การปรากฏและรูปแบบความไวรับต่อสารต้านจุลชีพของเชื้อแคมไพโลแบคเตอร์และเชื้ออาร์โคแบคเตอร์ที่แยกได้จากเนื้อสัตว์ที่จำหน่ายในซุปเปอร์มาร์เก็ตในกรุงเทพมหานคร

นางสาวณัฐพร เตชวาล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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OCCURRENCE AND ANTIMICROBIAL SUSCEPTIBILITY PATTERNS OF *CAMPYLOBACTER* AND *ARCOBACTER* ISOLATED FROM RAW MEAT IN SUPERMARKETS IN BANGKOK

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ณัฐพร เตชวาล : การปรากฏและรูปแบบความไวรับต่อสารต้านจุลชีพของเชื้อแคมไพโลแบคเตอร์และเชื้ออาร์โคแบคเตอร์ที่แยกได้จากเนื้อสัตว์ที่จำหน่ายในซุปเปอร์มาร์เก็ตในกรุงเทพมหานคร (OCCURRENCE AND ANTIMICROBIAL SUSCEPTIBILITY PATTERNS OF *CAMPYLOBACTER* AND *ARCOBACTER* ISOLATED FROM RAW MEAT IN SUPERMARKETS IN BANGKOK) อ. ที่ปรึกษาวิทยานิพนธ์หลัก: ธราดล เหลืองทองคำ, 91 หน้า.

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อตรวจหาการปรากฏ และรูปแบบความไวรับต่อสารต้านจุลชีพของแคมไพโลแบคเตอร์และอาร์โคแบคเตอร์ที่แยกได้จากเนื้อสัตว์ที่จำหน่ายในซุปเปอร์มาร์เก็ตในกรุงเทพมหานคร โดยทำการเก็บตัวอย่างเนื้อสัตว์จำนวน 352 ตัวอย่าง ซึ่งประกอบด้วยตัวอย่างเนื้อไก่ (104 ตัวอย่าง) เนื้อสุกร (104 ตัวอย่าง) เนื้อวัว (104 ตัวอย่าง) และเนื้อเป็ด (40 ตัวอย่าง) จากสาขาย่อยของซุปเปอร์มาร์เก็ตทั้งหมดจำนวน 52 สาขา ในระหว่างเดือนมิถุนายนถึงเดือนตุลาคม พ.ศ. 2556 และนำตัวอย่างเนื้อสัตว์มาเพาะแยกแคมไพโลแบคเตอร์ด้วยวิธี semiquantitative และเพาะแยกอาร์โคแบคเตอร์ด้วยวิธี membrane filtration จากนั้นแคมไพโลแบคเตอร์และอาร์โคแบคเตอร์ที่เพาะแยกได้จำนวน 375 เชื้อ จะนำมาทดสอบความไวรับต่อสารต้านจุลชีพ 5 ชนิด ผลการศึกษาพบว่ามีการปนเปื้อนของแคมไพโลแบคเตอร์เป็นจำนวนมากในเนื้อเป็ด (95.0%) และเนื้อไก่ (83.7%) ขณะที่ในเนื้อสุกร (9.6%)และเนื้อวัว (1.0%) มีการปนเปื้อนของแคมไพโลแบคเตอร์ในระดับต่ำ สำหรับอาร์โคแบคเตอร์ พบว่า มากกว่าร้อยละ 90.0 ของเนื้อเป็ดและเนื้อไก่ที่จำหน่ายในเขตกรุงเทพมหานคร ร้อยละ 68.0 ของเนื้อสุกร และร้อยละ 35.6 ของเนื้อวัว มีการปนเปื้อนของเชื้อนี้ ตัวอย่างเนื้อสัตว์ที่ให้ผลบวกกับแคมไพโลแบคเตอร์ส่วนใหญ่มีปริมาณเชื้อปนเปื้อนอยู่ในระดับต่ำ (2.3 MPN/g) ผลการทดสอบความไวรับต่อสารต้านจุลชีพในการศึกษาครั้งนี้ พบว่า แคมไพโลแบคเตอร์ส่วนใหญ่ดื้อต่อ ciprofloxacin (74.0%) รองลงมาได้แก่ การดื้อต่อ nalidixic acid (67.9%) tetracycline (58.0%) erythromycin (6.9%) และ gentamicin (2.3%) สำหรับอาร์โคแบคเตอร์ พบว่าอาร์โคแบคเตอร์ส่วนใหญ่มีการดื้อต่อ nalidixic acid (60.9%) เพียงชนิดเดียว ผลการศึกษาครั้งนี้สามารถสรุปได้ว่า เนื้อสัตว์ค้าปลีก โดยเฉพาะเนื้อสัตว์ปีกที่จำหน่ายในซุปเปอร์มาร์เก็ตในกรุงเทพมหานครมีการปนเปื้อนของแคมไพโลแบคเตอร์และอาร์โคแบคเตอร์ค่อนข้างมาก และรูปแบบการดื้อยาของแคมไพโลแบคเตอร์มีความหลากหลายกว่ารูปแบบการดื้อยาของอาร์โคแบคเตอร์ การศึกษาครั้งนี้แสดงให้เห็นว่ามาตรการด้านสุขอนามัยตลอดกระบวนการผลิตอาหาร รวมทั้งมาตรการในการเฝ้าระวังการดื้อยาอย่างต่อเนื่องเป็นสิ่งจำเป็น ทั้งนี้เพื่อช่วยส่งเสริมการควบคุมและป้องกันการดื้อยาในเชื้อแบคทีเรียก่อโรค ซึ่งสามารถถ่ายทอดผ่านกระบวนการผลิตอาหารมาสู่มนุษย์ได้

ภาควิชา สัตวแพทยสาธารณสุข ลายมือชื่อนิสิต .....

สาขาวิชา สัตวแพทยสาธารณสุข ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

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NATTHAPORN TECHAWAL: OCCURRENCE AND ANTIMICROBIAL SUSCEPTIBILITY PATTERNS OF *CAMPYLOBACTER* AND *ARCOBACTER* ISOLATED FROM RAW MEAT IN SUPERMARKETS IN BANGKOK. ADVISOR: TARADON LUANGTONGKUM, D.V.M., Ph.D., 91 pp.

The objective of the present study was to determine the occurrence and antimicrobial susceptibility patterns of *Campylobacter* and *Arcobacter* from raw meat in supermarkets in Bangkok. A total of 352 meat samples from chicken (n=104), pork (n=104), beef (n=104) and duck (n=40) were randomly collected from 52 retail stores during June to October 2013. The semiquantitative method and membrane filtration method were used for *Campylobacter* and *Arcobacter* isolation, respectively. In addition, antimicrobial susceptibilities of 375 *Campylobacter* and *Arcobacter* isolates to 5 antimicrobials were examined. Our findings showed that the vast majority of duck meat (95.0%) and chicken meat (83.7%) was contaminated with *Campylobacter*, while the low contamination rates were found in pork (9.6%) and beef (1.0%). For *Arcobacter*, more than 90.0% of duck and chicken meat, 68.0% of pork and 35.6% of beef samples sold in Bangkok were positive for *Arcobacter*. Most *Campylobacter* positive samples had low level of contamination (2.3 MPN/g). The most common resistance observed among *Campylobacter* isolates was ciprofloxacin (74.0%), followed by nalidixic acid (67.9%), tetracycline (58.0%), erythromycin (6.9%) and gentamicin (2.3%). For *Arcobacter*, the majority of isolates only exhibited high resistance to nalidixic acid (60.9%). In conclusion, this study reveals that retail meat, especially poultry meat, sold in supermarkets in Bangkok was frequently contaminated with *Campylobacter* and *Arcobacter*. The antimicrobial resistance patterns of *Campylobacter* isolates in our study were more diverse than those of *Arcobacter* isolates. Our results highlight the need for improved hygienic measures along food processing and continuous antimicrobial resistance monitoring program to support control and prevention of antimicrobial resistance in pathogenic bacteria that can be transmitted to humans via food chain.

