Prevalence of thermotolerant Campylobacter species in dogs and cats in Iran

Saam Torkan*, Behnam Vazirian†, Faham Khamesipour‡,§ and Gabriel O. Dida¶
*Department of Small Animal Internal Medicine, Faculty of Veterinary Medicine, Shahrekord Branch, Islamic Azad University, Shahrekord, Iran, †Young Researchers and Elite Club, Shahrekord Branch, Islamic Azad University, Shahrekord, Iran, ‡Cellular and Molecular Research Center, Sabzevar University of Medical Sciences, Sabzevar, Iran, §Student Research Committee, Shiraz University of Medical Sciences, Shiraz, Iran and ¶School of Public Health and Community Development, Maseno University, Maseno, Kenya

Abstract

Campylobacter is considered the most common bacterial cause of human gastroenteritis in the world with C. jejuni being regarded as the primary cause of bacterial gastroenteritis. A broad range of other Campylobacter species, including C. coli have also been implicated in human gastroenteritis. This study sought to isolate, characterize and assess the antibiogram of Campylobacter jejuni and C. coli from faecal samples obtained from cats and dogs in Isfahan and Shahrekord cities in Iran. Faecal samples were collected from 100 pets comprising of 50 dogs and 50 cats from March 2015 to March 2016; incorporating the four seasons (spring, summer, autumn and winter). Campylobacter spp. was isolated by culture, characterized by biochemical tests and confirmed by PCR-based assays. Antimicrobial susceptibility test was performed by the Kirby–Bauer disk diffusion method, using Mueller Hinton agar. A total of 19 Campylobacter isolates among them two C. jejuni and one C. coli were recovered from dogs and cats’ faecal samples. The prevalence rates of Campylobacter spp. were 16.0% (8 out of 50) in dogs and 22.0% (11 out of 50) in cats. The highest (4 out of 16, 25%) Campylobacter spp. prevalence among dogs was reported in autumn and the lowest (1 out of 11, 9.1%) in spring, while among the cats, the highest (4 out of 12, 33.3%) Campylobacter spp. prevalence was reported in summer and lowest (1 out of 11, 9.09%) in spring. Campylobacter spp. isolated from faecal samples obtained from cats and dogs exhibited the most frequent antimicrobial resistance against tetracycline at 81.8% and 87.5%, respectively, compared to all other antimicrobial agents. These results show a low prevalence of Campylobacter spp. in faecal samples obtained from pet dogs and cats in Shahrekord and Isfahan cities in Iran. Given the relatively low prevalence of the C. jejuni and C. coli in pet dogs and cats in Isfahan and Shahrekord cities, it can be assumed that their importance as reservoirs for infection in humans is likely to be limited to the studied cities, but should not be neglected.

Keywords: Campylobacter, cat, dog, PCR, Iran, thermotolerant.

Introduction

Campylobacteriosis is an important, cosmopolitan, gastrointestinal infection of humans caused by a micro-aerophilic bacterium; Campylobacter (John et al. 2002; Moyaert et al. 2008; Raissy et al. 2014; Jonaidi-Jafari et al. 2016). Campylobacter jejuni and C. coli are considered among the most common causes of bacterial enteritis in humans and various animals worldwide (Rahimi et al. 2012; Goni et al. 2017). Consumption of contaminated food (mainly poultry), undercooked meat, unpasteurized milk and contaminated water are the most common mode of transmission. Contamination during food preparation has also been reported in some studies (Rahimi et al. 2010, 2017; Ommi et al. 2017). Infection with C. jejuni and C. coli may be asymptomatic or associated
with some non-specific clinical signs such as diarrhoea, weight loss and anorexia (Hakkinen et al. 2007). *Campylobacter* spp. have been isolated from various domestic and wild animals worldwide with a high incidence reported among poultry and poultry by-products (Hosseinzadeh et al. 2015; Modirrousta et al. 2016; Rahimi et al. 2017). The bacterium has also been isolated from the environment, including aquatic environments and sewage (Ghane et al. 2010). However, the incidence of *Campylobacter* spp. in the environment largely depends on the climatic conditions of the geographical area (Basersialahi et al. 2007).

Repeated contact with pets and livestock can increase the risk of *Campylobacter* infection in humans (Rahimi et al. 2017) with dogs and cats serving as potent reservoir of the *Campylobacter* spp. infection to their owners (Rahimi et al. 2012). However, studies show that pet dogs and cats have a relatively lower prevalence of *Campylobacter* spp. infection compared to stray ones (Salihu et al. 2010; Goni et al. 2017). The prevalence of *Campylobacter* spp. infection in dogs and cats is influenced by factors such as age, concurrent infection with other enteric pathogens and antibiotic treatment (Goni et al. 2017). Younger animals have a higher risk of *Campylobacter* spp. infection compared to older ones (Holmberg et al. 2015).

