86)	Dogs: : *C. jejuni, C. upsaliensis,* and *C. helveticus* Cats: *C. jejuni, C. upsaliensis,* and *C. helveticus*	Malaysia

respectively (Carbonero et al., 2012). *Campylobacter upsaliensis, C.jejuni* and *C.helveticus* are most common species of *Campylobacter* in dogs and cats, however multiple species can be harboured at the same time in a single dog or cat (Hald et al., 2004; Koene et al., 2004; Moser et al., 2001; Shen et al., 2001).

The occurrence of *Campylobacter* from the faecal samples of children indicated 6.87% (11/160) of the faecal samples as positive for *Campylobacter* spp. However, a study conducted in Brazil on dogs and cats showed that 18.3% (22/120) of the pet samples tested were positive for *Campylobacter* spp. One hundred and twenty (120) faecal samples analysed were from 103 dogs and 17 cats with there carriage rate at 19.41% (20/103) and 11.7% (2/17) respectively (Rodrigues et al., 2015).

The zoonotic potential of *Campylobacter* from household pets to humans is still a major concern and is yet to be ascertained if it is transmitted through direct physical contact. However, it still remains a speculation but direct transmission of human with *C. jejuni* has been established. The prevalence of *Campylobacter* has been found to be higher in younger pets than older ones (Damborg et al., 2004; Hald et al., 2004). Similarly, in Nigeria a study conducted showed adult dogs and puppies recorded detection rates of 25.8% and 16.4% respectively while the prevalence

rates by females and males respectively varied significantly (p<0.05, OR=0.4027, 95% CI=1.437-4.290) (Karshima and Bobbo, 2016). Various studies that reported the prevalence rate across the globe are shown in Table 2.

PUBLIC HEALTH SIGNIFICANCE

Campylobacter jejuni is the most common specie of *Campylobacter* isolated from dogs and cats, This is a vital result from a public health perspective, because *C. jejuni* is the species most frequently associated with human gastroenteritis (Moore et al., 2005). The campylobacteriosis of great public health importance is *Campylobacter* enteritis caused by *C. jejuni* and *C. coli* (Coker et al., 2002). The incidence of *Campylobacter* in human is high, and often infection is through consumption of contaminated raw or under-cooked meat products and other potential reservoirs. This disease is particularly observed during travelling and hence the term "travellers' diarrhoea" (Sanders et al., 2002). In England and Wales, nearly 13,000 cases of travellers' diarrhoea have been confirmed to be caused by *C. coli* (Tam et al., 2003).

In most developing countries, national surveillance programs for campylobacteriosis are lacking despite the substantial burden of disease (Fullerton et al., 2007). The majority of *Campylobacter* spp. are considered emerging organisms and have virulence genes typically found in known

C. jejuni and *coli* indicating a role in human illness. Direct contact with animals including with kittens, puppies, cattle, chickens and pigs is a frequently identified risk factor for campylobacteriosis. Considering that asymptomatic carriage is very common in these animals, risk through direct exposure is not surprising (Friedman et al., 2004). *Campylobacter* can be found in water especially untreated; their presence in surface water and shallow wells is likely due to contamination by wild bird faeces, manure run-off from dairy or poultry farms, or human sewage (Clark et al., 2003; Olson et al., 2008). Most cases of *Campylobacter* infections in man are often attributed to consumption of raw milk, undercooked poultry and meat are identified as the main reservoirs. Poor food hygiene that leads to cross-contamination of uncooked food can cause human disease (Gras et al., 2012; Wilson et al., 2008).

Antibiotic Resistance

Campylobacter species like other emerging zoonotic disease-causing organisms are reported to be increasingly resistant to antibiotics mainly due to their widespread overuse in animals (Tauxe, 1997). Antibiotics are often regarded as one of the wonders of the 20th century; however the wonders raised by the issue of antibiotic resistance cannot be overemphasized (Davies and Davies, 2010). The potential development of resistance by these microbes have compromised the benefits of antimicrobial agents (Davies and Davies, 2010). Resistant *Campylobacter* species can be transferred to humans through direct ingestion of contaminated food or through contact with animals. The World Health Organization has suggested a halt in use of antibiotic as growth promoters that belong to an antimicrobial class used in human medicine. The continued usage of excess antibiotics in animals makes animals more susceptible to acquisition of the resistant strains of the organism (Angulo et al., 2004). The public health consequences of antibiotic use in animals can be evaluated more importantly when consideration of each pathogen-antibiotic situation (Son, 2005). Multidrug resistance has been reported in both *Campylobacter* species from various studies (Kabeya et al., 2004; Son et al., 2007).

Prevalence of Antibiotic Resistant Campylobacter

Occurrence of *Campylobacter* varies according to animal species and geographical location, with poultry meat recording the highest prevalence compared to beef and pork. (Son et al., 2007) in a study in the United States at a poultry processing plant showed the prevalence of antibiotic resistant *Campylobacter* recovered from broiler carcasses to be 99.5% to one or more antibiotics. On the other hand 28.4% were resistant to two or more antibiotics for *Campylobacter* (Son et al., 2007). The resistance displayed by *Campylobacter* to tetracycline was very high in *C. je-*

juni (99.5%) and *C.coli* (96.3%).

Similarly, a study conducted in Slovenia showed the occurrence of antibiotic resistance was higher in *C. coli* (75.9 %) than in *C. jejuni* (38.5 %) isolates. The resistance rate observed to enrofloxacin, nalidixic acid, erythromycin and tetracycline were 58.2, 49.1, 14.5 and 12.7 %, respectively. Eleven percent of *Campylobacter* isolated were resistant to erythromycin and ciprofloxacin and 12.7 % of the isolates were resistant to tetracycline and quinolones (Kurincic et al., 2005).

(Mackiw et al., 2012) in his study showed the highest rate of antibiotic resistance of *Campylobacter* isolates at 97.9% to ciprofloxacin, 64.3% of the same isolates were resistant to tetracycline and 9.1% were resistant to erythromycin and 6.3% to gentamicin. However, 7.0% of the 143 resistant *Campylobacter* strains were found to be resistant to at least three unrelated antibiotics (Mackiw et al., 2012).

A study on the prevalence of antibiotic resistance in dogs conducted in India showed all the isolates of *Campylobacter* were resistant to streptomycin, ampicillin, amoxicillin, aztreonam, lincomycin, tetracycline, oxytetracycline and penicillin. Only 2 isolates out of the total isolates used in the study were resistant to the entire 19 antibiotic used. Isolates had a high rate of resistance (97.35%) to Cefotaxim, chloramphenicol, floxacin, ciprofloxacin, cefaclor, nitrofurazone, norfloxacin, gentamicin, amikacin and enrofloxacin (Kulkarni et al., 2002).

CONCLUSION

It can be concluded that the occurrence of *Campylobacter* species in dogs and cats is of great public health significance due to there close contact with humans and therefore they serves as potential reserviour for human campylobacteriosis. The prevalence rate vary across the globe. PCR is the most reliable and sensitive method of detection. Good management and controlling the population of stray dogs and cats are key factors in preventing the spread of *Campylobacter* in these animal species. Antibiotic resistance in *Campylobacter* not only increases the risk of treatment failure in both humans and animals but also spreads antibiotic resistance genes.

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CONFLICT OF INTEREST

There is no conflict of interest in this review to declare.

AUTHORS' CONTRIBUTION

All the authors contributed equally for plan of review, article collection and manuscript writing.

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