Department: Veterinary Public Health Student's Signature .....
Field of Study: Veterinary Public Health Advisor's Signature .....
Academic Year: 2014

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LIST OF ABBREVIATIONS

A.	*Arcobacter*
bp	base pair(s)
ºC	degree (s) Celsius
C.	*Campylobacter*
CAT	cefoperazone-amphotericin B-teicoplanin
CFU	colony-forming unit
CIP	ciprofloxacin
CLSI	The Clinical and Laboratory Standards Institute
DNA	deoxyribonucleic acid(s)
dNTP	deoxyribonucleoside triphosphate(s)
ECOFF	Epidemiological cut off value(s)
EFSA	European Food Safety Authority
ERY	erythromycin
et al.	et alibi and others
GEN	gentamicin
h	hour(s)
mCCDA	modified Charcoal Cefoperazone Deoxycholate Agar

MDR	multidrug resistance
MHA	Muller Hinton agar
MIC	Minimum Inhibitory Concentration
min	minute(s)
ml	milliliter(s)
mM	milimolar(s)
MPN	Most Probable Number
NAL	nalidixic acid
NARMS	The National Antimicrobial Resistance Monitoring System
PCR	polymerase chain reaction
rpm	round per minute
spp.	species
TET	tetracycline
U	unit
µl	micro liter(s)
v/v	volume per volume
w/v	weight per volume

CHAPTER I
INTRODUCTION

Campylobacter is one of the leading causes of foodborne disease in humans worldwide. In 2012, a total of 214,268 confirmed cases were reported in Europe (EFSA, 2014[a]). *C. jejuni* and *C. coli* are the two major *Campylobacter* species associated with human gastroenteritis. Clinical symptoms of campylobacteriosis include bloody diarrhea, abdominal pain, nausea and vomiting. In addition to gastroenteritis, *Campylobacter* infection can trigger an acute immune-mediated polyneuropathy known as Guillain-Barré Syndrome (Nachamkin et al., 1998). Recently, *Arcobacter* is classified as an emerging foodborne pathogen by the International Commission on Microbiological Specifications for Foods (ICMSF, 2002). Among *Arcobacter* species, *A. butzleri*, *A. cryaerophilus* and *A. skirrowii* have been associated with diarrhea in humans (Samie et al., 2007). Unlike symptoms of foodborne campylobacteriosis, *Arcobacter* infection causes persistent watery diarrhea (Vandenberg et al., 2004). Although most cases of *Campylobacter* and *Arcobacter* infection are self-limiting, cases with severe symptoms can occur and usually require antibiotic treatment. Fluoroquinolones, one of the most common antimicrobials prescribed for treatment of bacterial gastroenteritis, have been recommended for the treatment of *Campylobacter* and *Arcobacter* infection.

Both *Campylobacter* and *Arcobacter* have been isolated from various foods of animal origin such as chicken, pork, beef, lamb, milk and seafood. Many studies have shown that retail meat was frequently contaminated with *Campylobacter* and *Arcobacter* (Whyte et al., 2004; Shah et al., 2011). Moreover, *Campylobacter* and

Arcobacter recovered from retail meat were found to be highly resistant to several antimicrobial agents (Son et al., 2007; Zhao et al., 2010; Ruzauskas et al., 2011). According to the European Food Safety Authority report (2014[a]), around 83.0% of *Campylobacter* isolated from poultry meat were resistant to ciprofloxacin. Moreover, the high prevalence of tetracycline resistance (57.3%) was also observed in *Campylobacter* from retail meat (EFSA, 2014[a]). The presence of antimicrobial-resistant organisms in retail meat is becoming a public health concern as these resistant organisms may be transmitted to humans through the food chain and cause disease which may result in treatment failure or prolong duration of illness in humans (CDC, 2014[a]).

In Thailand, the information on the occurrence and antimicrobial resistance of *Campylobacter* and *Arcobacter* is rather limited. Although *Campylobacter* and *Arcobacte*r contamination in retail poultry meat was reported in previous studies (Meeyam et al., 2004; Morita et al., 2004), the occurrence of these organisms in other meat types is not available. It is well known that the presence of *Campylobacter* in retail meat poses a great risk to consumers. To ensure the safety of meat products, it is necessary to monitor the contamination of foodborne pathogens including *Campylobacter* along the food chain. In addition to foodborne diseases, increasing resistance to antimicrobial agents among foodborne organisms is also a concern. During 1998-2003, approximately 93.0% and 82.0% of *C. jejuni* isolates from human cases in Thailand were resistant to ciprofloxacin and tetracycline, respectively (Serichantalergs et al., 2010). In addition, the high proportion of ciprofloxacin- and tetracycline-resistant *Campylobacter* in retail meat was also reported (Sukhapesna et al., 2005; Padungtod et al., 2006; Bodhidatta et al., 2013; Chokboonmongkol et al., 2013). Monitoring the

prevalence of *Campylobacter* and *Arcobacte*r contamination in retail meat and their susceptibility patterns will give a better understanding of the current situation of these organisms.

Therefore, the objectives of the present study were to examine the occurrence of *Campylobacter* and *Arcobacter* in raw retail meat and to determine their susceptibility patterns. The information obtained from this study will increase consumer's awareness of *Campylobacter* and *Arcobacter* contamination in various meat types sold in Bangkok. In addition, the result of antibiotic susceptibility patterns can be used as supporting information for appropriate selection of antimicrobial agents for treatment of *Campylobacter* and *Arcobacter* infection in humans.

CHAPTER II

LITERATURE REVIEW

2.1 General characteristics of *Campylobacter* and *Arcobacter*

2.1.1 General characteristics of *Campylobacter*

Campylobacter is a gram negative, motile, spiral rod shaped bacterium which belongs to the family *Campylobacteraceae*. Presently, the genus *Campylobacter* is comprised of 25 species and 8 subspecies (Man, 2011). It grows well in microaerobic condition consisting of approximately 10.0% carbon dioxide and 5.0% oxygen (Humphrey et al., 2007). The temperature for *Campylobacter* growth is between 30 and 46°C with the optimum growth temperature at 42°C. These organisms are classified as thermophilic *Campylobacter* (Humphrey et al., 2007). *Campylobacter* is sensitive to several environmental conditions such as freezing, heating, salinity and low water activity (Silva et al., 2011). *Campylobacter* colonies are usually present as grey, flat, spreading with an irregular edge after 18 to 24 h of incubation (Skirrow and Benjamin, 1980; Nachamkin et al., 2000). *Campylobacter* species have been isolated from mammals, birds, reptiles, shellfish and humans (Man, 2011). Most of thermophilic *Campylobacter* are recognized as zoonotic pathogen (Debruyne et al., 2008). Among thermophilic *Campylobacter* species, *C. jejuni* and *C. coli* are the most common causes of human gastroenteritis in developed countries (Moore et al., 2002).

2.1.2 General characteristics of *Arcobacter*

Arcobacter belongs to the family *Campylobacteraceae*. This organism is a gram-negative, curved rod shaped bacterium that exhibits corkscrew-like motility by a single polar flagellum (Vandamme et al., 1991; Saleem et al., 2011). *Arcobacter* ranges in size from approximately 0.2–0.9 μm wide and 1–3 μm long. This organism can grow at 15-37°C under aerobic and anaerobic conditions, with an optimal growth temperature at 30°C (Vandamme et al., 1991). Presumptive *Arcobacter* colonies are present as grey or clear-white pinpoint colonies (Aydin et al., 2007). The ability to grow at 15°C under aerobic conditions is used to differentiate *Arcobacter* from *Campylobacter* (Vandamme and De Ley, 1991). *Arcobacter* has been isolated from foods of animal origin, water and processing plants (Gude et al., 2005; Van Driessche et al., 2005; Ho et al., 2006; Collado and Figueras, 2011). At present, the genus *Arcobacter* consists of 18 species (Levican and Figueras, 2013). Three *Arcobacter* species including *A. butzleri*, *A. cryaerophilus* and *A. skirrowii* are pathogenic to humans and animals (Vandenberg et al., 2004; Fera et al., 2008).

2.2 *Campylobacter* and *Arcobacter* infection in humans

2.2.1 *Campylobacter* infection in humans

Campylobacter is recognized as an important foodborne pathogen causing bacterial gastroenteritis in human worldwide (Pearson and Healing, 1992). Currently, cases of foodborne campylobacteriosis are increasing in many countries. In 2013, Centers for Disease Control and Prevention (CDC) reported that *Campylobacter* is the second most frequent foodborne pathogen reported in the Foodborne Diseases Active

Surveillance Network (CDC, 2014[a]). The incidence of *Campylobacter* gastroenteritis in the US was 13.82 cases per 100,000 population (CDC, 2014[b]). In addition, *Campylobacter* has been the most common cause of zoonotic disease in the European Union (EU) (EFSA, 2014[b]). The incidence of *Campylobacter* in the EU was 55.49 cases per 100,000 population (EFSA, 2014[b]). A majority of campylobacteriosis in humans is caused by *C. jejuni* (approximately 90.0%), and the remaining of cases are caused by *C. coli* (Janssen et al., 2008). Although *C. jejuni* and *C. coli* are important pathogens causing human gastroenteritis, other *Campylobacter* species such as *C. lari*, *C. upsaliensis* and *C. concisus* have also been associated with human infection (Labarca et al., 2002; Vandenberg et al., 2006). Clinical symptoms of campylobacteriosis include diarrhea (frequently bloody diarrhea), abdominal pain, nausea and vomiting. Most *Campylobacter* infections are usually self-limiting and do not require antimicrobial therapy (Nobile et al., 2013). However, post-infectious complications such as Guillain-Barré, an auto-immune peripheral neuropathy which can lead to ascending paralysis and Miller Fisher syndromes, an uncommon variant of GBS associated with ataxia and ophthalmoplegia, may also occur (Salloway et al., 1996; Nachamkin et al., 1998; Moore et al., 2005). Consumption of contaminated meat products, milk and water or contact with pets or farm animals is regarded as important route of *Campylobacter* infection in human (Humphrey et al., 2007). Person to person transmission is uncommon, but may occur via direct or indirect contact with feces of patients with diarrhea (Schmid et al., 1987).