Microscopic and biochemical assays are commonly employed in the diagnosis of *Campylobacter* spp. in samples. However, these methods have proved inadequate for identification and classification of various *Campylobacter* species. This has led to the development of more sensitive molecular techniques such as the polymerase chain reaction (PCR) whose use has facilitated accurate identification and classification of a variety of *Campylobacter* species in different hosts (Rahimi et al. 2017).

A number of studies on *Campylobacter* spp. infection in Iran have focused on poultry (Rahimi & Ameri 2011; Hosseinzadeh et al. 2015; Modirrousta et al. 2016), cattle (John et al. 2002) and pets (Rahimi et al. 2012). This study sought to investigate the burden and identity of *Campylobacter* spp. infecting dogs and cats in Isfahan and Shahrekord cities in Iran.

### Material and methods

#### Sample collection

A total of 100 fresh faecal samples from cats ($n = 50$), and dogs ($n = 50$) were collected over the four seasons (spring, March to June; summer, June to September; autumn, September to December; and winter, December to March) between March 2015 and March 2016. The samples were stored in separate sterile plastic bags to prevent cross-contamination and immediately transported to the laboratory in a cooler box containing ice packs.

#### Microbiological analysis

The faecal samples were processed immediately upon arrival at the laboratory, using aseptic techniques. Approximately, 5 g of faeces were homogenized in 45 ml of Preston enrichment broth base-containing *Campylobacter* selective supplement IV (HiMedia Laboratories, Mumbai, India) and 5% (v/v) defibrinated sheep blood. After inoculation at 42°C for 24 h in a micro-aerophilic condition (85% N$_2$, 10% CO$_2$ and 5% O$_2$), 0.1 mL of the enrichment broth was streaked onto *Campylobacter* selective agar base (HiMedia Laboratories, Mumbai, India) supplemented with an antibiotic supplement for the selective isolation of *Campylobacter* species (HiMedia Laboratories, Mumbai, India) and 5% (v/v) defibrinated sheep blood. The agar plates were incubated at 42°C for 48 h under the same conditions. Presumptive thermotolerant *Campylobacter* colonies from each selective agar plate were subjected to biochemical tests. For identification, standard microbiological and biochemical procedures were used, including Gram staining, production of catalase, oxidase, hippurate hydrolysis, urease activity, indoxyl acetate hydrolysis and susceptibility to cephalotin (Rahimi & Ameri 2011).

#### DNA extraction and PCR conditions

From Preston's broth DNA was extracted from samples after the enrichment step, using a Genomic DNA purification kit (Fermentas, GmbH, Germ any,
K0512) following the manufacturer’s protocol. The PCR method used in this study is similar to the one previously described by Denis et al. (1999).

Using this protocol, the three genes selected for the identification of the Campylobacter spp., C. jejuni, and C. coli were the 16S rRNA gene (Linton et al. 1997), the mapA gene (Stucki et al. 1995), and the ceuE gene (Gonzalez et al. 1997), respectively. The primers sets used were: 16SrRNA (Forward: 5’- ATC TAA TGG CIT TAA CAT TAA AC and Reverse: 5’- GGA CGG TAA CTA GTT TAG TAG T) for the identification of Campylobacter spp., mapA (Forward: 5’- CTA TTT TAT TTT TGA GTG CTT GTG and Reverse: 5’- GCT TTA TTT GCC ATT TGT TTT ATT A) for C. jejuni and ceuE (Forward: 5’- AAT TGA AAA TGG CTC CAA CTA TG and Reverse: 5’- TGA TTT TAT TTT TAG CAG CG) for C. coli.

Amplification reactions were performed in a 30-µL mixture containing 0.6 U of Taq polymerase (Fermentas, GmbH, Germany), 100 µ mol L⁻¹ of each deoxynucleoside triphosphate (dNTP), 0.11 µ mol L⁻¹ of MD16S1 and MD16S2 primers, and 0.42 µ mol L⁻¹ of MDmapAl, MDmapA2, COL3 and MDCOL2 primers in the Fermentas buffer (Fermentas, GmbH, Germany). Amplification reactions were carried out, using a DNA thermal cycler (Master Cycle Gradiant, Eppendorf, Hamburg, Germany) with the following program: 1 cycle of 10 min at 95°C, 35 cycles each consisting of 30 s at 95°C, 1 min and 30 s at 59°C, 1 min at 72°C, and a final extension step of 10 min at 72°C. The amplification generated 857 bp, 589 bp, and 462 bp DNA fragments corresponding to the Campylobacter genus, C. jejuni, and C. coli, respectively.

