UNIVERSITI PUTRA MALAYSIA

OCCURRENCE AND ANTIBIOTIC RESISTANCE OF Campylobacter AND Arcobacter spp. IN DOGS AND CATS

MOHAMMED DAUDA GONI

FPV 2014 36

OCCURRENCE AND ANTIBIOTIC RESISTANCE OF *Campylobacter* AND *Arcobacter* spp. IN DOGS AND CATS

By

MOHAMMED DAUDA GONI

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfillment of the Requirements for the Master of Science

August 2014

DEDICATIONS

I would like to dedicate this work to my parents

Alh. Mohammed Goni and **Hajiya Aishatu Goni**

Who are my inspiration and for their affection, love, continuous support and prayers

My stepmother **Hajiya Fatsuma Goni**

And my siblings

For their continuous support and prayers

In memory of my Late Uncle

Alh. Ibrahim Abubakar Danbauchi

Abstract of thesis presented to the Senate Universiti Putra Malaysia in the fulfillment of the requirement for the Degree of Master of Science

OCCURRENCE AND ANTIBIOTIC RESISTANCE OF *Campylobacter* AND *Arcobacter* spp. IN DOGS AND CATS

By

MOHAMMED DAUDA GONI

August 2014

Chairman: Professor Saleha Abdul Aziz, PhD

Faculty: Veterinary Medicine

Campylobacter and *Arcobacter* are becoming more recognised because of their detection in a wide range of hosts and food of animal origin. *Campylobacter* is considered one of the most common causes while *Arcobacter* has emerged as a cause of gastro-enteritis in humans and both are of public health concern. They are gram negative, curved, spiral or S- shaped and are members of the order *Campylobacterales*, class *Epsilon* and phylum *Proteobacteria.* 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 like Malaysia. Due to this present scenario, this study was conducted to determine the presence of *Campylobacter* and *Arcobacter* in dogs and cats and to also determine antibiotic resistance patterns of the isolates.

The presence of these organisms was determined using conventional and molecular techniques. For *Arcobacter*, rectal and buccal swab samples were collected from owned dogs (40) and cats (40) presented to the University Veterinary Hospital (UVH), Universiti Putra Malaysia (UPM) and a private veterinary clinic within Kuala Lumpur, and stray dogs (61) and cats (46) from an animal shelter and Dewan Bandaraya Kuala Lumpur (DBKL) dog pound. Rectal swabs were also taken for the detection of *Campylobacter* in these animals. Suspected colonies of the two organisms were subcultured and subjected to biochemical tests which included catalase, oxidase, hippurate hydrolysis and indoxyl acetate hydrolysis tests. Multiplex polymerase chain reaction (mPCR) was employed for the confirmation of the suspected isolates and differentiation of species. Overall, the results showed carriage rates of 32.6% (15/46) and 12.5% (5/40) of *Campylobacter* in stray and client owned cats respectively, while *Arcobacter* was detected in 34.78% (16/46) and 45% (18/40) in stray and client owned cats respectively. In stray dogs, *Campylobacter* and *Arcobacter* were detected at 16.3% (10/61) and at 50% (31/61) respectively. *Arcobacter butzleri* was the only species that was isolated and

Campylobacter upsaliensis (60%), *C. helviticus* (20%) and *C. jejuni* (11.4%) were the species of *Campylobacter* isolated.

Risk factors for *Campylobacter* and *Arcobacter* infections in dogs and cats were determined through questionnaires filled by pet owners. Among the factors that were looked at included age, sex, breed category, single or multi-pet household, recent treatment with antibiotic, housing of the dogs and cats, source of drinking water, contact with other animals, consumption of raw meat and fish and place of residence of the owner. Factors found to significantly increase the risk for *Arcobacter* infections were multi-pets household type and source of drinking water in cats while none were significant in the case of dogs. None of the factors analyzed was significant in terms of the occurrence of *Campylobacter* in both dogs and cats.

Antibiotic resistance pattern using minimum inhibitory concentration (M.I.C) and disc diffusion methods were carried out. Eighty nine (89) *Arcobacter butzleri* and 28 *Campylobacter* isolates were tested against 12 antibiotics using the disc diffusion method namely ciprofloxacin (Cip) 5µg; ampicillin (Amp), 10 µg; tetracycline (Te), 30 µg; erythromycin (E), 15 µg; gentamicin (CN), 10 µg; cefotaxime (CTX), 30 µg; penicillin G (P), µg; streptomycin (S), µg; nalidixic acid (NA), µg; enrofloxacin (Enr), µg; amoxicillin/clavulanic acid (AMC), µg and ceftazidine (CAZ), µg. Four antibiotics, namely ampicillin, tetracycline, erythromycin and ciprofloxacin were used against *Campylobacter* and *Arcobacter butzleri* isolates for the M.I.C. Overall, the isolates were found resistant to at least one antibiotic using both techniques. For *Campylobacter* isolates, the resistance to the antibiotics using the disc diffusion method was as follows: ciprofloxacin (17.8%), gentamycin (32.1%), cefotaxime (42.8%), penicillin G (53.5%), tetracycline (32.1%), ampicillin (42.8%), erythromycin (50%), streptomycin (42.8%), nalidixic acid (46.4%), amoxycillin/clavulanic acid (17.8%), ceftazidine (50%) and enrofloxacin (21.4%). Using the M.I.C.E. strip (Oxoid), *Campylobacter* and *A. butzleri* isolates showed exception in the resistance to ciprofloxacin. For *Arcobacter* isolates the resistance to antibiotics using the disc diffusion was as follows: ciprofloxacin (2.1%), gentamicin (63.1%), cefotaxime (69.4%), penicillin G and ampicillin (98.9%), tetracycline (33.6%), erythromycin (53.6%), streptomycin (85.2%), nalidixic acid (61.0%), amoxycillin/clavulanic acid (43.1%), ceftazidine (3.6%) and enrofloxacin (31.5%). In comparison, the resistance rates between the disc diffusion and M.I.C. were not significantly different. The antibiotic resistance showed and 35 patterns for *Campylobacter* and *Arcobacter* isolates respectively. *Campylobacter* isolates were found resistant to nine (9) antibiotics while *Arcobacter* showed resistance to ten (10) antibiotics. Multi drug resistance (MDR) was reported among 50% and 78.9% of *Campylobacter* and *Arcobacter* isolates respectively.

It can be concluded that the occurrence of *Campylobacter* and *Arcobacter* species in dogs and cats is of great public health significance as pets are in close contact with humans. Good management and controlling the population of stray dogs and cats are key factors in preventing the spread of *Campylobacter* and *Arcobacter* in these animal species. Antibiotic resistance in *Campylobacter* and *Arcobacter* not only increases the risk of treatment failure in both humans and animals but also spreads antibiotic resistance genes.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

KEHADIRAN DAN KERINTANGAN ANTIBIOTIK *Campylobacter* DAN *Arcobacter* spp. PADA ANJING DAN KUCING

Oleh
8

MOHAMMED DAUDA GONI

Ogos 2014

Pengerusi : Professor Saleha Abdul Aziz, PhD

Fakulti : Perubatan Veterinar

Campylobacter dan *Arcobacter* menjadi lebih dikenali kerana pengesanan mereka pada pelbagai perumah dan makanan berasaskan haiwan. *Campylobacter* dianggap sebagai salah satu penyebab yang paling lazim dan *Arcobacter* telah muncul sebagai penyebab gastroenteritis pada manusia dan kedua-duanya membimbangkan kesihatan awam. Bakteria ini bersifat gram negatif, berbentuk melengkung, lingkaran atau berbentuk S dan merupakan anggota dalam *order Campylobacterales*, kelas *Epsilon* dan filum *Proteobacteria*. Beberapa kajian telah dijalankan di negara maju mengenai kejadian dan pencirian organisma tersebut pada anjing dan kucing tetapi kajian seumpama ini sangat kurang di kebanyakan negara sedang membangun seperti Malaysia. Berikutan daripada senario tersebut, kajian ini telah dijalankan untuk menentukan kehadiran *Campylobacter* dan *Arcobacter* pada anjing dan kucing dan juga menentukan corak kerintangan antibiotik isolat.