2.2.2 *Arcobacter* infection in humans

At present, *Arcobacter* has received increasing attention as one of the leading causes of human gastroenteritis. *Arcobacter* has been isolated from stool samples of asymptomatic patients and diarrheic patients in many countries (Vandamme et al., 1991; Vandenberg et al., 2004; Samie et al., 2007; Jiang et al., 2010). Among *Arcobacter* species, *A. butzleri* is the predominant species associated with enteritis and bacteremia in humans (Vandenberg et al., 2004). In addition, *A. cryaerophilus* and *A. skirrowii* could be detected in stool samples of patients as well (Wybo et al., 2004; Samie et al., 2007). In 1983, the first *Arcobacter*-related outbreak was discovered in an Italian nursery and primary school where ten children showed abdominal cramp without diarrhea. Causative agents were classified as *A. butzleri* (Bhunia, 2008). An eight-year study of Vandenberg et al. (2004) demonstrated that *A. butzleri* was the fourth most frequent *Campylobacter*-like organisms isolated from stool samples of patients. Furthermore, *A. cryaerophilus* has also been detected in stool samples of diarrheic patients as well as blood samples of infants with bacteremia (On et al., 1995; Lau et al., 2002). Apart from clinical cases, *A. cryaerophilus* was isolated from 1.4% of healthy people who work at slaughterhouses in Switzerland (Houf and Stephan, 2007) as well as 3.0% of asymptomatic people in South Africa (Samie et al., 2007). However, the number of *Arcobacter* infection in humans is likely underestimated due to the lack of standard protocol for *Arcobacter* isolation and identification (Vandenberg et al., 2004; Snelling et al., 2006; Figueras et al., 2008). Clinical symptoms of *Arcobacter* infection include persistent watery diarrhea with abdominal pain and stomach cramps (Vandamme et al., 1992a; Lerner et al., 1994). Presently, the role of *Arcobacter* in human disease is still unclear. The route of *Arcobacter* transmission to humans seems to occur via

consumption of contaminated food or water (Vandamme et al., 1992; Collado et al., 2009) and contact with pets (Houf et al., 2008).

2.3. *Campylobacter* and *Arcobacter* in animals and foods of animal origin

2.3.1 *Campylobacter* in animals and foods of animal origin

Poultry are natural reservoirs and regarded as a major source of *Campylobacter* infection in humans. In addition to poultry, *Campylobacter* can also be isolated from swine, cattle and sheep. Animals can be infected with *Campylobacter* asymptomatically or symptomatically. *Campylobacter* can cause enteritis and abortion in pets and farm animals (Humphrey et al., 2007). Among thermophilic *Campylobacter*, *C. jejuni* is the most prevalent species recovered from poultry and cattle, while *C. coli* is the most common species found in swine (Thakur and Gebreyes, 2005). The prevalence of *Campylobacter* in broilers, swine and cattle varied widely among studies ranging from 2.9% – 100.0% in broilers, 50.0%-69.0% in pigs and 42.0%-83.0% in cattle (Humphrey et al., 2007). In retail meat, poultry meat is generally more contaminated with *Campylobacter* than red meat (Zhao et al., 2001; Whyte et al., 2004). The prevalence of *Campylobacter* in poultry meat was relatively high, with an average prevalence of 63.8% in North America , 83.2% in Middle and south America, 53.3% in Europe, 60.3% in Asia, 90.4% in Oceania and 73.1% in Africa (Suzuki and Yamamoto, 2009). Contamination rates of *Campylobacter* in pork varied widely from 2.0% to 100.0% (Svedhem et al., 1981; Whyte et al., 2004; Wong et al., 2007), while the lower prevalence of *Campylobacter* usually less than 20.0% was observed in beef (Bohaychuk et al., 2006; Wong et al., 2007; Rahimi et al., 2010).

2.3.2 *Arcobacter* in animals and foods of animal origins

Four *Arcobacter* species including *A. butzleri*, *A. cryaerophilus*, *A. skirrowii* and *A. thereius* have been associated with enteritis, mastitis and abortion in livestock animals (vandamme et al., 1992b; Ho et al., 2006). *Arcobacter* has been recovered from aborted porcine and bovine fetuses (Ellis et al., 1977; Higgins and Degre, 1979; de Oliveira et al., 1997) as well as from placenta and oviductal tissue of sows with reproductive disorders (Schroeder-Tucker et al., 1996; de Oliveira et al., 1997). Among *Arcobacter* species, *A. cryaerophilus* was the predominant species causing abortion in farm animals. Apart from reproductive disorders, *A. butzleri* has been recovered from feces of pigs, cattle, horses with diarrhea, while *A. skirrowii* has been recovered from hemorrhagic colitis of sheep and cattle (Collado and Figueras, 2011). Although *Arcobacter* can cause disease in animals, it was also detected in feces of healthy animals (van Driessche et al., 2003). Transmission route of *Arcobacter* to humans seems to occur via consumption of undercooked or contaminated meat products. *Arcobacter* contamination in foods of animal origin has been reported in many countries. It was well documented that *Arcobacter* was more frequently detected in poultry meat than red meat (Kabeya et al., 2004; Rivas et al., 2004). The prevalence of *Arcobacter* in retail chicken meat varied widely among studies, ranging from below 15.0% to 100.0%, with an average prevalence at 60.0% or more (Morita et al., 2004; Rivas et al., 2004; Scullion et al., 2006; Mohan et al., 2014; Rahimi, 2014). Other than chicken meat, contaminated pork (7.0%-61.0%), beef (1.3%-38.0%), mutton (15.0%), turkey (4.0%-33.3%), duck (11.4%-40.0%) and milk (3.2%-46.0%) were also reported (Aydin et al., 2007; Collado et al., 2009; Shah et al., 2011; Bodhidatta et al., 2013; Rahimi, 2014). Among *Arcobacter*

species, *A. butzleri* was the most common species isolated from meat samples, followed by *A. cryaerophilus* and *A. skirrowii* (Lehner et al., 2005).

2.4 Detection of *Campylobacter* and *Arcobacter*

2.4.1 Detection of *Campylobacter*

Several methods have been developed for isolation of *Campylobacter* from environmental, food and stool samples. Direct plating on selective agar is commonly used for detection of *Campylobacter* from stool samples, which contain a large number of viable *Campylobacter* cells (Altekruse et al., 1999; Jacobs-Reitsma et al., 2008). On the other hand, pre-enrichment procedure is recommended for isolation of *Campylobacter* from food and environmental samples that contain low numbers of organisms (Richardson et al., 2009; Williams et al., 2009). Using enrichment broth before plating on selective agar was found to promote the recovery rate of *Campylobacter* from food samples (Arimi et al., 1988). Common pre-enrichment broth used for *Campylobacter* isolation include Bolton broth, *Campylobacter* enrichment broth, Exeter broth, Park & Sanders broth and Preston broth (Donnison, 2003). To differentiate *Campylobacter* from other microorganisms, several biochemical tests such as oxidase, catalase, nitrate reduction, hippurate hydrolysis and resistance to cephalotin and nalidixic acid were used (Steinbrueckner et al., 1999). However, due to its biochemically inert characteristics, the most effective confirmation method used nowadays is PCR assay (Silva et al., 2011). In terms of epidemiological studies, the most common methods used for molecular typing of *Campylobacter* include amplified fragment length polymorphism (AFLP), *flaA* Short Variable Region (*flaA*-SVR), multi-locus

sequence typing (MLST), pulsed-field gel electrophoresis (PFGE) and restriction fragment length polymorphism of the *flaA* gene (*flaA*-RFLP) (Taboada et al., 2013; Carrillo and Oyarzabal, 2014).