Campylobacter coli (ATCC 33559) and C. jejuni (ATCC 33560) were used as the positive controls and DNase-free water was used as the negative control. The PCR products were stained with a 1% solution of ethidium bromide and were visualized under UV light after gel electrophoresis on 1.5% agarose.

Statistical analysis

Data generated were subjected to descriptive statistics using Microsoft Excel version 2010 (Microsoft, USA) and expressed in percentages. The association of age, sex and location with the presence of Campylobacter were compared by the χ² test using the statistical package for social sciences (SPSS) version 26.
one in 8 positive samples tested for Campylobacter jejuni accounting for 12.5% of the isolates. However, no C. coli was isolated from dogs’ faecal samples in the current study (Table 1). The prevalence (5 of 15, 33.3%) of Campylobacter spp. in dogs greater than 1 year of age was significantly higher ($P = 0.029$) compared to dogs aged below 1 year (3 of 35, 8.58%). A higher Campylobacter species isolation rate was recorded in male (6 of 30, 20%) than female dogs (2 of 20, 10%), though the difference was not statistically significant ($P = 0.345$). Campylobacter spp. isolated from dogs was higher in Shahrekord city (3 of 17, 17.6%) than Isfahan city (5 of 33, 15.2%), while infection was highest during autumn (4 of 16, 25%) and lowest during spring (1 of 11, 9.09%) (Table 1). However, the prevalence of Campylobacter spp. infection in dogs did not show any significant differences with regards to location ($P = 0.820$) nor with seasons ($P = 0.780$).

Among the cats, an overall Campylobacter spp. prevalence of 22% (11 out of 50) was reported in the current study. Campylobacter jejuni and C. coli accounted for 7.69% (1 of 13 positive isolates) each. A higher prevalence of Campylobacter spp. was recorded among female cats (8 of 32, 25%) and those cats aged below 1 year (7 of 30, 23.3%), compared to male cats (3 of 18, 16.7%) and cats above 1-year-old (4 of 20, 20%). The differences observed in the prevalence of Campylobacter between the cats of different age groups ($P = 0.780$) and sexes ($P = 0.495$) were, however, not statistically significant. Campylobacter spp. isolated from cats were higher in Shahrekord city (3 of 6, 50%) than Isfahan city (8 of 44, 18.2%). In addition, Campylobacter spp. isolates were relatively more during summer and lower during spring, though the differences with regards to locations ($P = 0.078$) and seasons ($P = 0.082$) were not significant (Table 2). Generally, there was no significant difference ($P = 0.444$) in the prevalence of Campylobacter infection recorded in dogs and cats in this study.

### Antibiotic sensitivity of Campylobacter species in dogs and cats

Multiple antibiotic resistance patterns were observed in the current study. Campylobacter species were most frequently resistant to tetracycline (7 of 8, 87.5%), ciprofloxacin (6 of 8, 75%), nalidixic acid (5 of 8, 62.5%), cefazolin (4 of 8, 50%) and amoxicillin (2 of 8, 25%). Overall, Campylobacter spp. showed some level of resistance to all antimicrobial agents

### Table 1. Prevalence of Campylobacter species in dogs in Iran

| Parameters | No. sampled | No. positive (%) | Campylobacter spp. | C. jejuni | C. coli |
|------------|-------------|------------------|--------------------|-----------|--------|
| Age        |             |                  |                    |           |        |
| <1 year    | 35          | 3 (8.58)         | 0 (0.00)           | 0 (0.00)  |        |
| >1 year    | 15          | 5 (33.33)        | 1 (6.66)           | 0 (0.00)  |        |
| Sex        |             |                  |                    |           |        |
| Male       | 30          | 6 (20.00)        | 1 (3.33)           | 0 (0.00)  |        |
| Female     | 20          | 2 (10.00)        | 0 (0.00)           | 0 (0.00)  |        |
| Location   |             |                  |                    |           |        |
| Isfahan    | 33          | 5 (15.15)        | 0 (0.00)           | 0 (0.00)  |        |
| Shahrekord | 17          | 3 (17.65)        | 1 (5.89)           | 0 (0.00)  |        |
| Season     |             |                  |                    |           |        |
| Summer     | 13          | 2 (15.39)        | 0 (0.00)           | 0 (0.00)  |        |
| Autumn     | 16          | 4 (25.00)        | 1 (6.25)           | 0 (0.00)  |        |
| Winter     | 10          | 1 (10.00)        | 0 (0.00)           | 0 (0.00)  |        |
| Spring     | 11          | 1 (9.09)         | 0 (0.00)           | 0 (0.00)  |        |
| Total      | 50          | 8 (16.00)        | 1 (2.00)           | 0 (0.00)  |        |