Kehadiran organisma ini telah ditentukan dengan menggunakan kaedah konvensional dan molekular. Untuk *Arcobacter*, sampel swab rektum dan bukka telah diambil daripada anjing (40) dan kucing (40) peliharaan yang dibawa ke Hospital Veterinar Universiti (UVH), Universiti Putra Malaysia (UPM) dan satu klinik veterinar swasta di Kuala Lumpur, serta anjing liar (61) dan kucing liar (46) di pusat perlindungan haiwan dan tempat simpanan anjing di Dewan Bandaraya Kuala Lumpur (DBKL). Swab rektum juga diambil bagi pengesanan *Campylobacter* pada haiwan tersebut. Koloni bakteria yang disyaki disubkultur, dan menjalani ujian biokimia termasuk *catalase, oxidase, hippurate hydrolysis* dan *indoxyl acetate hydrolysis*. *Multiplex polymerase chain reaction* (mPCR) telah dilakukan bagi pengesahan dan menentukan spesis isolat. Secara keseluruhannya, keputusan menunjukkan kadar peratus *Campylobacter* adalah 32.6% (15/46) pada kucing liar dan 12.5% (5/40) pada kucing kesayangan, manakala *Arcobacter* dikesan sebanyak 34.78% (16 /46) pada kucing liar dan 45% (18 /40) pada kucing peliharaan. Pada anjing liar,

Campylobacter dikesan sebanyak 16.3% (10/61) dan 50% (31/61) untuk *Arcobacter*. *Arcobacter butzleri* adalah satu-satunya spesis yang diasingkan dan *Campylobacter upsaliensis* (60%), *C. helveticus* (20%) dan *C. jejuni* (11.4%) adalah spesis *Campylobacter* yang telah diasingkan.

Faktor berisiko bagi jangkitan *Campylobacter* dan *Arcobacter* pada anjing dan kucing ditentukan secara statistik melalui soal-selidik yang diisi oleh pemilik haiwan kesayangan. Antara faktor yang dilihat termasuk umur, jantina, jenis baka, haiwan kesayangan yang terdapat dalam isi rumah sama ada tunggal atau pelbagai, rawatan terkini haiwan yang disampel dengan antibiotik, tempat tinggal anjing dan kucing, sumber air minuman, sentuhan dengan haiwan lain, pengambilan daging dan ikan mentah dan tempat kediaman pemilik. Faktor berisiko yang signifikan ke atas jangkitan *Arcobacter* adalah pelbagai jenis haiwan kesayangan di rumah dan sumber air minuman bagi kucing manakala tidak signifikan bagi anjing. Faktor yang di analisis bagi kehadiran Campylobacter pada anjing dan kucing didapati tidak signifikan.

Corak kerintangan antibiotik dilakukan menggunakan kaedah *Minimum Inhibitory Concentration* (M.I.C) dan *disk diffusion*. Lapan puluh sembilan (89) isolat *Arcobacter butzleri* dan 28 isolat *Campylobacter* telah diuji terhadap 12 antibiotik menggunakan kaedah *disk diffusion* iaitu *ciprofloxacin* (Cip) 5µg ; *ampicillin* (Amp), 10 µg ; *tetracycline* (Te), 30 µg ; *erythromycin* (E), 15 µg ; *gentamicin* (CN), 10 µg ; *cefotaxime* (CTX), 30 µg ; penisilin G (P), 10µg ; *streptomycin* (S), 10µg ; asid nalidixik (NA), 5µg ; *enrofloxacin* (ENR), 5µg ; *amoxicillin* / asid klavulanik (AMC), 10µg dan *ceftazidine* (Caz), 30µg. Empat antibiotik iaitu *ampicillin*, *tetracycline*, *erythromycin* dan *ciprofloxacin* telah digunakan terhadap 16 isolat *Campylobacter* dan *A. butzleri* untuk kaedah M.I.C. Secara keseluruhannya, isolat didapati rintang terhadap salah satu antibiotik menggunakan kedua-dua kaedah. Untuk isolat *Campylobacter*, kerintangan terhadap antibiotik menggunakan kaedah *disk diffusion* adalah seperti berikut: *ciprofloxacin* (17.8%), *gentamicin* (32.1%), *cefotaxime* (42.8%), penisilin G (53.5%), *tetracycline* (32.1%), *ampicillin* (42.8%), *erythromycin* (50%), *streptomycin* (42.8%), asid nalidixic (46.4%), *amoxycillin* / asid klavulanik (17.8%), *ceftazidine* (50%) dan *enrofloxacin* (21.4%). Dengan menggunakan strip M.I.C.E (Oxoid), isolat *Campylobacter* dan *Arcobacter butzleri* tidak menunjukkan kerintangan terhadap *ciprofloxacin*. Untuk isolat *Arcobacter*, kerintangan antibiotik dengan menggunakan *disk diffusion* adalah seperti berikut: *ciprofloxacin* (2.1%), *gentamicin* (63.1%), *cefotaxime* (69.4%), penisilin G dan *ampicillin* (98.9%), *tetracycline* (33.6%), *erythromycin* (53.6%), *streptomycin* (85.2%), asid nalidixik (61.0%), *amoxycillin* / asid klavulanik (43.1%), *ceftazidine* (3.6%) dan *enrofloxacin* (31.5%). Secara perbandingan, tiada perbezaan signifikan bagi kadar kerintangan antibiotik di antara *disk diffusion* dan MICE. *Campylobacter* menunjukkan 18 corak kerintangan dan *Arcobacter* menunjukkan 35 corak. Isolat *Campylobacter* didapati menunjukkan kerintangan terhadap sembilan antibiotik manakala *Arcobacter* menunjukkan kerintangan terhadap sepuluh antibiotik. Kerintangan multi-drug dilaporkan di kalangan 50% isolat *Campylobacter* dan di kalangan 78.9% isolat *Arcobacter*.

Dapat disimpulkan bahawa pengesanan spesis *Campylobacter* dan *Arcobacter* pada anjing dan kucing mempunyai kepentingan kesihatan awam disebabkan ianya berhubungan rapat dengan manusia. Pengurusan yang baik dan kawalan populasi anjing dan kucing liar adalah faktor utama dalam mencegah penyebaran

Campylobacter dan *Arcobacter* pada spesis haiwan tersebut. Kerintangan antibiotik pada *Campylobacter* dan *Arcobacter* tidak hanya boleh meningkatkan risiko kegagalan rawatan pada kedua-dua manusia dan haiwan malah dapat menyebarkan gen kerintangan antibiotik.

ACKNOWLEDGEMENTS

All praises be to Allah (SWT), the creator, nourisher, cherisher, sustainer and provider of one and all who bestowed the ability in me making my dreams a reality. I would like to express my sincere appreciation and profound gratitude to the Chairman of my supervisory committee Prof. Dr. Saleha Abdul Aziz for her unwavering support, scholarly criticisms throughout the research and the program as a whole. Her thorough scrutiny and suggestions made this reality. I am grateful and indebted to supervisory committee members, Assoc. Prof. Dr. Zunita Zakaria and Assoc. Prof. Dr. Gurmeet for their valuable suggestions throughout this study.

Many thanks to Puan Fauziah Nordin of Veterinary Public Health Lab, Krishnama and all staff of Bacteriology Lab of the Faculty of Veterinary Medicine for their kind support, assistance and cooperation throughout my laboratory work. I am indeed very grateful to my lab mates Rasheed, Jalo, Teguh, Yousif, Wint Wint, Emelia and Abdelrahman for their friendly support and cooperation which I cherish a lot.

I am very thankful to my friends and house mates Usman, MD Usman, Abdulaziz Ibrahim, Adamu Yerima, Mustapha, Alhassan, Sadiq, Konto, Goje and many whom space would not permit me to mention. All have been good friends and supportive brothers.

My special gratitude and thanks go to my family, relatives and all well wishers for their prayers and support.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory committee were as follows:

Saleha Abdul Aziz, PhD
Professor
Faculty of Veterinary Medicine
Universiti Putra Malaysia
(Chairman)

Zunita Zakaria, PhD
Associate Professor
Faculty of Veterinary Medicine
Universiti Putra Malaysia
(Member)

Gurmeet Dhaliwal, PhD
Associate Professor
Faculty of Veterinary Medicine
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of graduate studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: _____

Name and Matric No.: _____

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

Signature: _____
Name of
Chairman of
Supervisory
Committee: _____

Signature: _____
Name of
Member of
Supervisory
Committee: _____

Signature: _____
Name of
Member of
Supervisory
Committee: _____

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ATCC	American Type Culture Collection
bp	Base pairs
CCUG	Culture Collection of the University of Goteborg
cueE	Siderophoreenterochelin
CLSI	Clinical Laboratory Standard Institute
^{0}C	Degree celcius
DNA	Deoxyribonucleic acid
EDTA	Ethylenediaminetetraacetic
flaA	Flagellin A gene
glyA	Serine hydroxyl methyl transferase gene
g	Gram(s)
h	Hour(s)
hip	Hippuricase gene
Kb	Kilobase
ml	Mililitre
mg	Milligram
mg	Milligram(s)
min	Minute(s)
MDR	Multidrug resistance
MIC	Minimum inhibitory concentration
MICE	Minimum Inhibitory Concentration Evaluator
mPCR	Multiplex Polymerase Chain Reaction
NaCl	Sodium chloride
NCCLS	National Committee for Clinical Laboratory Standards
PFGE	Pulsed Field Gel Electrophoresis
PBS	Phosphate buffered saline
PCR	Polymerase Chain Reaction
RNA	Ribonucleic acid

rRNA	Ribosomal RNA
s	Second(s)
Spp.	Species
TAE	Tris-acetate-EDTA
TBE	Tris-borate EDTA
UV	Ultraviolet
V	Volt
Taq	Thermophilus aquaticus
WHO	World Health Organization
µL	Micro liter
µg	Micro Gram
µM	Micro molar