2.4.2 Detection of *Arcobacter*

At present, there are no standardized methods for *Arcobacter* isolation. The most common isolation method for *Arcobacter* is selective-enrichment broth combined with membrane filtration over an antibiotic-free blood agar (Atabay and Corry, 1997). An enrichment broth used for *Arcobacter* isolation usually contains cefoperazone, amphotericin B, and teicoplanin. This method increases the recovery rate of *Arcobacter* and effectively prevents the growth of competitive organisms (Lammerding et al., 1996). For identification, biochemical tests such as catalase, nitrate reduction, indoxyl acetate hydrolysis, resistance to cefoperazone and growth in the presence of 3.5% NaCl and glycine were used to differentiate *Arcobacter* from other bacteria (Collado and Figueras, 2011). Like *Campylobacter*, *Arcobacter* is metabolically inert, so biochemical results may not be completely accurate (On et al., 1996). Therefore, several molecular methods including AFLP, RFLP and PCR assays have been developed for identification of *Arcobacter* (Houf, 2009; González et al., 2012). Among these molecular methods, multiplex PCR method targeting the 16S and 23S rRNA genes is the most common method used for *Arcobacter* identification (Collado and Figueras, 2011). For molecular typing of *Arcobacter*, several methods have been developed to differentiate one strain of *Arcobacter* from another. Many molecular typing methods used in current research include enterobacterial repetitive intergenic consensus-PCR

(ERIC-PCR), randomly amplified polymorphic DNA-PCR (RAPD-PCR), AFLP, multilocus sequence typing (MLST), and pulsed-field gel electrophoresis (PFGE) (Houf, 2009; Collado and Figueras, 2011).

2.5 Antimicrobial resistance of *Campylobacter* and *Arcobacter*

2.5.1 Antimicrobial resistance of *Campylobacter*

Although most *Campylobacter* infections do not require antimicrobial therapy, antibiotic treatment is required for prolonged or systemic infections (Humphrey et al., 2007). Macrolides (e.g. erythromycin) and fluoroquinolones (e.g. ciprofloxacin) are commonly used for treating patients with campylobacteriosis (Nachamkin et al., 1998; Aquino et al., 2002). The European Food Safety Authority (EFSA) reported that the high frequencies of resistance among *Campylobacter* isolates from humans in EU were found to nalidixic acid (48.8%) and ciprofloxacin (47.4%), followed by ampicillin (36.4%) and tetracycline (32.4%) (EFSA, 2014[a]). According to CDC report, 23.0% of *Campylobacter* isolates from humans in the US were resistant to ciprofloxacin and 2.0% of these isolates were resistant to azithromycin (CDC, 2013). In addition, many studies have shown that the frequency of ciprofloxacin resistance in human isolates has increased, while erythromycin resistance remains low (Engberg et al., 2001; Belanger and Shryock, 2007; Luangtongkum et al., 2009; CDC, 2013). Fortunately, co-resistance between erythromycin and ciprofloxacin, which are the first- and second-line drugs of choice for the treatment of campylobacteriosis, in humans was generally low (EFSA, 2013).

In foods of animal origin, fluoroquinolone and tetracycline resistance were common in many countries (Ge et al., 2003; Wieczorek and Osek, 2013). Among European countries, a high proportion of *Campylobacter* isolates from chicken meat were resistant to ciprofloxacin (59.5% for *C. jejuni* and 82.7% for *C. coli*) and tetracycline (47.5% for *C. jejuni* and 57.3% for *C. coli*) (EFSA, 2014[a]). In Asian countries, approximately 90.0% of *Campylobacter* isolates especially *C. coli* from retail meat in Korea and China were resistant to fluoroquinolones and teracyclines (Hong et al., 2007; Ma et al., 2014). On the other hand, studies in the US demonstrated that the lower fluoroquinolone resistance rate (approximately 20.0%) was observed in retail meat, while tetracycline resistance rate was relatively high (31.5% to 82.0%) (Ge et al., 2003; Han et al., 2009; Zhao et al., 2010; NARMS, 2011). Compared to fluoroquinolones, erythromycin resistance in retail meat remains low for *C. jejuni* (Houf, 2009; EFSA, 2014[a]). The higher erythromycin resistance rate was found in *C. coli*, especially *C. coli* isolates from pork, which may be associated with the extensive use of macrolides such as tylosin in swine husbandry (Engberg et al., 2001; Juntunen et al., 2010). In general, erythromycin resistance remained at <5.0% for *C. jejuni* and <10.0% for *C. coli* isolated from chicken meat and up to 20% for *C. coli* in pork (Hong et al., 2007; Zhao et al., 2010; NARMS, 2011; EFSA, 2014[a]). Furthermore, co-resistance to ciprofloxacin and erythromycin was found in 1.0%-26.0% of *Campylobacter* isolated from retail meat (Ge et al., 2003; Thakur et al., 2010; Nobile et al., 2013).

2.5.2 Antimicrobial resistance of *Arcobacter*

Like *Campylobacter*, *Arcobacter* infection in humans is self-limiting. Antimicrobial treatment is essential only in cases with severe symptoms. Ciprofloxacin and tetracycline are considered as drugs of choice for treatment of *Arcobacter* infection in humans (Vandenberg et al., 2006; Collado and Figueras, 2011). Although several methods including Epsilometer-test (E test), broth microdilution, agar disc diffusion and agar dilution were used to determine antimicrobial susceptibility of *Arcobacter*, there is no standardized method and breakpoints available for *Arcobacter* species (Fera et al., 2003; Houf et al., 2004; Vandenberg et al., 2006; Son et al., 2007). Therefore, susceptibility results from different studies are difficult to compare. In humans, the study of Vandenberg et al. (2006) demonstrated that most *Arcobacter* isolates were susceptible to quinolones and fluoroquinolones, while 21.3% of these isolates were found to be resistant to ampicillin and erythromycin. Compared to human isolates, *Arcobacter* isolates from foods of animal origin tended to be resistant to ampicillin, azithromycin, clindamycin, erythromycin, nalidixic acid and vancomycin (Kabeya et al., 2004; Son et al., 2007; Teague et al., 2010; Shah et al., 2012), but susceptible to tetracycline (Fera et al., 2003; Son et al., 2007; Kayman et al., 2012; Shah et al., 2012). The presence of multidrug-resistant *Arcobacter* was reported in a few studies (Son et al., 2007; Zacharow et al., 2015). Son et al. (2007) revealed that most *A. butzleri* isolates from chicken carcasses in US were resistant to azithromycin, clindamycin and nalidixic acid. Likewise, Abay et al. (2012) found that all *A. butzleri* isolates from chicken carcasses in Turkey were resistant to three or more antimicrobial agents.

2.6 Studies of *Campylobacter* and *Arcobacter* in Thailand

2.6.1 Studies of *Campylobacter* in Thailand

Previous studies in Thailand reported that the prevalence of *Campylobacter* in chicken meat ranged from 28.8% to 51.0% and *C. coli* was the predominant species in retail chicken meat (Meeyam et al., 2004; Padungtod and Kaneene, 2005; Noppon et al., 2011). Compared to poultry meat, the prevalence of *Campylobacter* in duck meat, pork and beef was lower, with the prevalence of 31.0%, 5.0% and 1.0%, respectively (Rasrinaul et al., 1988; Boonmar et al., 2007). For antimicrobial resistance, the high prevalence of fluoroquinolone resistance in *Campylobacter* isolates from humans in Thailand was observed (Padungtod et al., 2006; Serichantalergs et al., 2010). The prevalence of ciprofloxacin resistance in *Campylobacter* isolates from humans increased from 76.0% in 1996 to 93.0% in 2001-2003 (Serichantalergs et al., 2007; Serichantalergs et al., 2010). Not only *Campylobacter* isolates from humans were resistant to clinically important antibiotics, but *Campylobacter* isolates from animals and food products were also resistant to fluoroquinolones and other antimicrobial agents such as ampicillin, azithromycin, chloramphenicol and erythromycin (Sukhapesna et al., 2005; Padungtod et al., 2006; Chokboonmongkol et al., 2013). Approximately 58.0%-100.0% of *Campylobacter* isolates from meat products in Thailand were resistant to ciprofloxacin and tetracycline, while less than 15.0% of the isolates were resistant to erythromycin (Sukhapesna et al., 2005; Padungtod et al., 2006; Bodhidatta et al., 2013; Chokboonmongkol et al., 2013).

2.6.2 Studies of *Arcobacter* in Thailand

Like *Campylobacter*, only few studies on the occurrence and antimicrobial susceptibility of *Arcobacter* have been reported in Thailand. The study of Taylor et al. (1991), which is the first study of *Arcobacter* in Thailand, found that the prevalence of *Arcobacter* in diarrheic children under 5 years old was 2.4%. In foods of animal origin, the prevalence of *Arcobacter* in chicken meat and chicken carcasses at retail level varied widely from 21.0% to 100.0% (Morita et al., 2004; Vindigni et al., 2007). Compared to other enteric pathogens, *Arcobacter* was frequently found in cooked food products. One study in Thailand reported that the prevalence of *Arcobacter* in food samples collected from 121 restaurants in Bangkok was higher than that of *Salmonella* and *Campylobacter* (13.0% for *Arcobacter* versus 2.0% for *Salmonella* and 0.0% for *Campylobacter*). Furthermore, the majority of *A. butzleri* isolates in that study were also resistant to broad spectrum macrolides such as azithromycin (Teague et al., 2010).