### Table 2. Prevalence of Campylobacter species in cats in Iran

| Parameters | No. sampled | No. positive (%) | Campylobacter spp. | C. jejuni | C. coli |
|------------|-------------|------------------|--------------------|-----------|--------|
| Age        |             |                  |                    |           |        |
| <1 year    | 30          | 7 (23.33)        | 1 (3.33)           | 1 (3.33)  |        |
| >1 year    | 20          | 4 (20.00)        | 0 (0.00)           | 0 (0.00)  |        |
| Sex        |             |                  |                    |           |        |
| Male       | 18          | 3 (16.66)        | 0 (0.00)           | 0 (0.00)  |        |
| Female     | 32          | 8 (25.00)        | 1 (3.13)           | 1 (3.13)  |        |
| Location   |             |                  |                    |           |        |
| Isfahan    | 44          | 8 (18.18)        | 1 (2.27)           | 0 (0.00)  |        |
| Shahrekord | 6           | 3 (50.00)        | 0 (0.00)           | 1 (16.66) |        |
| Season     |             |                  |                    |           |        |
| Summer     | 12          | 4 (33.33)        | 1 (8.33)           | 0 (0.00)  |        |
| Autumn     | 15          | 4 (26.66)        | 0 (0.00)           | 1 (6.66)  |        |
| Winter     | 12          | 2 (16.66)        | 0 (0.00)           | 0 (0.00)  |        |
| Spring     | 11          | 1 (9.09)         | 0 (0.00)           | 0 (0.00)  |        |
| Total      | 50          | 11 (22.00)       | 1 (2.00)           | 1 (2.00)  |        |

© 2018 The Authors. Veterinary Medicine and Science Published by John Wiley & Sons Ltd.
Veterinary Medicine and Science (2018), 4, pp. 296–303
except gentamicin. However, *C. jejuni* isolates from dogs’ faeces showed resistance to five (nalidixic acid, ciprofloxacin, tetracycline, cefazolin and lincomycin) of the 12 antimicrobial agents tested in this study (Table 3). Considering *Campylobacter* strains isolated from cats’ faeces, the largest proportion of *Campylobacter* spp. (9 of 11, 81.8%) *C. jejuni* (10 of 11, 90.9%) and *C. coli* (1 of 1, 100%) were resistant to tetracycline while 72.7% (8 of 11) of *Campylobacter* spp. and 63.6% (7 of 11) of *C. jejuni* were resistant to erythromycin. In addition, *C. jejuni* was highly resistant to nalidixic acid, ciprofloxacin, amoxicillin, enrofloxacin, cefazolin and lincomycin while low resistance was recorded against streptomycin, ampicillin and chloramphenicol. The single *C. coli* isolate from cats’ faeces was sensitive to all the antibiotics tested except nalidixic acid (100%), ciprofloxacin (100%) and tetracycline (100%) (Table 4).

**Discussion**

Most investigations concerning campylobacteriosis in Iran have largely focused on poultry and its products (Rahimi & Ameri 2011; Hosseinizadeh et al. 2015; Modirrousta et al. 2016), with only a few studies focusing on dogs and cats in the country (Rahimi et al. 2012). The overall prevalence of *Campylobacter* spp. reported among dogs (16%) and cats (22%) in the current study were similar to those reported by Goni et al. (2017) in Malaysia but lower than those previously reported in other parts of Iran and a few other countries (Hald et al. 2004; Salihu et al. 2010; Carbonero et al. 2012). The variations in the prevalence of *Campylobacter* species in dogs and cats have been associated with the locality under study, population of dogs sampled, method of identification and the fastidious nature of the organism (Byrne et al. 2007; Goni et al. 2017). The detection of *Campylobacter* infection in dogs and cats in the present study and a previous report by Rahimi et al. (2012) suggests that the organism may be endemic in parts of Iran, thus implying that the infection could be triggered by various environmental and host factors. This observation, however, requires further investigation to better understand the transmission dynamics of the *Campylobacter* spp. infection in the study area.