CHAPTER 1

INTRODUCTION

Arcobacter is widely regarded as an emerging food-borne pathogen because of its relationship with food production and human health. *Arcobacter* was initially recognized as 'aerotolerant *Campylobacter'* belonging to the family *Campylobacteraceae*, genus *Campylobacter* due to its phenotypic and phylogenetic resemblance with *Campylobacter*. However, the ability to grow at 15^{o}C and its aerotolerance distinguishes it from *Campylobacter* (Vandamme and De Ley, 1991). From the discovery of *Arcobacter* in 1977 to date, various species have been identified and discovered in various animals which include domestic animals, pets, wild animals, birds and food products originating from domestic animals and may result in diseases such as mastitis, abortion and diarrhoea in animals (Collado and Figueras, 2011). Ten species have so far been identified of which seven are regarded as emerging food-borne pathogens namely: *A. butzleri, A. skirrowii, A. cryaerophilus, A. cibarius, A. mytili, A. thereius,* and *A. trophiarum. Arcobacter butzleri, A. skirrowii,* and *A. cryaerophilus* have been isolated from faecal samples of human beings and healthy farm animals (Driessche *et al*., 2005; Merga *et al*., 2011). However, the current identification and detection method of *Arcobacter* species is difficult and cumbersome thereby the incidence is most likely underestimated (Vandenberg *et al.*, 2004)

Arcobacter transmission is usually through the consumption of contaminated food and drinking water; infection can also occur through direct contact with infected animals and humans (Corry and Atabay, 2001). The organism is ubiquitous and can be found in sewage, surface water, sea water, ground water and drinking water which suggests their wider presence in the environment which can serve as an alternative means of exposure and transmission of infection to animals and humans (Fera *et al.*, 2009; Fera *et al.*, 2004; Moreno *et al.*, 2003). There are a substantial number of studies on the epidemiology of *Arcobacter* globally, but these are limited to livestock animals and not much has been done on their presence in dogs and cats in South East Asia in general and Malaysia in particular.

Campylobacter is the most widely reported bacterial agent that causes enteric disease in human beings across the world with millions of cases recorded yearly (WHO 2012). It is the most reported zoonotic enteric disease in Europe exceeding salmonellosis (Fosse *et al.*, 2007). There are about 37 species and sub species of *Campylobacter* which can be classified as thermophilic and non thermophilic *Campylobacter* based on their ability to grow at 42^{0}C and 37^{0}C (Weese, 2011). *Campylobacter* enteritis is a zoonosis of significant public health concern and it has indeed been shown to be a greater problem than *Salmonella* infection in some countries (Rosef *et al.*, 1983). The first human isolate of *Campylobacter* was from blood samples of patients suffering from diarrhoea in 1938. It was reported that there was difficulty isolating from faecal samples due to the fastidious nature of *Campylobacter* and contamination by the faecal flora (Kulkarni *et al.*, 2002). The pathogenic effect produced by *Campylobacter* in dogs is less common (Koene *et al.*,

2004). However, gastroenteritis caused by *Campylobacter* has been reported in healthy animals and they have been shown to carry the organisms (Baker *et al.,* 2008; Hald and Madsen, 1997).

Healthy dogs and cats have been shown to be carriers with the carriage rate as high as 50% for *C. upsaliensis* and *C. jejuni* as the most predominant species isolated. In human, *C. jejuni* is the most dominant species isolated followed by *C. coli* (Carbonero *et al.,* 2012b; Hald *et al.*, 2004; Jaime *et al.,* 2002).

The consumption of undercooked poultry, handling of raw poultry, drinking of untreated water, drinking unpasteurised milk or dairy products produced from non-thermo treated milk, and international travel are all considered to pose a risk to *Campylobacter* infection (Danis *et al.*, 2009). *Campylobacter* and *Arcobacter* infection in humans can be due to exposure and frequent contact with dogs and cats having diarrhea. This infection in man is reported to be due to pets ownership and has been identified and reported as a risk factor for its transmission to humans (Tenkate and Stafford, 2001). The increase in number of dogs and cats kept as pets may thus lead to the increase in *Campylobacter* and *Arcobacter* infection in human.

Campylobacteriosis is often self limiting in humans but is also associated with complications at the later stage of the infection such as Guillain-Barre Syndrome (neurological) and Reiter's Syndrome (reactive arthritis) (Yan *et al.*, 2005). *Arcobacter* infections in man are more frequently associated with persistent and watery diarrhoea and less associated with bloody diarrhoea (Vandenberg *et al.,* 2004).

The use of antibiotics in domestic animals has been widely reported to cause the development of antibiotic resistance. In pet animals, this problem is of public health significance due to close contact with human resulting in transmission of antibiotic resistant organisms.

A very limited study on *Arcobacter* has been carried out in Malaysia but none in dogs and cats. However the prevalence of *Arcobacter* in various sources ranging from chicken, beef, fresh raw dairy milk, and treated water in cattle farms have been reported in Malaysia (Shah *et al.*, 2012; Amare *et al.,* 2011;). Several studies on *Campylobacter* have been reported in chicken and other domestic animals but only one study in cats and dogs.

The hypotheses of this study were:

1. There is a low presence of *Campylobacter* and *Arcobacter* in dogs and cats.
2. The occurrence of antibiotic resistance in *Campylobacter and Arcobacter* isolated from dogs and cats is high.

Thus, the objectives of the study were:

1. To determine the prevalence of *Campylobacter* and *Arcobacter* in dogs and cats and associated risk factors
2. To determine the species of *Campylobacter* and *Arcobacter* isolates
3. To determine the antibiotic resistance of the isolates.

REFERENCES

Abdelbaqi, K., Buissonnière, A., Prouzet-Mauleon, V., Gresser, J., Wesley, I., Mégraud, F., & Ménard, A. (2007). Development of a real-time fluorescence resonance energy transfer PCR to detect *Arcobacter* species. *Journal of Clinical Microbiology, 45*(9), 3015-3021.

Abu-Halaweh, M., Bates, J., & Patel, B. K. (2005). Rapid detection and differentiation of pathogenic *Campylobacter jejuni* and *Campylobacter coli* by real-time PCR. *Research in Microbiology, 156*(1), 107-114.

Acke, E., McGill, K., Golden, O., Jones, B., Fanning, S., & Whyte, P. (2009). A comparison of different culture methods for the recovery of *Campylobacter* species from pets. *Zoonoses and Public Health, 56*(9-10), 490-495.

Adak, G., Cowden, J., Nicholas, S., & Evans, H. (1995). The Public Health Laboratory Service national case-control study of primary indigenous sporadic cases of *Campylobacter* infection. *Epidemiology and Infection, 115*(1), 15.

Adesiji, Y., & Oloke, J. (2009). Detection of *Arcobacters* from faeces of healthy pigs in Osogbo, south western Nigeria. *Tropical Veterinarian, 27*(1), 28-35.

Adkin, A., Hartnett, E., Jordan, L., Newell, D., & Davison, H. (2006). Use of a systematic review to assist the development of *Campylobacter* control strategies in broilers. *Journal of Applied Microbiology, 100*(2), 306-315.

Amare, L., Saleha, A., Zunita, Z., Jalila, A., & Hassan, L. (2011). Prevalence of *Arcobacter* spp. on chicken meat at retail markets and in farm chickens in Selangor, Malaysia. *Food Control, 22*(5), 732-736.

Angulo, F., Nargund, V., & Chiller, T. (2004). Evidence of an Association Between Use of Anti-microbial Agents in Food Animals and Anti-microbial Resistance Among Bacteria Isolated from Humans and the Human Health Consequences of Such Resistance. *Journal of Veterinary Medicine, Series B, 51*(8-9), 374-379.

Atabay, H., Corry, J., & On, S. L. (1998). Diversity and prevalence of *Arcobacter* spp. in broiler chickens. *Journal of Applied Microbiology, 84*(6), 1007-1016.

Aydin, F., Gümüşsoy, K., Atabay, H., Ica, T., & Abay, S. (2007). Prevalence and distribution of *Arcobacter* species in various sources in Turkey and molecular analysis of isolated strains by ERIC-PCR. *Journal of Applied Microbiology, 103*(1), 27-35.

Bailey, G. D., Vanselow, B. A., Hornitzky, M. A., Hum, S. I., Eamens, G. J., Gill, P. A., Cronin, J. P. (2003). A study of the foodborne pathogens: *Campylobacter*, *Listeria* and *Yersinia*, in faeces from slaughter-age cattle and sheep in Australia. *Communicable Diseases Intelligence, 27*(2), 249-256.

Baker, J., Barton, M. D., & Lanser, J. (1999). *Campylobacter* species in cats and dogs in South Australia. *Australian Veterinary Journal, 77*(10), 662-666.