CHAPTER III
MATERIALS AND METHODS

3.1 Sampling frame

This study focused on retail meat sold in supermarkets in Bangkok, Thailand. Major supermarkets where different types of meat including chicken, pork, beef and duck were collected are operated by nine companies. At present, these 9 major supermarket chains have 165 stores all over Bangkok. Proportionate stratified sampling was used to select appropriate number of stores per chain from which samples would be collected. A total of 52 stores were included in this study.

3.2 Sampling procedure

Meat samples were collected from supermarkets in Bangkok during June to October 2013. In total, 352 meat samples including chicken (n=104), pork (n=104), beef (n=104) and duck (n=40) were obtained from 52 retail stores of 9 major supermarket chains (Table 1). On each sampling day, 2 stores were randomly selected. Two packages of each meat type except duck meat were collected from each store. For duck meat, samples were collected only from supermarket chain B because it is the only major supermarket chain in Bangkok that sells duck meat. Five packages of duck meat were collected per store. All meat samples were kept in a cooler bag containing ice packs and immediately transported to the laboratory and processed within 3 h after sampling.

Table 1. The number of retail stores and meat samples collected from each chain

Supermarket chain	No. of stores	No. of stores selected	No. of total samples*
A	56	17	102
B	29	9	94
C	22	7	42
D	15	5	30
E	13	4	24
F	10	3	18
G	10	3	18
H	6	2	12
I	4	2	12
Total	165	52	352

*No. of total samples were calculated by no. of stores selected x 2 samples per meat types x 3 meat types except in chain B where 40 duck samples were also included.

3.3 *Campylobacter* isolation and enumeration

The modified ISO 10272-3: 2010 (semi-quantitative method) was used for *Campylobacter* detection and enumeration (ISO, 2010). Briefly, 15 grams of each meat samples were aseptically placed into sterile plastic bag containing 120 ml of Exeter broth and homogenized in stomacher (Seward, London, UK) for 1-2 min. After homogenization, 90 ml of an initial suspension were placed into sterile plastic bag, corresponding to 10^1. Ten milliliters of an initial suspension were transferred to a new test tube, corresponding to 10^0. Then, series of ten-fold dilution were made by

transferring 1 ml of suspension to 9 ml of Exeter broth (up to 10^{-4}). All samples were incubated at 37°C for 42-48 h microaerobically. Enriched cultures from each dilution were streaked onto modified Charcoal Cefoperazone Deoxycholate Agar (mCCDA; Oxoid, Hampshire, UK) and incubated under the same condition as previously described. After incubation, typical *Campylobacter* colonies (grayish, flat and moistened) were subcultured onto blood agar and further confirmed by polymerase chain reaction. The results were reported as the most probable number (MPN) per gram as described by ISO 10272-3: 2010/AC: 2011 (ISO, 2011). The isolates were stored at -80°C in skim milk and 30.0% glycerol (v/v) for further study.

3.4 Confirmation of *Campylobacter*

Campylobacter isolates were identified to species level using multiplex PCR according to the previously published protocol (Wang et al., 2002) with minor modifications. *C. jejuni* ATCC 33560 and *C. coli* NCTC 11353 were used as positive controls. Briefly, DNA template was prepared by the boiling method. After boiling for 10 minutes, samples were centrifuged for 5 min at 13,000 rpm. The supernatant was used as DNA template for PCR. Two sets of primers specific for *hipO* and *glyA* were used for *C. jejuni* and *C. coli* identification, respectively. Primers used in the multiplex PCR assay are shown in Table 2. The 25 µl PCR reaction mixture consisted of 1.25U Taq DNA polymerase (Kappa Biosystems, Boston, USA), 0.4 mM of each dNTP, 10 pmol of each primer and 5 µl of DNA template. Amplification was carried out in thermal cycler with an initial denaturation at 95°C for 5 min followed by 30 cycles of denaturation at 95°C for 45 s, annealing at 58°C for 45 s, and extension at 72°C for 45

s, with a final extension at 72°C for 7 min. Five µl of PCR products were run on 1.2% (w/v) agarose gel for 30 min and visualized under ultraviolet light after stained with ethidium bromide. PCR amplicons specific for *C. jejuni* and *C. coli* were 323 bp and 126 bp, respectively.

Table 2. PCR primers used for *Campylobacter* identification in this study

***Campylobacter* species**	**Primer**	**Amplicon size (bp)**	**Target gene**	**Primer sequences (5' to 3')**
C. jejuni	CJF	323	*hipO*	ACTTCTTTATTGCTTGCTGC
	CJR			GCCACAACAAGTAAAGAAGC
C. coli	CCF	126	*glyA*	GTAAAACCAAAGCTTATCGTG
	CCR			TCCAGCAATGTGTGCAATG

3.5 *Arcobacter* isolation

Ten grams of each meat types were inoculated into 90 ml of *Arcobacter* enrichment broth (Oxoid, Hampshire, UK) with cepfoperazone (8mg/l), amphotericin (10 mg/l), and teicoplanin (4mg/l) (CAT) supplement (Atabay and Corry, 1998) and incubated at 25°C for 48 h under aerobic conditions. After enrichment, a membrane filtration technique was used as previously described (Atabay et al., 2003) with some modifications. Two hundred microliters of each enriched sample were dropped onto a 0.45 µm pore size 47 mm diameter nitrocellulose membrane filter (Pall Corporation, Ann Arbor, MI, USA) laid on mCCDA plate. After 30 min, the filter was removed and mCCDA plate was incubated aerobically at 25°C for 48 h. Presumptive *Arcobacter* colonies (clear-white and/or gray pinpoint colonies) were streaked onto blood agar

and further confirmed by multiplex PCR (Douidah et al., 2010). All *Arcobacter* isolates were stored at -80°C under the similar condition as that of *Campylobacter*.

3.6 Confirmation of *Arcobacter*

Identification of *Arcobacter* species was performed by multiplex PCR as described previously (Douidah et al., 2010) with some modifications. *A. butzleri* NCTC 12481, *A. skirrowii* NCTC 12731 and *A. cryaerophilus* NCTC 11885 were used as positive controls. DNA templates were prepared as described earlier. The 25 µl PCR reaction mixture consisted of 1X PCR buffer (Kappa Biosystems, Boston, USA), 0.75U Taq DNA polymerase (Kappa Biosystems, Boston, USA), 200 µM of each dNTP, 25 pmol of each primers and 5 µl of DNA template. DNA amplification was performed with an initial denaturation at 94°C for 3 min followed by 30 cycles of denaturation at 94°C for 45 s, annealing at 58°C for 45 s, and extension for at 72°C for 2 min, with a final extension at 72°C for 5 min. PCR products were analyzed as described for *Campylobacter*. The amplicon size of *A. butzleri*, *A. skirrowii* and *A. cryaerophilus* was 2,061 bp, 198 bp and 395 bp, respectively. Primers used for *Arcobacter* identification are shown in Table 3.

Table 3. PCR primers used for *Arcobacter* identification in this study

Arcobacter species	Primer	Amplicon size (bp)	Target gene	Primer sequences (5' to 3')
A. butzleri	ArcoF	2,061	23S rRNA	GCYAGAGGAAGAGAAATCAA
	ButR		23S rRNA	TCCTGATACAAGATAATTGTACG
A. skirrowii	ArcoF	198	23S rRNA	GCYAGAGGAAGAGAAATCAA
	SkiR		23S rRNA	TCAGGATACCATTAAAGTTATTGATG
A. cryaerophilus	GyrasF	395	Gyrase A	AGAACATCACTAAATGAGTTCTCT
	GyrasR		Gyrase A	CCAACAATATTTCCAGTYTTTGGT

3.7 Antimicrobial susceptibility testing

Campylobacter and *Arcobacter* isolates were examined for their susceptibilities to 5 antimicrobial agents including ciprofloxacin, erythromycin, gentamicin, nalidixic acid and tetracycline by the agar dilution method as recommended by the Clinical and Laboratory Standard Institute (CLSI) guideline (CLSI, 2008). *C. jejuni* ATCC 33560 was used as a quality control strain. Briefly, *Campylobacter* and *Arcobacter* isolates were subcultured onto blood agar and incubated at 42°C for 42-48 h microaerobically and at 25°C for 42-48 h aerobically, respectively. After incubation, *Campylobacter* and *Arcobacter* colonies were diluted in 0.85% saline and adjusted to 0.5 McFarland standard (approximately 10^8 CFU/ml). Bacterial inocula were transferred onto Mueller-Hinton agar containing two-fold dilutions of each antimicrobial agents and 5.0% defibrinated sheep blood (v/v) using the multi-point inoculator to give a final concentration of 10^4 CFU/spot. All inoculated plates were incubated for 48 h at 37°C. After incubation, the minimum inhibitory concentration (MIC), which is the lowest concentration of antimicrobial agent that can inhibit visible growth of microorganism,

was determined. The CLSI and the National Antimicrobial Resistance Monitoring System (NARMS) resistance breakpoints were used to interpret the MIC results. Resistance breakpoints used in this study are shown in Table 4.