The commonly isolated *Campylobacter* species in dogs and cats include *C. upsaliensis*, *C. helveticus*, *C. jejuni* and *C. coli* with the predominant isolate being *C. upsaliensis* in dogs and cats. In the present study, only *C. jejuni* and *C. coli* were isolated, with the former being predominant. This observation is similar to findings by Baker et al. (1999) and Carbonero et al. (2012) who reported higher *C. jejuni* isolates compared to *C. coli* in dogs and cats. Both *C. jejuni* and *C. coli* have also been isolated successfully from environmental sources, faeces and by-products of various mammals and birds (Rosef et al. 1985; Hakkinen et al. 2007; Moyaert et al. 2008; Goni et al. 2017).

**Table 3.** Antimicrobial resistance profiles of *Campylobacter* strains isolated from faeces of dogs

| Antimicrobial agent | *Campylobacter* spp. (%) | *C. jejuni* (%) |
|--------------------|--------------------------|----------------|
| Nalidixic acid     | 5 (62.5%)                | 1 (100%)       |
| Ciprofloxacin      | 6 (75%)                  | 1 (100%)       |
| Erythromycin       | 1 (12.5%)                | 0 (0%)         |
| Tetracycline       | 7 (87.5%)                | 1 (100%)       |
| Streptomycin       | 1 (12.5%)                | 0 (0%)         |
| Ampicillin         | 1 (12.5%)                | 0 (0%)         |
| Amoxicillin        | 2 (25%)                  | 0 (0%)         |
| Gentamicin         | 0 (0%)                   | 0 (0%)         |
| Chloramphenicol    | 1 (12.5%)                | 0 (0%)         |
| Enrofloxacin       | 1 (12.5%)                | 0 (0%)         |
| Cefazolin          | 4 (50%)                  | 1 (100%)       |
| Lincomycin         | 6 (75%)                  | 1 (100%)       |

**Table 4.** Antimicrobial resistance profiles of *Campylobacter* strains isolated from faeces of cats

| Antimicrobial agent | *Campylobacter* spp. (%) | *C. jejuni* (%) | *C. coli* (%) |
|--------------------|--------------------------|----------------|--------------|
| Nalidixic acid     | 6 (54.54%)               | 7 (63.63%)     | 1 (100%)     |
| Ciprofloxacin      | 5 (45.45%)               | 4 (36.36%)     | 1 (100%)     |
| Erythromycin       | 8 (72.72%)               | 7 (63.63%)     | 0 (0%)       |
| Tetracycline       | 9 (81.81%)               | 10 (90.90%)    | 1 (100%)     |
| Streptomycin       | 2 (18.19%)               | 1 (9.09%)      | 0 (0%)       |
| Ampicillin         | 0 (0%)                   | 1 (9.09%)      | 0 (0%)       |
| Amoxicillin        | 4 (36.37%)               | 5 (45.45%)     | 0 (0%)       |
| Gentamicin         | 0 (0%)                   | 0 (0%)         | 0 (0%)       |
| Chloramphenicol    | 0 (0%)                   | 1 (9.09%)      | 0 (0%)       |
| Enrofloxacin       | 5 (45.45%)               | 4 (36.36%)     | 0 (0%)       |
| Cefazolin          | 5 (45.45%)               | 4 (36.36%)     | 0 (0%)       |
| Lincomycin         | 5 (63.63%)               | 4 (36.36%)     | 0 (0%)       |
et al. 2017). Nawal (2011) isolated C. jejuni from humans and poultry in Egypt implying that a wide range of organisms could be susceptible. The small sample size in the current study may be incriminated for the low incidence of C. coli reported among cats and absence of the same in dogs.

Dogs above 1 year of age had significantly higher prevalence of Campylobacter infection compared to younger ones in the present study. These findings contradicted those of other researchers who reported higher Campylobacter infections in younger dogs than older dogs (Hald et al. 2004; Wieland et al. 2005; Rahimi et al. 2012; Goni et al. 2017). Consistent with the current findings, Rahimi et al. (2012b) also reported that the age of dogs and cats did not have a significant influence on Campylobacter infection.

Seasonal variations of the Campylobacter species infection in dogs and cats observed in the current study contradicts the findings presented by Rahimi et al. (2012) in which they reported an insignificant association between Campylobacter infection and seasons in Iran. Large-scale epidemiological studies should thus be conducted in dogs and cats in Iran to establish the statistical reliability of seasonality on campylobacteriosis in these animals.