Baker, J., Barton, M. D., & Lanser, J. (2008). *Campylobacter* species in cats and dogs in South Australia. *Australian Veterinary Journal, 77*(10), 662-666.

Beach, J. C., Murano, E. A., & Acuff, G. R. (2002). Prevalence of *Salmonella* and *Campylobacter* in beef cattle from transport to slaughter. *Journal of Food Protection, 65*(11), 1687-1693.

Bender, J. B., Shulman, S. A., Averbeck, G. A., Pantlin, G. C., & Stromberg, B. E. (2005). Epidemiologic features of *Campylobacter* infection among cats in the upper midwestern United States. *Journal of the American Veterinary Medical Association, 226*(4), 544-547.

Bessède, E., Delcamp, A., Sifré, E., Buissonnière, A., & Mégraud, F. (2011). New methods for detection of campylobacters in stool samples in comparison to culture. *Journal of Clinical Microbiology, 49*(3), 941-944.

Blaser, M. J., LaForce, F. M., Wilson, N. A., & Wang, W. L. L. (1980). Reservoirs for human campylobacteriosis. *Journal of Infectious Diseases, 141*(5), 665-669.

Blaser, M. J., Taylor, D. N., & Feldman, R. A. (1983). Epidemiology of *Campylobacter jejuni* infections. *Epidemiologic Reviews, 5*, 157-176.

Bourke, B., Chan, V. L., & Sherman, P. (1998). *Campylobacter upsaliensis*: waiting in the wings. *Clinical Microbiology Reviews, 11*(3), 440-449.

Brown, P., Christensen, O., Clough, H., Diggle, P., Hart, C., Hazel, S., Sutherst, J. (2004). Frequency and spatial distribution of environmental *Campylobacter* spp. *Applied and Environmental Microbiology, 70*(11), 6501-6511.

Bull, S., Allen, V., Domingue, G., Jørgensen, F., Frost, J., Ure, R., Gillard-King, J. (2006). Sources of *Campylobacter* spp. colonizing housed broiler flocks during rearing. *Applied and Environmental Microbiology, 72*(1), 645-652.

Bungay, A. A. C., Reyes, C. d., & Estacio, M. J. (2005). The Zoonotic Potential of Campylobacteriosis and Its Implication to Human Health. *Philippine Journal of Science, 134*(1), 69.

Butzler, J. P. (2004). *Campylobacter*, from obscurity to celebrity. *Clinical Microbiology and Infection, 10*(10), 868-876.

Byrd, J., Corrier, D., Hume, M., Bailey, R., Stanker, L., & Hargis, B. (1998). Incidence of *Campylobacter* in crops of preharvest market-age broiler chickens. *Poultry Science, 77*(9), 1303-1305.

Bywater, R. (2004). Veterinary use of antimicrobials and emergence of resistance in zoonotic and sentinel bacteria in the EU. *Journal of Veterinary Medicine, Series B, 51*(8-9), 361-363.

Campana, R., Patrone, V., Federici, S., Fulvi, S., & Baffone, W. (2010). Antibiotic resistance of *Campylobacter* spp isolated from chickens and humans in central italy. *Journal of Food Safety, 30*(4), 924-940.

Carbonero, A., Torralbo, A., Borge, C., García-Bocanegra, I., Arenas, A., & Perea, A. (2012a). *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*(6), 505-512.

Carbonero, A., Torralbo, A., Borge, C., García-Bocanegra, I., Arenas, A., & Perea, A. (2012b). *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*.

Clark, C. G., Price, L., Ahmed, R., Woodward, D. L., Melito, P. L., Rodgers, F. G., Ellis, A. (2003). Characterization of waterborne outbreak–associated *Campylobacter jejuni*, Walkerton, Ontario. *Emerging Infectious Diseases, 9*(10), 1232.

Coker, A. O., Isokpehi, R. D., Thomas, B. N., Amisu, K. O., & Obi, C. L. (2002). Human campylobacteriosis in developing countries. *Emerging Infectious Diseases, 8*(3), 237-244.

Collado, L., Cleenwerck, I., Van Trappen, S., De Vos, P., & Figueras, M. J. (2009). *Arcobacter mytili* sp. nov., an indoxyl acetate-hydrolysis-negative bacterium isolated from mussels. *International Journal of Systematic And Evolutionary Microbiology, 59*(6), 1391-1396.

Collado, L., & Figueras, M. J. (2011). Taxonomy, epidemiology, and clinical relevance of the genus Arcobacter. *Clinical Microbiology Reviews, 24*(1), 174-192.

Collado, L., Guarro, J., & Figueras, M. J. (2009). Prevalence of *Arcobacter* in meat and shellfish. *Journal of Food Protection, 72*(5), 1102-1106.

Corry, J., & Atabay, H. (2001). Poultry as a source of *Campylobacter* and related organisms. *Journal of Applied Microbiology, 90*(S6), 96S-114S.

Damborg, P., Olsen, K. E., Nielsen, E. M., & Guardabassi, L. (2004). Occurrence of *Campylobacter jejuni* in pets living with human patients infected with *C. jejuni*. *Journal of Clinical Microbiology, 42*(3), 1363-1364.

Danis, K., Di Renzi, M., O'Neill, W., Smyth, B., McKeown, P., Foley, B., Devine, M. (2009). Risk factors for sporadic *Campylobacter* infection: an all-Ireland case-control study. *European Surveillence, 14*(7).

Davies, J., & Davies, D. (2010). Origins and evolution of antibiotic resistance. *Microbiology and Molecular Biology Reviews, 74*(3), 417-433.

De Smet, S., De Zutter, L., Van Hende, J., & Houf, K. (2010). *Arcobacter* contamination on pre-and post-chilled bovine carcasses and in minced beef at retail. *Journal of Applied Microbiology, 108*(1), 299-305.

Dekeyser, P., Gossuin-Detrain, M., Butzler, J., & Sternon, J. (1972). Acute enteritis due to related vibrio: first positive stool cultures. *Journal of Infectious Diseases, 125*(4), 390-392.

Deming, M. S., Tauxe, R. V., Blake, P. A., Dixon, S. E., Fowler, B. S., Jones, T. S., Sikes, R. O. (1987). *Campylobacter* enteritis at a university: transmission from eating chicken and from cats. *American Journal of Epidemiology, 126*(3), 526-534.

Diergaardt, S., Venter, S., Spreeth, A., Theron, J., & Brözel, V. (2004). The occurrence of campylobacters in water sources in South Africa. *Water Research, 38*(10), 2589-2595.

Driessche, E. V., Houf, K., Vangroenweghe, F., Zutter, L. D., & Hoof, J. V. (2005). Prevalence, enumeration and strain variation of *Arcobacter* species in the faeces of healthy cattle in Belgium. *Veterinary Microbiology, 105*(2), 149-154.

El-Shibiny, A., Connerton, P., & Connerton, I. (2005). Enumeration and diversity of campylobacters and bacteriophages isolated during the rearing cycles of free-range and organic chickens. *Applied and Environmental Microbiology, 71*(3), 1259-1266.

Ellis, W., Neill, S., O'brien, J., Ferguson, H., & Hanna, J. (1977). Isolation of *Spirillum*/*Vibrio*-like organisms from bovine fetuses. *Veterinary Record, 100*(21), 451-452.

Engvall, E. O., Brändström, B., Andersson, L., Båverud, V., Trowald-Wigh, G., & Englund, L. (2003). Isolation and identification of thermophilic *Campylobacter* species in faecal samples from Swedish dogs. *Scandinavian Journal of Infectious Diseases, 35*(10), 713-718.

Fera, M., La Camera, E., Carbone, M., Malara, D., & Pennisi, M. (2009). Pet cats as carriers of Arcobacter spp. in Southern Italy. *Journal of Applied Microbiology, 106*(5), 1661-1666.

Fera, M., Maugeri, T., Giannone, M., Gugliandolo, C., La Camera, E., Blandino, G., & Carbone, M. (2003). In vitro susceptibility of *Arcobacter butzleri* and

Arcobacter cryaerophilus to different antimicrobial agents. *International Journal of Antimicrobial Agents, 21*(5), 488-491.

Fera, M., Maugeri, T., Gugliandolo, C., Beninati, C., Giannone, M., La Camera, E., & Carbone, M. (2004). Detection of *Arcobacter* spp. in the coastal environment of the Mediterranean Sea. *Applied and Environmental Microbiology, 70*(3), 1271-1276.

Fernández, H., Krause, S., & Paz Villanueva, M. (2004). *Arcobacter butzleri* an emerging enteropathogen: communication of two cases with chronic diarrhea. *Brazilian Journal of Microbiology, 35*(3), 216-218.

Fitzgerald, C., Whichard, J., Nachamkin, I., Szymanski, C., & Blaser, M. (2008). Diagnosis and antimicrobial susceptibility of *Campylobacter* species. *Campylobacter*(Ed. 3), 227-243.