Table 4. Resistance breakpoints and quality control ranges for *Campylobacter* and *Arcobacter* used in this study

Antimicrobial agents	**Breakpoints (µl/ml)***	**QC Ranges for *C. jejuni* ATCC 33560 at 37°C for 48 h (µg/ml)**
Ciprofloxacin	≥ 4	0.12-1
Erythromycin	≥ 32	1-8
Gentamicin	≥ 8	0.5-2
Nalidixic acid	≥ 64	8-32
Tetracycline	≥ 16	1-4

*CLSI resistance breakpoints were used for ciprofloxacin, erythromycin and tetracycline, while NARMS resistance breakpoints were used for gentamicin and nalidixic acid.

3.8 Statistical analysis

Statistical analysis was carried out using SPSS software version 22 (SPSS Inc., Chicago, IL, USA). Chi-square and Fisher's exact two tailed test were used to compare the differences in contamination rates among different meat types and resistance rates between species of *Campylobacter* and *Arcobacter*. A p-value of <0.05 was considered significant.

CHAPTER IV

RESULTS

4.1 Occurrence of *Campylobacter*

Occurrence of *Campylobacter* in chicken, pork, beef and duck obtained from 9 supermarket chains in Bangkok is shown in Table 5. The overall occurrence of *Campylobacter* was 38.6% (136 out of 352 samples). Of the 136 *Campylobacter* positive samples, 102 samples (75.0%) were contaminated with *C. jejuni*, 15 samples (11.0%) were contaminated with *C. coli* and 19 samples (14.0%) were contaminated with both *C. jejuni and C. coli*. Among four different meat types, duck meat exhibited the highest contamination rate (95.0%), followed by chicken (83.7%), pork (9.6%) and beef (1.0%). There was a significant difference ($p<0.05$) in *Campylobacter* prevalence among meat types. The contamination rate of *Campylobacter* in chicken and duck meat was significantly higher than that of beef and pork ($p<0.05$). In addition, when the contamination rate between beef and pork was compared, it was found that pork was significantly more contaminated with *Campylobacter* than beef ($p<0.05$).

Table 5. Occurrence of *Campylobacter* in retail meat obtained from 9 supermarket chains in Bangkok

Source	No. of positive samples/ No. of samples collected (%)	Samples positive for (%)		
		C. jejuni	*C. coli*	Mixed infection
Chicken	87/104 (83.7)	71/87 (81.6)	3/87 (3.4)	13/87 (14.9)
Pork	10/104 (9.6)	5/10 (50.0)	3/10 (30.0)	2/10 (20.0)
Beef	1/104 (1.0)	1/1 (100.0)	0 (0.0)	0 (0.0)
Duck	38/40 (95.0)	25/38 (65.8)	9/38 (23.7)	4/38 (10.5)
Total	136/352 (38.6)	102/136 (75.0)	15/136 (11.0)	19/136 (14.0)

4.2 Contamination rate of *Campylobacter* by supermarket chain

The overall contamination rates of *Campylobacter* in 9 supermarket chains ranged from 20.0% in chain D to 59.6% in chain B. Of the 104 chicken meat samples, chain F and I had the highest contamination rate (100.0%), while chain D had the lowest contamination rate (60.0%). No significant difference in contamination rates for chicken meat among supermarket chains was observed ($p>0.05$). For pork, chain C had the highest contamination rate (42.9%), while none of pork samples from chain D, F, G, H and I were *Campylobacter* positive. Furthermore, pork obtained from chain C had significantly higher contamination rate than chain A ($p=0.001$) and chain D ($p=0.024$), while difference between chain C and other 6 chains (chain B, E, F, G, H and I) was not statistically significant ($p>0.05$). For beef, only one out of 104 samples was *Campylobacter* positive (chain H). For duck meat, 38 out of 40 samples collected from chain B, the only supermarket chain that sells duck meat in this study, were contaminated with *Campylobacter*. Overall, the contamination rate of *Campylobacter*

in supermarket chains in Bangkok was around 33.0% or less, except for chain B and chain C that the rate of contamination was 59.6% and 42.9%, respectively. The contamination rate of *Campylobacter* by supermarket chain is shown in Table 6.

Table 6. The contamination rate of *Campylobacter* in different meat types by supermarket chain

Supermarket chain	No. of stores	No. of *Campylobacter* positive samples/ No. of samples collected (%)				
		Chicken	Pork	Beef	Duck [a]	Total
A	17	28/34 (82.4)	1/34 (2.9)	0/34 (0.0)	n/a [b]	29/102 (28.4)
B	9	16/18 (88.9)	2/18 (11.1)	0/18 (0.0)	38/40 (95.0)	56/94 (59.6)
C	7	12/14 (85.7)	6/14 (42.9)	0/14 (0.0)	n/a	18/42 (42.9)
D	5	6/10 (60.0)	0/10 (0.0)	0/10 (0.0)	n/a	6/30 (20.0)
E	4	7/8 (87.5)	1/8 (12.5)	0/8 (0.0)	n/a	8/24 (33.3)
F	3	6/6 (100.0)	0/6 (0.0)	0/6 (0.0)	n/a	6/18 (33.3)
G	3	5/6 (83.3)	0/6 (0.0)	0/6 (0.0)	n/a	5/18 (27.8)
H	2	3/4 (75.0)	0/4 (0.0)	1/4 (25.0)	n/a	4/12 (33.3)
I	2	4/4 (100.0)	0/4 (0.0)	0/4 (0.0)	n/a	4/12 (33.3)
Total	52	87/104(83.7)	10/104(9.6)	1/104(1.0)	38/40 (95.0)	136/352 (38.6)

[a] Duck meat was sold only in supermarket chain B.

[b] n/a, not applicable.

4.3 Enumeration of *Campylobacter*

The level of *Campylobacter* load in meat samples is shown in Table 7. The concentration of this organism in *Campylobacter* positive samples ranged from 0.23 to more than 2,400 MPN/g for chicken and duck meat, 0.23-230 MPN/g for pork and 0.23 MPN/g for beef. Almost 90.0% of contaminated chicken harbored *Campylobacter* between 2.3 and 230 MPN/g, while the majority of duck meat (84.3%) were

contaminated with *Campylobacter* at the low level ranging from 0.23 to 2.3 MPN/g. Overall, the majority of retail meat samples examined in this study had count of 2.3 MPN/g. Only two poultry samples (one sample from chicken and one sample from duck) had very high count of above 2,400 MPN/g.

Table 7. Distribution of *Campylobacter* load in raw retail meat

Origin	*Campylobacter* positive samples	No. of samples with Campylobacter count of (MPN/g) (%)					
		0.23	2.3	23	230	2400	∞
Chicken	87	6 (6.9)	31 (35.6)	26 (29.9)	21 (24.1)	2 (2.3)	1 (1.1)
Pork	10	3 (30.0)	6 (60.0)	0 (0.0)	1 (10.0)	0 (0.0)	0 (0.0)
Beef	1	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Duck	38	11 (29.0)	21 (55.3)	4 (10.5)	0 (0.0)	1 (2.6)	1 (2.6)
Total	136	21 (15.4)	58 (42.6)	30 (22.1)	22(16.2)	3 (2.2)	2 (1.5)

4.4 Occurrence of *Arcobacter*

The overall occurrence of *Arcobacter* was 68.5% (241 out of 352 samples). Among 241 *Arcobacter* positive samples, 159 samples (66.0%) were positive for *A. butzleri*, 5 samples (2.1%) were positive for *A. skirrowii*, 1 samples (0.4%) were positive for *A. cryaerophilus* and 76 samples (31.5%) were contaminated with 2 or more *Arcobacter* species. Similar to *Campylobacter*, most duck meat (97.5%) and chicken meat (90.4%) were contaminated with *Arcobacter*, followed by pork (68.3%) and beef (35.6%), respectively (Table 8). Significant difference in *Arcobacter* contamination rates among different meat types was found in this study ($p<0.05$). The

contamination rate of *Arcobacter* was significantly higher in poultry meat than red meat ($p<0.05$). When the contamination rate of *Arcobacter* in pork and beef was compared, pork displayed significantly higher rate of contamination than beef ($p<0.05$). The occurrence of *Arcobacter* in chicken, pork, beef and duck obtained from 9 supermarket chains in Bangkok is shown in Table 8.