Antibiotic resistance of Campylobacter species has been identified as an increasing public health concern (Silva et al. 2011; WHO, 2013). This is emphasized by the increasing number of multi-drug resistant isolates, especially to macrolides and fluoroquinolones (Alfredson & Korolic 2007). Tetracycline resistance was most frequent in Campylobacter strains isolated from both dogs and cats in this study which corroborates the reports by Rahimi et al. (2017), D’lima et al. (2007) and Nawal (2011). This is particularly important because cats and dogs represent potential sources of spread of antimicrobial resistance. Increased frequency of antimicrobial resistance often results from the indiscriminate and frequent use of a number of antimicrobials for prophylactic and therapeutic treatment of a wide range of bacterial infections, thus promoting the development of resistance among many bacteria. According to Watson & Rosin (2000), the most frequent causes of antimicrobial treatment in dogs and cats are skin and wound infections, otitis externa, respiratory infections, and urinary tract infections.

In the current study, a high frequency of resistance, ranging from 62.5% to 75.0%, was recorded for ciprofloxacin, lincomycin and nalidixic acid in dogs. These findings are almost similar to previous reports in livestock, poultry and humans in Iran and Poland (Rozynek et al. 2008; Kumar et al. 2012; Rahimi et al. 2017). Furthermore, low levels of resistance were recorded for erythromycin, streptomycin, ampicillin, chloramphenicol, enrofloxacin and amoxicillin in dogs in this study. This was also similar to the resistance patterns reported by Rahimi et al. (2017). It, however, contradicts the reports in poultry by Ge et al. (2003), Nawal (2011) and Kumar et al. (2012). The variations in the antibiogram may be associated with the different animal species studied.

All Campylobacter isolates from dogs and cats’ faecal samples were sensitive to gentamicin, which is consistent with the reports of Nawal (2011) and Rahimi et al. (2017). The antibiogram of C. jejuni in dogs in the current study were similar to those reported by Rahimi et al. (2017). The high frequency of resistance observed for some antimicrobial agents in the current study is a source of concern, given the close contact between household pets and humans, which offer favourable conditions for transmission of the bacteria by direct contact (e.g. through petting, licking or physical injuries) or through contact with contaminated household environment like floors and carpets (Tan 1997). Furthermore, children are at a relatively higher risk compared to adults because of their closer physical contact with pets as well as contaminated environments (Salfield & Pugh 1987).

The present investigation showed a low prevalence of Campylobacter spp. in both pet dogs and cats. However, the results suggest an age predisposition where older dogs are more likely to shed Campylobacter spp. than younger dogs. Though the sample size was considerably low, (n = 100), the findings provide an insight into the epidemiology of Campylobacter infections in dogs and cats in Isfahan and Shahrekord cities in Iran. Nevertheless, given the relatively low prevalence of the C. jejuni and C. coli in pet dogs and cats in the current study, it can be assumed that their importance as reservoirs for infection in humans is likely to be limited, but should not be neglected. To establish the zoonotic potential of canine and feline Campylobacter isolates,

© 2018 The Authors. Veterinary Medicine and Science Published by John Wiley & Sons Ltd.
Veterinary Medicine and Science (2018), 4, pp. 296–303
both human and canine/feline isolates have to be further characterized and compared.

Acknowledgements

The authors thank Prof. Dr. E. Rahimi of the Department of Food Hygiene and Quality Control, Faculty of Veterinary Medicine, Islamic Azad University, Shahrekord Branch, Shahrekord, Iran for his overwhelming support and Dr. A. Kaikabo Ahmad for their advice and comments.

Source of funding

This study did not receive funding from public or private sector agencies.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization.

Ethics statement

The experimental protocol of the present study was approved by Faculty of Veterinary Medicine and Ethical and Research Committee of Islamic Azad University, Shahrekord Branch, Shahrekord, Iran.

Contributions

All authors read and approved the final manuscript.