Fleming, M. (1983). Association of *Campylobacter jejuni* with enteritis in dogs and cats. *Veterinary Record, 113*(16), 372-374.

Fluit, A., Van der Bruggen, J., Aarestrup, F., Verhoef, J., & Jansen, W. (2006). Priorities for antibiotic resistance surveillance in Europe. *Clinical Microbiology and Infection, 12*(5), 410-417.

Fosse, J., Seegers, H., & Magras, C. (2007). Foodborne zoonoses due to meat: a quantitative approach for a comparative risk assessment applied to pig slaughtering in Europe. *Veterinary Research, 39*(1), 1-1.

Fox, J. G., Hering, A. M., Ackerman, J. I., & Taylor, N. S. (1983). The pet hamster as a potential reservoir of human campylobacteriosis. *The Journal of Infectious Diseases, 147*(4), 784.

Friedman, C. R., Hoekstra, R. M., Samuel, M., Marcus, R., Bender, J., Shiferaw, B., Hardnett, F. (2004). Risk factors for sporadic *Campylobacter* infection in the United States: a case-control study in FoodNet sites. *Clinical Infectious Diseases, 38*(Supplement 3), S285-S296.

Fullerton, K. E., Ingram, L. A., Jones, T. F., Anderson, B. J., McCarthy, P. V., Hurd, S., Hayes, T. (2007). Sporadic *Campylobacter* infection in infants: a population-based surveillance case-control study. *The Pediatric Infectious Disease Journal, 26*(1), 19-24.

Gargiulo, A., Rinaldi, L., D'Angelo, L., Dipineto, L., Borrelli, L., Fioretti, A., & Menna, L. (2008). Survey of *Campylobacter jejuni* in stray cats in southern Italy. *Letters in Applied Microbiology, 46*(2), 267-270.

Gebhart, C., Ward, G., Chang, K., & Kurtz, H. (1983). *Campylobacter hyointestinalis* (new species) isolated from swine with lesions of proliferative ileitis. *American Journal of Veterinary Research, 44*(3), 361.

Gonzalez, I., Garcia, T., Antolin, A., Hernandez, P. E., & Martin, R. (2000). Development of a combined PCR-culture technique for the rapid detection of *Arcobacter* spp. in chicken meat. *Letters in Applied Microbiology*, *30*(3), 207-212.

Goossens, H., Vlaes, L., De Boeck, M., Levy, J., De Mol, P., Butzler, J.-P., Vandamme, P. (1990). Is "*Campylobacter upsaliensis*" an unrecognised cause of human diarrhoea? *The Lancet, 335*(8689), 584-586.

Gras, L. M., Smid, J. H., Wagenaar, J. A., de Boer, A. G., Havelaar, A. H., Friesema, I. H., van Pelt, W. (2012). Risk factors for campylobacteriosis of chicken, ruminant, and environmental origin: a combined case-control and source attribution analysis. *PLoS One, 7*(8), e42599.

Grau, F. (1988). *Campylobacter jejuni* and *Campylobacter hyointestinalis* in the intestinal tract and on the carcasses of calves and cattle. *Journal of Food Protection, 5(1).*

Guardabassi, L., & Kruse, H. (2003). Overlooked aspects concerning development and spread of antimicrobial resistance. *Expert Review of Anti-Infective Therapy, 1*(3), 359-362.

Guardabassi, L., Schwarz, S., & Lloyd, D. H. (2004). Pet animals as reservoirs of antimicrobial-resistant bacteria Review. *Journal of Antimicrobial Chemotherapy*, *54*(2), 321-332.

Gude, A., Hillman, T., Helps, C., Allen, V., & Corry, J. (2005). Ecology of *Arcobacter* species in chicken rearing and processing. *Letters in Applied Microbiology, 41*(1), 82-87.

Hakanen, A., Huovinen, P., Kotilainen, P., Siitonen, A., & Jousimies-Somer, H. (2002). Quality control strains used in susceptibility testing of *Campylobacter* spp. *Journal of Clinical Microbiology, 40*(7), 2705-2706.

Hald, B., & Madsen, M. (1997). Healthy puppies and kittens as carriers of *Campylobacter* spp., with special reference to *Campylobacter upsaliensis*. *Journal of Clinical Microbiology, 35*(12), 3351-3352.

Hald, B., Pedersen, K., Wainø, M., Jørgensen, 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*(5), 2003-2012.

Han, K., Jang, S. S., Choo, E., Heu, S., & Ryu, S. (2007). Prevalence, genetic diversity, and antibiotic resistance patterns of *Campylobacter jejuni* from retail raw chickens in Korea. *International Journal of Food Microbiology, 114*(1), 50-59.

Hänninen, M. L., Niskanen, M., & Korhonen, L. (1998). Water as a Reservoir for *Campylobacter jejuni* Infection in Cows Studied by Serotyping and Pulsed-field Gel Electrophoresis (PFGE). *Journal of Veterinary Medicine, Series B, 45*(1-10), 37-42.

Harmon, K. M., & Wesley, I. V. (1997). Multiplex PCR for the identification of *Arcobacter* and differentiation of *Arcobacter butzleri* from other Arcobacters. *Veterinary Microbiology, 58*(2), 215-227.

Harmon, K. M., & Wesley, I. V. (1996). Identification of *Arcobacter* isolates by PCR. *Letters in Applied Microbiology, 23*(4), 241-244.

Harvey, S., & Greenwood, J. (1985). Isolation of *Campylobacter fetus* from a pet turtle. *Journal of Clinical Microbiology, 21*(2), 260-261.

Hatch, J. J. (1996). Threats to public health from gulls (Laridae). *International Journal of Environmental Health Research, 6*(1), 5-16.

Hébert, G., Hollis, D., Weaver, R., Lambert, M., Blaser, M., & Moss, C. (1982). 30 years of campylobacters: biochemical characteristics and a biotyping proposal for *Campylobacter* jejuni. *Journal of Clinical Microbiology, 15*(6), 1065-1073.

Ho, H. T., Lipman, L. J., & Gaastra, W. (2006). *Arcobacter*, what is known and unknown about a potential foodborne zoonotic agent! *Vet Microbiol, 115*(1), 1-13.

Ho, T., Lipman, L. J., van der Graaf-van Bloois, L., van Bergen, M., & Gaastra, W. (2006). Potential routes of acquisition of *Arcobacter* species by piglets. *Veterinary Microbiology, 114*(1), 123-133.

Houf, K., De Smet, S., Baré, J., & Daminet, S. (2008). Dogs as carriers of the emerging pathogen *Arcobacter*. *Veterinary Microbiology, 130*(1), 208-213.

Houf, K., De Zutter, L., Verbeke, B., Van Hoof, J., & Vandamme, P. (2003). Molecular characterization of *Arcobacter* isolates collected in a poultry slaughterhouse. *Journal of Food Protection, 66*(3), 364-369.

Houf, K., Devriese, L. A., Haesebrouck, F., Vandenberg, O., Butzler, J.-P., Hoof, J. V., & Vandamme, P. (2004). Antimicrobial susceptibility patterns of *Arcobacter butzleri* and *Arcobacter cryaerophilus* strains isolated from humans and broilers. *Microbial Drug Resistance, 10*(3), 243-247.

Houf, K., Devriese, L. A., Van Hoof, J., & Vandamme, P. (2001). Susceptibility of *Arcobacter butzleri*, *Arcobacter cryaerophilus*, and *Arcobacter skirrowii* to antimicrobial agents used in selective media. *Journal of Clinical Microbiology, 39*(4), 1654-1656.

Houf, K., Tutenel, A., Zutter, L., Hoof, J., & Vandamme, P. (2000). Development of a multiplex PCR assay for the simultaneous detection and identification of

Arcobacter butzleri, Arcobacter cryaerophilus and *Arcobacter skirrowii*. *FEMS Microbiology Letters, 193*(1), 89-94.

Houf, K., On, S. L., Coenye, T., Debruyne, L., De Smet, S., & Vandamme, P. (2009). *Arcobacter thereius* sp. *nov*., isolated from pigs and ducks. *International Journal of Systematic and Evolutionary Microbiology, 59*(10), 2599-2604.

Houf, K., & Stephan, R. (2007). Isolation and characterization of the emerging foodborn pathogen *Arcobacter* from human stool. *Journal Microbiol Methods, 68*(2), 408-413.

Hurtado, A., & Owen, R. J. (1997). A molecular scheme based on 23S rRNA gene polymorphisms for rapid identification of *Campylobacter* and *Arcobacter* species. *Journal of Clinical Microbiology, 35*(9), 2401-2404.

Inglis, G. D., & Kalischuk, L. D. (2003). Use of PCR for direct detection of *Campylobacter* species in bovine feces. *Applied and Environmental Microbiology, 69*(6), 3435-3447.

Jacob, J., Woodward, D., Feuerpfeil, I., & Johnson, W. (1998). Isolation of *Arcobacter butzleri* in raw water and drinking water treatment plants in Germany. *Zentralblatt für Hygiene und Umweltmedizin International Journal of Hygiene and Environmental Medicine, 201*(2), 189.