Table 8. Occurrence of *Arcobacter* in retail meat obtained from 9 supermarket chains in Bangkok

Source	No. of positive samples/No. of sample collected (%)	Samples positive for (%)			
		A. butzleri	*A. skirrowii*	*A. cryaerophilus*	Mixed infection
Chicken	94/104 (90.4)	51/94 (54.3)	4/94 (4.3)	0/94 (0.0)	39/94 (41.5)
Pork	71/104 (68.3)	53/71 (74.6)	0/71 (0.0)	1/71 (1.4)	17/71 (23.9)
Beef	37/104 (35.6)	33/37 (89.2)	0/37 (0.0)	0/37 (0.0)	4/37 (10.8)
Duck	39/40 (97.5)	22/39 (56.4)	1/39 (2.6)	0/39 (0.0)	16/39 (41.0)
Total	241/352 (68.5)	159/241 (66.0)	5/241 (2.1)	1/241 (0.4)	76/241 (31.5)

4.5 Contamination rate of *Arcobacter* by supermarket chain

The overall contamination rates of *Arcobacter* in 9 supermarket chains ranged from 40.0% in chain D to 100.0% in chain H. All chicken meat samples obtained from chain B, E, F, H and I were *Arcobacter* positive, while the lowest contamination rate in chicken meat (66.7%) was found in chain G. Significant difference in *Arcobacter* contamination rate between chicken meat sold in supermarket was found only between chain A and B ($p=0.039$). Among pork samples, chain C, H and I had the highest contamination rate (100.0%), while chain D had the lowest contamination rate

(30.0%). Pork samples obtained from chain C were significantly more contaminated with *Arcobacter* than chain A (p=0.004), chain D (p<0.001) and chain F (p=0.003), whereas difference between chain C and other chains (chain B, E, G, H and I) was not statistically significant (p>0.05). In addition, the contamination rate of *Arcobacter* in chain B was significantly higher than chain D (p = 0.05). For beef samples, chain H had the highest *Arcobacter* contamination rate (100.0%). None of beef samples from chain D were found positive for *Arcobacter*. Beef samples obtained from chain H had significantly higher contamination rate than chain A (p=0.032), chain C (p=0.023) and chain D (p=0.001), while the difference between chain H and other chains (chain B, E, F, G and I) was not statistically significant (p>0.05). Furthermore, beef samples from chain A and B displayed significantly higher *Arcobacter* contamination rate than chain D (p<0.05). Overall, more than 80.0% of chicken samples in every supermarket chain except chain G were contaminated with *Arcobacter*, while less than 40.0% of beef samples in almost supermarket chains were contaminated with this organism. In contrast, *Arcobacter* contamination rates in pork samples from 9 supermarket chains varied widely from 30.0% to 100.0%.The occurrence of *Arcobacter* by supermarket chain is shown in Table 9.

Table 9. Occurrence of *Arcobacter* among retail meat by supermarket chain

Supermarket chain	No. of stores	No. of *Arcobacter* positive samples/ No. of samples collected (%)				
		Chicken	Pork	Beef	Duck [a]	Total
A	17	28/34 (82.4)	20/34 (58.8)	13/34 (38.2)	n/a [b]	61/102 (59.8)
B	9	18/18 (100.0)	13/18 (72.2)	7/18 (38.9)	39/40 (97.5)	77/94 (81.9)
C	7	13/14 (92.9)	14/14 (100.0)	5/14 (35.7)	n/a	32/42 (76.2)
D	5	9/10 (90.0)	3/10 (30.0)	0/10 (0.0)	n/a	12/30 (40.0)
E	4	8/8 (100.0)	6/8 (75.0)	3/8 (37.5)	n/a	17/24 (70.8)
F	3	6/6 (100.0)	2/6 (33.3)	2/6 (33.3)	n/a	10/18 (55.6)
G	3	4/6 (66.7)	5/6 (83.3)	2/6 (33.3)	n/a	11/18 (61.1)
H	2	4/4 (100.0)	4/4 (100.0)	4/4 (100.0)	n/a	12/12 (100.0)
I	2	4/4 (100.0)	4/4 (100.0)	1/4 (25.0)	n/a	9/12 (75.0)
Total	52	94/104 (90.4)	71/104(68.3)	37/104(35.6)	39/40 (97.5)	241/352 (68.5)

[a] Duck meat was sold only in supermarket chain B.

[b] n/a, not applicable.

4.6 Antimicrobial resistance of *Campylobacter*

In the present study, 131 *Campylobacter* isolates were determined for their susceptibilities to 5 antimicrobial agents. Distribution of MICs and resistance rate of *Campylobacter* tested is shown in Table 10. Of the 106 *C. jejuni* isolates, the highest resistance rate was found to ciprofloxacin (69.8%), followed by nalidixic acid (62.3%) and tetracycline (53.8%), while the lower rates were found to erythromycin (1.9%) and gentamicin (0.9%). Among 25 *C. coli* isolates, the majority of the isolates were resistant to ciprofloxacin (92.0%), nalidixic acid (92.0%) and tetracycline (76.0%). Compared to *C. jejuni* isolates, *C. coli* exhibited higher rates of resistance to erythromycin (28.0%) and gentamicin (8.0%). The modal MIC values for ciprofloxacin, erythromycin,

gentamicin, nalidixic acid and tetracycline of *C. jejuni* were 16, 0.5, 0.5, 128 and 64 µg/ml, respectively. Like *C. jejuni*, *C. coli* isolates had similar modal MIC values for ciprofloxacin, nalidixic acid, gentamicin and tetracycline, except for erythromycin which the modal MIC value of *C. coli* was 4-fold higher than that of *C. jejuni*.

Although the MIC values for erythromycin of most *Campylobacter* isolates in this study were < 2µg/ml, some stains exhibited high erythromycin resistance levels (MIC of >512 µg/ml). When the MIC_{50} and MIC_{90} of *C. jejuni* and *C. coli* isolates were compared, it was demonstrated that there was two- to four-fold differences in the MICs for most antimicrobial agents, except for erythromycin which the MIC_{90} of *C. coli* was 512-fold higher than that of *C. jejuni* isolates. The frequency of resistance to all antimicrobial agents except to gentamicin was significantly higher in *C. coli* than *C. jejuni* ($p<0.05$). Interestingly, all erythromycin-resistant *Campylobacter* were also resistant to ciprofloxacin and nalidixic acid.

Resistance rates of *Campylobacter* by meat types are shown in Table 11. *Campylobacter* isolates from all meat types exhibited high resistance rates to ciprofloxacin, nalidixic acid and tetracycline. For erythromycin, only *C. coli* isolated from poultry meat and both *C. jejuni* and *C. coli* isolated from pork were resistant to this antimicrobial agent. When the erythromycin resistance rate of *C. coli* in chicken and pork was compared, *C. coli* from pork showed markedly higher resistance to erythromycin than *C. coli* from poultry meat (80.0% vs 30.0%). Interestingly, the MICs of all erythromycin-resistant *Campylobacter* isolates in this study were ≥512 µg/ml. In terms of multidrug resistance, which is defined as resistance to three or more classes of antimicrobials, it was only found in *C. coli* isolated from chicken and pork. Multidrug-resistant *C. coli* was detected in 30.0% of chicken isolates and 80.0% of pork isolates.

The two most common resistance patterns observed in this study were CIP-NAL-TET (41.2%) and CIP-NAL (19.1%)(Table 12).

Table 10. Distribution of MICs and resistance rates in 131 *Campylobacter* strains isolated from retail meat obtained from supermarket chains in Bangkok

Antimicrobial agents[a]	Distribution of MICs (µg/ml)[b]																	MIC_{50}/ MIC_{90}	%R[c]
	0.015	0.03	0.06	0.12	0.25	0.5	1	2	4	8	16	32	64	128	256	512	>512		
Ciprofloxacin																			
C. jejuni	1	8	14	8			1		9	29	31	5						8/16	69.8
C. coli		1	1							4	12	5	2					16/16	92.0*
Erythromycin																			
C. jejuni				4	10	54	29	6							1		1	0.5/1	1.9
C. coli					1	2	1	13	1					1		1	5	2/>512	28.0*
Gentamicin																			
C. jejuni				5	46	51	3					1						0.5/0.5	0.9
C. coli					2	19	1	1						2				0.5/2	8.0
Nalidixic acid																			
C. jejuni							1	6	18	5	1	9	18	40	8			64/128	62.3
C. coli									1	1			6	16	1			128/128	92.0*
Tetracycline																			
C. jejuni	16			14	4	5	3	3	1	3	6	17	20	13	1			16/128	53.8
C. coli				1	3	1	1				2	2	10	3	2			64/128	76.0*

[a]106 *C. jejuni* isolates and 25 *C. coli* isolates.