References

Alfredson D.A. & Korolc V. (2007) Antibiotic resistance and resistance mechanisms in Campylobacter jejuni and Campylobacter coli. FEMS Microbiology Letters 277, 123–132. https://doi.org/10.1111/j.1574-6968.2007.00935.x. PMID:18031331.
Baker J., Barton M.D. & Lanser J. (1999) Campylobacter species in cats and dogs in South Australia. Australian Veterinary Journal 77, 662–666.
Baserisalehi M., Bahador N. & Kapadnis B. (2007) Isolation and characterization of Campylobacter spp. from domestic animal and poultry in south of Iran. Pakistan Journal of Biological Science 10, 1519–1524.
Byrne C.M., Clyne M. & Bourke B. (2007) Campylobacter jejuni adhere to and invade chicken intestinal epithelial cells in vitro. Microbiology 153, 561–569.
Carbonero A., Torralbo A., Borge C., García-Bocanegra I., Arenas A. & Perea A. (2012) Campylobacter spp., C. jejuni and C. upsaliensis infection associated factors in healthy and ill dogs from clinics in Cordoba, Spain. Screening tests for antimicrobial susceptibility. Comparative Immunology, Microbiology and Infectious Diseases 35, 505–512.
Denis M., Soumet C., Rivoal K., Ermel G., Bivet D., Salvat G. & Colin P. (1999) Development of am-PCR assay for simultaneous identification of Campylobacter jejuni and C. coli. Letters in Applied Microbiology 29, 406–410.
D’lima C.B., Miller W.G., Mandrell R.E., Wright S.L., Silezky R.M., Carver D.K. & Kathariou S. (2007) Clonal population structure and specific genotypes of multidrug-resistant Campylobacter coli from turkeys. Applied and Environmental Microbiology 73, 2156–2164. https://doi.org/10.1128/aem.02346-06. PMID: 17293500.
Ge B., White D.G., McDermott P.F., Girard W., Zhao S., Hubert S. & Meng J. (2003) Antimicrobial-resistant Campylobacter species from retail raw meats. Applied and Environmental Microbiology 69, 3005–3007. https://doi.org/10.1128/AEM.69.5.3005-3007. PMID: 12732579.
Ghane M., Bahador N. & Baserisalehi M. (2010) Isolation, identification and characterization of Campylobacter spp. isolates from environmental samples in North Iran. Nature Environment and Pollution Technology 9, 823–828.
Goni M.D., Abdul-Aziz S., Dhaliwal G.K., Zunita Z., Bitrus A.A., Ialo J.M. et al. (2017) Occurrence of Campylobacter in dogs and cats in Selangor Malaysia and the associated risk factors. Malaysian Journal of Microbiology 13, 164–171.
Gonzalez I., Grant K.A., Richardson P.T., Park S.F. & Collins M.D. (1997) Specific identification of the enteropathogens Campylobacter jejuni and Campylobacter coli by using a PCR test based on the ceuE gene encoding a putative virulence determinant. Journal of Clinical Microbiology 35, 759–763.
Hakkinen M., Heiska H. & Hanninen M. (2007) Prevalence of Campylobacter spp. in Cattle in Finland and antimicrobial susceptibilities of bovine Campylobacter jejuni strains. Applied and Environmental Microbiology 73, 3232–3238.
Hald B., Pedersen K., Waino M., Jorgensen J.C. & Madsen M. (2004) Longitudinal study of the excretion patterns of thermophilic Campylobacter spp. in young pet dogs in Denmark. Journal of Clinical Microbiology 42, 2003–2012.
Holmberg M., Rosendal T., Engvald E.O., Ohlson A. & Lindberg A. (2015) Prevalence of thermophilic Campylobacter species in Swedish dogs and characterization of C. jejuni isolates. Acta Veterinaria Scandinavica 1, 19. https://doi.org/10.1186/s13028-015-0108-0.

Hosseinzadeh S., Mardani K., Aliakbarlu J. & Ghorbanzadehghani M. (2015) Occurrence of Campylobacter in chicken wings marketed in the northwest of Iran. International Food Research Journal 22, 41–45.

John C.B., Elsa A.M. & Gary R.A. (2002) Prevalence of Salmonella and Campylobacter in beef cattle from transport to slaughter. Journal of Food Protection 65, 1687–1693.

Jonaidi-Jafari N., Khamesipour F., Ranjbar R. & Kheiri R. (2016) Prevalence and antimicrobial resistance of Campylobacter species isolated from the avian eggs. Food Control 70, 35–40.

Kumar R., Verma A.K., Kumar A., Srivastava M. & Lai H.P. (2012) Prevalence and antibiotic of Campylobacter infections in dogs of Mathura, India. Asian Journal of Animal and Veterinary Advances 7, 434–440. https://doi.org/10.3923/ajava.2012.

Linton D., Lawson A., Owen R. & Stanley J. (1997) PCR detection, identification to species level, and fingerprinting of Campylobacter jejuni and Campylobacter coli direct from diarrheic samples. Journal of Clinical Microbiology 35, 2568–2572.