Jaime, A. L., Joan, S., Lee, B., Nancy, S., Sydney, M. H., Eleanor, L., Laurene, M. (2002). *Campylobacter upsaliensis*: another pathogen for consideration in the United States. *Clinical Infectious Diseases, 34*(11), e59-e60.

Jiang, Z.-D., DuPont, H. L., Brown, E. L., Nandy, R. K., Ramamurthy, T., Sinha, A., Rodrigues, S. (2010). Microbial etiology of travelers' diarrhea in Mexico, Guatemala, and India: importance of enterotoxigenic Bacteroides fragilis and *Arcobacter* species. *Journal of Clinical Microbiology, 48*(4), 1417-1419.

Jones, F., Orcutt, M., & Little, R. B. (1931). Vibrios (Vibrio jejuni, n. sp.) associated with intestinal disorders of cows and calves. *The Journal of Experimental Medicine, 53*(6), 853-863.

Kabeya, H., Maruyama, S., Morita, Y., Ohsuga, T., Ozawa, S., Kobayashi, Y., Mikami, T. (2004). Prevalence of *Arcobacter* species in retail meats and antimicrobial susceptibility of the isolates in Japan. *International Journal of Food Microbiol, 90*(3), 303-308.

Kapperud, G., Espeland, G., Wahl, E., Walde, A., Herikstad, H., Gustavsen, S., Digranes, A. (2003). Factors associated with increased and decreased risk of *Campylobacter* infection: a prospective case-control study in Norway. *American Journal of Epidemiology, 158*(3), 234-242.

Kapperud, G., & Rosef, O. (1983). Avian wildlife reservoir of *Campylobacter fetus* subsp. *jejuni*, *Yersinia* spp., and *Salmonella* spp. in Norway. *Applied and Environmental Microbiology, 45*(2), 375-380.

Kayman, T., Abay, S., Hizlisoy, H., Atabay, H. İ., Diker, K. S., & Aydin, F. (2012). Emerging pathogen *Arcobacter* spp. in acute gastroenteritis: molecular identification, antibiotic susceptibilities and genotyping of the isolated arcobacters. *Journal of Medical Microbiology, 61*(Pt 10), 1439-1444.

Kiehlbauch, J., Brenner, D., Nicholson, M., Baker, C., Patton, C., Steigerwalt, A., & Wachsmuth, I. (1991). *Campylobacter butzleri* sp. nov. isolated from humans and animals with diarrheal illness. *Journal of Clinical Microbiology, 29*(2), 376-385.

Kim, H. M., Hwang, C. Y., & Cho, B. C. (2010). *Arcobacter marinus* sp. nov. *International Journal of Systematic and Evolutionary Microbiology, 60*(3), 531-536.

Koene, M., Houwers, D., Dijkstra, J., Duim, B., & Wagenaar, J. (2004). Simultaneous presence of multiple *Campylobacter* species in dogs. *Journal of Clinical Microbiology, 42*(2), 819-821.

Kroemer, S., Garch, F. E., Galland, D., Petit, J.-L., Woehrle, F., & Boulouis, H.-J. (2013). Antibiotic susceptibility of bacteria isolated from infections in cats and dogs throughout Europe (2002-2009). *Comparative Immunology, Microbiology and Infectious Diseases*, 167(5):2073-2081.

Kulkarni, S., Lever, S., Logan, J., Lawson, A., Stanley, J., & Shafi, M. (2002). Detection of *Campylobacter* species: a comparison of culture and polymerase chain reaction based methods. *Journal of Clinical Pathology, 55*(10), 749-753.

Kurincic, M., Berce, I., Zorman, T., & Mozina, S. S. (2005). The prevalence of multiple antibiotic resistance in *Campylobacter* spp. from retail poultry meat. *Food Technology and Biotechnology, 43*(2), 157-163.

Lehner, A., Tasara, T., & Stephan, R. (2005). Relevant aspects of *Arcobacter* spp as potential foodborne pathogen. *International Journal Food Microbiology, 102*(2), 127-135.

Levy, S. B. (1997). Antibiotic resistance: an ecological imbalance. *Antibiotic Resistance: Origins, Evolution, Selection and Spread, 207*, 1-14.

Linton, D., Owen, R., & Stanley, J. (1996). Rapid identification by PCR of the genus *Campylobacter* and of five *Campylobacter* species enteropathogenic for man and animals. *Research in Microbiology, 147*(9), 707-718.

Lior, H., Woodward, D., Edgar, J., Laroche, L., & Gill, P. (1982). Serotyping of *Campylobacter jejuni* by slide agglutination based on heat-labile antigenic factors. *Journal of Clinical Microbiology, 15*(5), 761-768.

Little, C., Richardson, J., Owen, R., De Pinna, E., & Threlfall, E. (2008). *Campylobacter* and *Salmonella* in raw red meats in the United Kingdom: Prevalence, characterization and antimicrobial resistance pattern, 2003–2005. *Food Microbiology, 25*(3), 538-543.

Lloyd, D. H. (2007). Reservoirs of antimicrobial resistance in pet animals. *Clinical Infectious Diseases, 45*(Supplement 2), S148-S152.

López, C. M., Giacoboni, G., Agostini, A., Cornero, F. J., Tellechea, D. M., & Trinidad, J. J. (2002). Thermotolerant *Campylobacters* in domestic animals in a defined population in Buenos Aires, Argentina. *Preventive Veterinary Medicine, 55*(3), 193-200.

Luangtongkum, T., Morishita, T. Y., El-Tayeb, A. B., Ison, A. J., & Zhang, Q. (2007). Comparison of antimicrobial susceptibility testing of *Campylobacter* spp. by the agar dilution and the agar disk diffusion methods. *Journal of Clinical Microbiology, 45*(2), 590-594.

M., La Camera, E., Carbone, M., Malara, D., & Pennisi, M. (2009). Pet cats as carriers of Arcobacter spp. in Southern Italy. *Journal of Applied Microbiology, 106*(5), 1661-1666.

Maćkiw, E., Korsak, D., Rzewuska, K., Tomczuk, K., & Rożynek, E. (2012). Antibiotic resistance in *Campylobacter jejuni* and *Campylobacter coli* isolated from food in Poland. *Food Control, 23*(2), 297-301.

Magiorakos, A. P., Srinivasan, A., Carey, R., Carmeli, Y., Falagas, M., Giske, C., Olsson-Liljequist, B. (2012). Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. *Clinical Microbiology and Infection, 18*(3), 268-281.

Maher, M., Finnegan, C., Collins, E., Ward, B., Carroll, C., & Cormican, M. (2003). Evaluation of culture methods and a DNA probe-based PCR assay for detection of *Campylobacter* species in clinical specimens of feces. *Journal of Clinical Microbiology, 41*(7), 2980-2986.

Man, S. M. (2011). The clinical importance of emerging *Campylobacter* species. *Nature Reviews Gastroenterology and Hepatology, 8*(12), 669-685.

Mandrell, R. E., Harden, L. A., Bates, A., Miller, W. G., Haddon, W. F., & Fagerquist, C. K. (2005). Speciation of *Campylobacter coli, C. jejuni, C. helveticus, C. lari, C. sputorum,* and *C. upsaliensis* by matrix-assisted laser desorption ionization-time of flight mass spectrometry. *Applied and Environmental Microbiology, 71*(10), 6292-6307.

Mannering, S., West, D., Fenwick, S., Marchant, R., & O'Connell, K. (2006). Pulsed-field gel electrophoresis of *Campylobacter jejuni* sheep abortion isolates. *Veterinary Microbiology, 115*(1), 237-242.

Manser, P., & Dalziel, R. (1985). A survey of *Campylobacter* in animals. *Epidemiology and Infection, 95*(1), 15-21.

Merga, J., Leatherbarrow, A., Winstanley, C., Bennett, M., Hart, C., Miller, W., & Williams, N. (2011). Comparison of *Arcobacter* Isolation Methods, and Diversity of *Arcobacter* spp. in Cheshire, United Kingdom. *Applied and Environmental Microbiology, 77*(5), 1646-1650.

Miflin, J. K., Templeton, J. M., & Blackall, P. (2007). Antibiotic resistance in *Campylobacter jejuni* and *Campylobacter coli* isolated from poultry in the South-East Queensland region. *Journal of Antimicrobial Chemotherapy, 59*(4), 775-778.

Miller, W. G., Wesley, I. V., On, S. L., Houf, K., Mégraud, F., Wang, G., Mason, C. J. (2009). First multi-locus sequence typing scheme for *Arcobacter* spp. *BMC Microbiology, 9*(1), 196.

Moore, J. E., Gilpin, D., Crothers, E., Canney, A., Kaneko, A., & Matsuda, M. (2002). Occurrence of *Campylobacter* spp. and *Cryptosporidium* spp. in seagulls (Larus spp.). *Vector Borne and Zoonotic Diseases, 2*(2), 111-114.

Moreno, Y., Botella, S., Alonso, J. L., Ferrús, M. A., Hernández, M., & Hernández, J. (2003). Specific detection of *Arcobacter* and *Campylobacter* strains in water and sewage by PCR and fluorescent in situ hybridization. *Applied and Environmental Microbiology, 69*(2), 1181-1186.

Morita, Y., Maruyama, S., Kabeya, H., Boonmar, S., Nimsuphan, B., Nagai, A., Kimura, H. (2004). Isolation and phylogenetic analysis of *Arcobacter* spp. in ground chicken meat and environmental water in Japan and Thailand. *Microbiology and Immunology, 48*(7), 527.

Moser, I., Rieksneuwöhner, B., Lentzsch, P., Schwerk, P., & Wieler, L. (2001). Genomic Heterogeneity and O-Antigenic Diversity of *Campylobacter upsaliensis* and *Campylobacter helveticus* Strains Isolated from Dogs and Cats in Germany. *Journal of Clinical Microbiology, 39*(7), 2548-2557.

Moyaert, H., Haesebrouck, F., Dewulf, J., Ducatelle, R., & Pasmans, F. (2009). *Helicobacter equorum* is highly prevalent in foals. *Veterinary Microbiology, 133*(1), 190-192.

Newell, D., & Fearnley, C. (2003). Sources of *Campylobacter* colonization in broiler chickens. *Applied and Environmental Microbiology, 69*(8), 4343-4351.

Nikaido, H. (2009). Multidrug resistance in bacteria. *Annual Review of Biochemistry, 78*, 119.

Olson, C. K., Ethelberg, S., Pelt, W. v., Tauxe, R. V., Nachamkin, I., Szymanski, C., & Blaser, M. (2008). Epidemiology of *Campylobacter jejuni* infections in industrialized nations. *Campylobacter*(Ed. 3), 163-189.

On, S. (1996). Identification methods for campylobacters, helicobacters, and related organisms. *Clinical Microbiology Reviews, 9*(3), 405-422.

Öngör, H., Cetinkaya, B., Acik, M., & Atabay, H. (2004). Investigation of arcobacters in meat and faecal samples of clinically healthy cattle in Turkey. *Letters in Applied Microbiology, 38*(4), 339-344.

Park, S. F. (2002). The physiology of *Campylobacter* species and its relevance to their role as foodborne pathogens. *International Journal Food Microbiology, 74*(3), 177-188.

Patyal, A., Rathore, R., Mohan, H., Dhama, K., & Kumar, A. (2011). Prevalence of *Arcobacter* spp. in humans, animals and foods of animal origin including sea food from India. *Transboundary and Emerging Diseases, 58*(5), 402-410.

Pearce, R., Wallace, F., Call, J., Dudley, R., Oser, A., Yoder, L., Luchansky, J. (2003). Prevalence of *Campylobacter* within a swine slaughter and processing facility. *Journal of Food Protection, 66*(9), 1550-1556.

Penner, J. (1988). The genus *Campylobacter*: a decade of progress. *Clinical Microbiology Reviews, 1*(2), 157-172.

Persson, S., & Olsen, K. E. P. (2005). Multiplex PCR for identification of *Campylobacter coli* and *Campylobacter jejuni* from pure cultures and directly on stool samples. *Journal of Medical Microbiology, 54*(11), 1043.

Petersen, R. F., Harrington, C. S., Kortegaard, H. E., & On, S. (2007). A PCR-DGGE method for detection and identification of *Campylobacter*, *Helicobacter*, *Arcobacter* and related *Epsilobacteria* and its application to saliva samples from humans and domestic pets. *Journal of Applied Microbiology, 103*(6), 2601-2615.

Phillips, C. (2001). *Arcobacter* spp in food: isolation, identification and control. *Trends in Food Science & Technology, 12*(8), 263-275.

Ramees, T. P., Rathore, R. S., Bagalkot, P. S., Mohan, H. V., Kumar, A., & Dhama, K. (2014). Detection of *Arcobacter butzleri* and *Arcobacter cryaerophilus* in Clinical Samples of Humans and Foods of Animal Origin by Cultural and Multiplex PCR Based Methods. *Asian Journal of Animal & Veterinary Advances, 9*(4).

Rivas, L., Fegan, N., & Vanderlinde, P. (2004). Isolation and characterisation of *Arcobacter butzleri* from meat. *International Journal Food Microbiology, 91*(1), 31-41.

Rosef, O., Gondrosen, B., Kapperud, G., & Underdal, B. (1983). Isolation and characterization of Campylobacter jejuni and Campylobacter coli from

domestic and wild mammals in Norway. *Applied and Environmental Microbiology, 46*(4), 855-859.

Russell, R. G., Blaser, M., Sarmiento, J., & Fox, J. (1989). Experimental Campylobacter jejuni infection in Macaca nemestrina. *Infection and Immunity, 57*(5), 1438-1444.

Russell, R. G., Kiehlbauch, J., Gebhart, C., & DeTolla, L. (1992). Uncommon *Campylobacter* species in infant Macaca nemestrina monkeys housed in a nursery. *Journal of Clinical Microbiology, 30*(11), 3024-3027.

Samie, A., Obi, C., Barrett, L., Powell, S., & Guerrant, R. (2007). Prevalence of *Campylobacter* species, *Helicobacter pylori* and *Arcobacter* species in stool samples from the Venda region, Limpopo, South Africa: Studies using molecular diagnostic methods. *Journal of Infection, 54*(6), 558-566.

Sandberg, M., Bergsjø, B., Hofshagen, M., Skjerve, E., & Kruse, H. (2002). Risk factors for *Campylobacter* infection in Norwegian cats and dogs. *Preventive Veterinary Medicine, 55*(4), 241-253.

Sanders, J., Isenbarger, D., Walz, S., Pang, L., Scott, D., Tamminga, C., Pitarangsi, C. (2002). An observational clinic-based study of diarrheal illness in deployed United States military personnel in Thailand: presentation and outcome of *Campylobacter* infection. *The American Journal of Tropical Medicine and Hygiene, 67*(5), 533-538.

Sandstedt, K., Ursing, J., & Walder, M. (1983). Thermotolerant *Campylobacter* with no or weak catalase activity isolated from dogs. *Current Microbiology, 8*(4), 209-213.

Sato, K., Bartlett, P., Kaneene, J., & Downes, F. (2004). Comparison of prevalence and antimicrobial susceptibilities of *Campylobacter* spp. isolates from organic and conventional dairy herds in Wisconsin. *Applied and Environmental Microbiology, 70*(3), 1442-1447.

Schroeder-Tucker, L., Wesley, I. V., Kiehlbauch, J. A., Larson, D. J., Thomas, L. A., & Erickson, G. A. (1996). Phenotypic and ribosomal RNA characterization of *Arcobacter* species isolated from porcine aborted fetuses. *Journal of Veterinary Diagnostic Investigation, 8*(2), 186-195.

Scullion, R., Harrington, C. S., & Madden, R. H. (2004). A comparison of three methods for the isolation of *Arcobacter* spp. from retail raw poultry in Northern Ireland. *Journal of Food Protection, 67*(4), 799-804.

Shah, A., Saleha, A., Zunita, Z., Cheah, Y., Murugaiyah, M., & Korejo, N. (2012). Genetic characterization of *Arcobacter* isolates from various sources. *Veterinary Microbiology, 160*(3), 355-361.

Shah, A., Saleha, A., Zunita, Z., & Murugaiyah, M. (2011). *Arcobacter*–An emerging threat to animals and animal origin food products? *Trends in Food Science & Technology, 22*(5), 225-236.

Shah, A., Saleha, A., Zunita, Z., Murugaiyah, M., Aliyu, A., & Jafri, N. (2013). Prevalence, distribution and antibiotic resistance of emergent *Arcobacter* spp. from clinically healthy cattle and goats. *Transboundary and Emerging Diseases, 60*(1), 9-16.

Shen, Z., Feng, Y., Dewhirst, F., & Fox, J. (2001). Coinfection of Enteric *Helicobacter* spp. and *Campylobacter* spp. in Cats. *Journal of Clinical Microbiology, 39*(6), 2166-2172.

Simpson, J., Burnie, A., Ferguson, S., & Brunton, W. A. T. (1981). Isolation of thermophilic campylobacters from two populations of dogs. *Veterinary Research Communications, 5*(1), 63-66.

Singh, H., Rathore, R., Singh, S., & Cheema, P. S. (2011). Comparative analysis of cultural isolation and PCR based assay for detection of *Campylobacter jejuni* in food and faecal samples. *Brazilian Journal of Microbiology, 42*(1), 181-186.

Skirrow, M. (1977). *Campylobacter* enteritis: a" new" disease. *British Medical Journal, 2*(6078), 9.