Modirrousta S., Shapouri R., Rezasoltani S. & Molaabazadeh H. (2016) Prevalence of Campylobacter spp. and their common serotypes in 330 cases of red-meat, chicken-meat and egg-shell in Zanjan City, Iran. Infection Epidemiology and Medicine 2, 8–10.

Moyaert H., Ceelen L., Dewulf J., Haesebrouck F. & Pmans F. (2008) PCR detection of Campylobacter species in faeces from dogs. Vlaams Diergeneeskundig Tijdschrift 78, 92–96.

Nawal A.H. (2011) Antimicrobial resistant Campylobacter jejuni isolated from humans and animals in Egypt. Global Veterinaria 6, 195–200.

Omidi D., Hemmatinezhad B., Taktaz Hafshejani T. & Khamesipour F. (2017) Incidence and antimicrobial resistance of Campylobacter and Salmonella from houseflies (Musca domestica) in kitchens, farms, hospitals and slaughter houses. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences 87, 1285–1291.

Rahimi E. & Ameri M. (2011) Antimicrobial resistance patterns of Campylobacter spp. isolated from raw chicken, turkey, quail, partridge, and ostrich meat in Iran. Food Control 22, 1165–1170. https://doi.org/10.1016/j.foodcont.2011.01.010.

Rahimi E., Mottomaz H., Bonyadlan M. (2010). PCR detection of Campylobacter spp. from turkey carcasses during processing plant in Iran. Food Control 21, 692e694.

Rahimi E., Chakeri A. & Esmizadeh K. (2012) Prevalence of Campylobacter species in fecal samples from cats and dogs in Iran. Slovenian Veterinary Research 49, 117–122.

Rahimi E., Afipoor-Amroabadi M. & Khamesipour F. (2017) Investigation of prevalence of thermotolerant Campylobacter spp. in livestock faeces. Canadian Journal of Animal Science 97, 207–213. dx.doi.org/10.1139/cjas-2015-0166.

Rahimi E., Chamesipour F., Rahimi E. & Khodadoostan A. (2014) Occurrence of Vibrio spp., Aeromonas hydrophila, Escherichia coli and Campylobacter spp. in crayfish (Astaxis leptodactylus) from Iran. Iranian Journal of Fisheries Sciences 13, 944–954.

Rosef O., Kapperud G., Lauwers S. & Gondrosen B. (1985) Serotyping of Campylobacter jejuni, Campylobacter coli, and Campylobacter laridis from domestic and wild animals. Applied and Environmental Microbiology 49, 1507–1510.

Rozyniec E., Dzierzanowska-Fangrat K., Korsak D., Konieczny P., Wardak S., Szych J. et al. (2008) Comparison of antimicrobial resistance of Campylobacter jejuni and Campylobacter coli isolated from humans and chicken carcasses in Poland. Journal of Food Protection 71, 602–607. PMID: 18389707.

Salfield N.J. & Pugh E.J. (1987) Campylobacter enteritis in young children living in households with puppies. British Medical Journal 294, 21–22.

Salihu M.D., Magaji A.A., Abdulkadir J.U. & Kolawal A. (2010) Survey of thermophilic Campylobacter species in cats and dogs in north-western Nigeria. Veterinaria italiana 46, 425–430.

Silva J., Leite D., Fernandes M., Mena C., Gibbs P.A. & Teixeira P. (2011) Campylobacter spp. as a foodborne pathogen: a review. Frontiers in Microbiology 2, 200. PMID:21991264.

Stucki U., Frey J., Nicolet J. & Burnens A.P. (1995) Identification of Campylobacter jejuni on the basis of a species-specific gene that encodes a membrane protein. Journal of Clinical Microbiology 33, 855–859.

Tan J.S. (1997) Human zoonotic infections transmitted by flies (Musca domestica) in kitchens, farms, hospitals and slaughter houses. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences 46, 1933–1943.

Watson A.D.J. & Rosin E. (2000) Antimicrobial drug use in dogs and cats. In: Antimicrobial Therapy in Veterinary Medicine. 3rd edn, 537–575. (eds J.F. Prescott, J.D. Baggot & R.D. Walker), Iowa State University Press: IA.

Wieland B., Regula G., Danuser J., Wittwer M., Burnens A.P., Wassenaar T.M. & Stark K.D. (2005) Campylobacter spp. in dogs and cats in Switzerland: risk factor analysis and molecular characterization with AFLP. Journal of Veterinary Medicine 52, 183–189.

World Health Organization (WHO) (2013) The global view of Campylobacteriosis: report of an expert consultation. World Health Organization: Utrecht, The Netherlands.