Skov, M., Spencer, A., Hald, B., Petersen, L., Nauerby, B., Carstensen, B., & Madsen, M. (2004). The role of litter beetles as potential reservoir for *Salmonella enterica* and thermophilic *Campylobacter* spp. between broiler flocks. *Avian Diseases, 48*(1), 9-18

Smith, T. (1919). The etiological relation of *Spirilla* (Vibrio fetus) to bovine abortion. *The Journal of Experimental Medicine, 30*(4), 313-323.

Snelling, W., Matsuda, M., Moore, J., & Dooley, J. (2006). Under the microscope: *Arcobacter*. *Letters in Applied Microbiology, 42*(1), 7-14.

Son, I. (2005). Prevalence, genetic diversity and antimicrobial resistance patterns of *Arcobacter* and *Campylobacter* on broiler carcasses during processing (Doctoral dissertation, University of Georgia).

Son, I., Englen, M. D., Berrang, M. E., Fedorka-Cray, P. J., & Harrison, M. A. (2007). Antimicrobial resistance of *Arcobacter* and *Campylobacter* from broiler carcasses. *International Journal of Antimicrobials Agents, 29*(4), 451-455.

Stern, N., Nachamkin, I., Blaser, M., & Tompkins, L. (1992). Reservoirs for *Campylobacter jejuni* and approaches for intervention in poultry. *American Society for Microbiology, Washington, DC(USA). 1992.*

Stirling, J., Griffith, M., Blair, I., Cormican, M., Dooley, J., Goldsmith, C., Matsuda, M. (2008). Prevalence of gastrointestinal bacterial pathogens in a population of zoo animals. *Zoonoses and Public Health, 55*(3), 166-172.

Stoyanchev, T. T. (2004). Detection of *Campylobacter* using standard culture and PCR of 16S rDNA gene in freshly chilled poultry and poultry products in a slaughterhouse. *Trakia Journal of Sciences, 2*(3), 59-64.

Tam, C., O'Brien, S., Adak, G., Meakins, S., & Frost, J. (2003). *Campylobacter coli*—an important foodborne pathogen. *Journal of Infection, 47*(1), 28-32.

Tauxe, R. V. (1997). Emerging foodborne diseases: an evolving public health challenge. *Emerging Infectious Diseases, 3*(4), 425.

Taylor, D. N., Kiehlbauch, J. A., Tee, W., Pitarangsi, C., & Echeverria, P. (1991). Isolation of group 2 aerotolerant *Campylobacter* species from Thai children with diarrhea. *Journal of Infectious Diseases, 163*(5), 1062-1067.

Teague, N. S., Srijan, A., Wongstitwilairoong, B., Poramathikul, K., Champathai, T., Ruksasiri, S., Mason, C. J. (2010). Enteric pathogen sampling of tourist restaurants in Bangkok, Thailand. *Journal of Travel Medicine, 17*(2), 118-123.

Tenkate, T., & Stafford, R. (2001). Risk factors for *Campylobacter* infection in infants and young children: a matched case-control study. *Epidemiology and Infection, 127*(03), 399-404.

Teuber, M. (1999). Spread of antibiotic resistance with food-borne pathogens. *Cellular and Molecular Life Sciences CMLS, 56*(9-10), 755-763.

Tillotson, G. S., & Theriault, N. (2013). New and alternative approaches to tackling antibiotic resistance. *F1000prime reports, 5*.

Tsai, H.-J., Huang, H.-C., Lin, C.-M., Lien, Y.-Y., & Chou, C.-H. (2007). *Salmonellae* and campylobacters in household and stray dogs in northern Taiwan. *Veterinary Research Communications, 31*(8), 931-939.

Umber, J. K., & Bender, J. B. (2009). Pets and antimicrobial resistance. *Veterinary Clinics of North America: Small Animal Practice, 39*(2), 279-292.

Ursing, J., Walder, M., & Sandstedt, K. (1983). Base composition and sequence homology of deoxyribonucleic acid of thermotolerant *Campylobacter* from human and animal sources. *Current Microbiology, 8*(5), 307-310.

Vandamme, P., & De Ley, J. (1991). Proposal for a new family, *Campylobacteraceae*. *International Journal of Systematic Bacteriology, 41*(3), 451-455.

Vandamme, P., Falsen, E., Rossau, R., Hoste, B., Segers, P., Tytgat, R., & De Ley, J. (1991). Revision of *Campylobacter*, *Helicobacter*, and *Wolinella* taxonomy: emendation of generic descriptions and proposal of *Arcobacter* gen. nov. *International Journal of Systematic Bacteriology, 41*(1), 88-103.

Van Dyke, M. I., Morton, V. K., McLellan, N. L., & Huck, P. M. (2010). The occurrence of *Campylobacter* in river water and waterfowl within a

watershed in southern Ontario, Canada. *Journal of Applied Microbiology, 109*(3), 1053-1066.

Vandamme, P., Giesendorf, B., Van Belkum, A., Pierard, D., Lauwers, S., Kersters, K., Quint, W. (1993). Discrimination of epidemic and sporadic isolates of *Arcobacter butzleri* by polymerase chain reaction-mediated DNA fingerprinting. *Journal of Clinical Microbiology, 31*(12), 3317-3319.

Vandamme, P., Pugina, P., Benzi, G., Van Etterijck, R., Vlaes, L., Kersters, K., Lauwers, S. (1992). Outbreak of recurrent abdominal cramps associated with *Arcobacter butzleri* in an Italian school. *Journal of Clinical Microbiology, 30*(9), 2335-2337.

Vandenberg, O., Dediste, A., Houf, K., Ibekwem, S., Souayah, H., Cadranel, S., Vandamme, P. (2004). *Arcobacter* species in humans. *Emerging Infectious Diseases, 10*(10), 1863.

Vandenberg, O., Houf, K., Douat, N., Vlaes, L., Retore, P., Butzler, J.-P., & Dediste, A. (2006). Antimicrobial susceptibility of clinical isolates of non-jejuni/coli campylobacters and arcobacters from Belgium. *Journal of Antimicrobial Chemotherapy, 57*(5), 908-913.

Waldenström, J., Broman, T., Carlsson, I., Hasselquist, D., Achterberg, R. P., Wagenaar, J. A., & Olsen, B. (2002). Prevalence of *Campylobacter jejuni*, *Campylobacter lari*, and *Campylobacter coli* in different ecological guilds and taxa of migrating birds. *Applied and Environmental Microbiology, 68*(12), 5911-5917.

Wang, G., Clark, C. G., Taylor, T. M., Pucknell, C., Barton, C., Price, L., Rodgers, F. G. (2002). Colony multiplex PCR assay for identification and differentiation of *Campylobacter jejuni, C. coli, C. lari, C. upsaliensis*, and *C. fetus* subsp. *fetus*. *Journal of Clinical Microbiology, 40*(12), 4744-4747.

Weese, J. S. (2008). Antimicrobial resistance in companion animals. *Anim Health Resistant Review, 9*(2), 169-176.

Weese, J. S. (2011). Bacterial enteritis in dogs and cats: diagnosis, therapy, and zoonotic potential. *The Veterinary Clinics of North America. Small Animal Practice, 41*(2), 287.

Wesley, I., Schroeder-Tucker, L., Baetz, A., Dewhirst, F., & Paster, B. (1995). *Arcobacter*-specific and *Arcobacter butzleri*-specific 16S rRNA-based DNA probes. *Journal of Clinical Microbiology, 33*(7), 1691-1698.

Wieland, B., Regula, G., Danuser, J., Wittwer, M., Burnens, A., Wassenaar, T., & Stärk, K. (2005). *Campylobacter* spp. in dogs and cats in Switzerland: risk factor analysis and molecular characterization with AFLP. *Journal of Veterinary Medicine, Series B, 52*(4), 183-189.

Wilson, D. J., Gabriel, E., Leatherbarrow, A. J., Cheesbrough, J., Gee, S., Bolton, E., Diggle, P. J. (2008). Tracing the source of campylobacteriosis. *PLoS Genetics, 4*(9), e1000203.

Yamazaki-Matsune, W., Taguchi, M., Seto, K., Kawahara, R., Kawatsu, K., Kumeda, Y., Tsukamoto, T. (2007). Development of a multiplex PCR assay for identification of *Campylobacter coli*, *Campylobacter fetus*, *Campylobacter hyointestinalis* subsp. *hyointestinalis*, *Campylobacter jejuni*, *Campylobacter lari* and *Campylobacter upsaliensis*. *Journal of Medical Microbiology, 56*(11), 1467-1473.

Yan, S. S., Pendrak, M. L., Foley, S. L., & Powers, J. H. (2005). *Campylobacter* infection and Guillain–Barré syndrome: public health concerns from a microbial food safety perspective. *Clinical and Applied Immunology Reviews, 5*(5), 285-305.

Yildirim, M., & Ersin, I. (2005). Comparison of disc diffusion and E test® for in vitro antimicrobial susceptibility testing of *Campylobacter jejuni* and *Campylobacter coli* isolated from poultry development, *17*, 18.