[b] The grey shading indicates resistant isolates.

[c]%R, percentage of resistant isolates.

* Significant difference in resistance rates between *C. jejuni* and *C. coli* isolates ($p<0.05$)

Table 11. Antimicrobial resistance of *C. jejuni* and *C. coli* isolated from different meat types

Species	Origin[a]	No. of isolates	Percentage of isolates resistant to[b]					%MDR[c]
			CIP	ERY	GEN	NAL	TET	
C. jejuni	Chicken	76	65.8	0.0	1.3	57.9	53.9	0.0
	Pork	5	100.0	20.0	0.0	60.0	40.0	0.0
	Beef	1	100.0	0.0	0.0	100.0	100.0	0.0
	Duck	24	75.0	4.2	0.0	75.0	54.2	0.0
C. coli	Chicken	10	90.0	30.0	10.0	90.0	80.0	30.0
	Pork	5	100.0	80.0	20.0	100.0	80.0	80.0
	Duck	10	90.0	0.0	0.0	90.0	60.0	0.0

[a]None of *C. coli* was isolated from beef.

[b]CIP, ciprofloxacin; ERY, erythromycin; GEN, gentamicin; NAL, nalidixic acid; TET, tetracycline.

[C]%MDR, percentage of multidrug resistance.

Table 12. Resistance patterns of 131 *Campylobacter* isolates from retail meat in Bangkok

Resistance patterns	No. of resistant *Campylobacter* isolates (%)		
	C. jejuni (n=106)	*C. coli* (n=25)	Total (n=131)
CIP	2 (1.9)	0 (0.0)	2 (1.5)
NAL	2 (1.9)	0 (0.0)	2 (1.5)
TET	6 (5.7)	1 (4.0)	7 (5.3)
CIP-ERY	1 (0.9)	0 (0.0)	1 (0.8)
CIP-NAL	20 (18.9)	5 (20.0)	25 (19.1)
CIP-TET	7 (6.6)	0 (0.0)	7 (5.34)
GEN-TET	1 (0.9)	0 (0.0)	1 (0.8)
CIP-NAL-ERY	1 (0.9)	0 (0.0)	1 (0.8)
CIP-NAL-TET	43 (40.6)	11 (44.0)	54 (41.2)
CIP-NAL-TET-ERY*	0 (0.0)	5 (20.0)	5 (3.8)
CIP-NAL-TET-GEN-ERY*	0 (0.0)	2 (8.0)	2 (1.5)
No resistance	23 (21.7)	1 (4.0)	24 (18.3)

*Multidrug resistance.

4.7 Antimicrobial resistance of *Arcobacter*

A total of 244 *Arcobacter* isolates were tested for their susceptibilities to 5 antimicrobial agents. MICs distribution and resistance rate of *Arcobacter* isolates from retail meat are shown in Table 13. For *A. butzleri*, the modal MIC values for ciprofloxacin, erythromycin, gentamicin, nalidixic acid and tetracycline were 0.12, 2, 1, 64 and 1 µg/ml, respectively. Likewise, the modal MIC values for all antimicrobials of *A. cryaerophilus* were quite similar to those of *A. butzleri*. At present, specific breakpoints for *Arcobacter* are not available. If MIC breakpoints of *Campylobacter* were used, around 62.0% and 67.0% of *A. butzleri* and *A. cryaerophilus* isolates would be resistant to nalidixic acid, respectively. In addition, 17.3% of *A. butzleri* isolates would be resistant to ciprofloxacin, while less than 1.0% these isolates would be resistant to erythromycin and gentamicin. Although most of *A. butzleri* isolates were susceptible to erythromycin, 13.3% of *A. cryaerophilus* isolates were resistant to erythromycin. In contrast to *Campylobacter*, none of *A. butzleri* isolates and less than 7.0% of *A. cryaerophilus* in this study were resistant to tetracycline. Interestingly, none of *A. skirrowii* isolates were resistant to all antimicrobial agents tested in this study.

Resistance rates of *Arcobacter* strains isolated from different meat types are shown in Table 14. At least 50% of *A. butzleri* isolates from all meat types exhibited high resistance to nalidixic acid, while the rates of nalidixic acid resistance in *A. cryarophilus* varied from 33.0% in pork isolates to 100.0% in duck isolates. For ciprofloxacin, less than 30% of *A. butzleri* and none of *A. cryaerophilus* from all meat types were resistant to this antimicrobial agent. Although the low frequency of erythromycin resistance was observed in *A. butzleri* isolates from pork and duck, the high frequency of resistance was found in 20.0% and 50.0% of *A. cryaerophilus* from

chicken and duck, respectively. Additionally, only *A. cryaerophilus* isolated from chicken meat was resistant to tetracycline. Compared to other meat types, *A. butzleri* isolates from beef showed lower resistance rates to all antimicrobial agents. None of *Arcobacter* isolates in this study were multidrug-resistant. In terms of antimicrobial resistance patterns, the two most common resistance patterns observed were NAL (43.9%) and CIP-NAL (14.8%) (Table15).

In the absence of established clinical breakpoints for *Arcobaacter*, epidemiological cut-off values (ECOFFs) may be useful for distinguishing wild-type strains from strains with acquired resistance. Generally, ECOFFs can be calculated as 2-fold dilutions above the modal MIC (Latta et al., 2015). Since the modal MIC values of *A. butzleri* for ciprofloxacin, erythromycin, gentamicin, nalidixic acid and tetracycline were 0.12, 2, 1, 64 and 1 µg/ml, respectively, the ECOFFs for ciprofloxacin, erythromycin, gentamicin, nalidixic acid and tetracycline of *A. butzleri* in the present study would be 0.5, 8, 4, 256 and 4 µg/ml, respectively (Figures 1-5). If the ECOFFs for *A. butzleri* calculated in this study were used, 60 isolates (26.7%), 9 isolates (4.0%), 2 isolates (0.9%), 39 isolates (17.3%) and 2 isolates (0.9%) would show decreased susceptibility to ciprofloxacin, erythromycin, gentamicin, nalidixic acid and tetracycline, respectively. Generally, the ECOFFs for *A. butzleri* in the present study were lower than those of recently used *Campylobacter* breakpoints for ciprofloxacin (0.5 vs ≥4 µg/ml), erythromycin (8 µg/ml vs ≥32 µg/ml), gentamicin (4 µg/ml vs ≥8 µg/ml) and tetracycline (4 µg/ml vs ≥16 µg/ml), except for nalidixic acid that the ECOFFs breakpoint was slightly higher than that of *Campylobacter* breakpoint (256 µg/ml vs ≥64 µg/ml).

Table 13 Distribution of MICs and resistance rates in 244 *Arcobacter* strains isolated from retail meat in 9 supermarket chains in Bangkok

Antimicrobial agents[a]	Distribution of MICs (µg/ml)																MIC_{50}/ MIC_{90}	%R[b]
	0.03	0.06	0.12	0.25	0.5	1	2	4	8	16	32	64	128	256	512	>512		
Ciprofloxacin																		
A. butzleri	10	48	61	33	13	15	6	2	5	13	9	3	7				0.12/16	17.3
A. cryaerophilus			4	4	5	2											0.25/1	0.0
A. skirrowii	1	2	1														0.06/0.12	0.0
Erythromycin																		
A. butzleri			1	7	26	53	67	39	23	7	2						2/8	0.9
A. cryaerophilus						1	8	1	3		2						2/32	13.3*
A. skirrowii					3												0.5/0.5	0.0
Gentamicin																		
A. butzleri				2	66	93	59	3					2				1/2	0.9
A. cryaerophilus					1	5	8	1									2/2	0.0
A. skirrowii					1	1	1	1									0.5/4	0.0
Nalidixic acid																		
A. butzleri								6	14	28	37	48	37	16	9	30	64/>512	62.2
A. cryaerophilus									1	1	3	8	1		1		64/128	66.7
A. skirrowi									1	2	1						16/32	0.0
Tetracycline																		
A. butzleri		1	8	10	72	86	43	3	2								1/2	0.0
A. cryaerophilus						3	11				1						2/2	6.7
A. skirrowii			1	2	1												0.25	0.0

[a]225 *A. butzleri*, 15 *A. cryaerophilus* and 4 *A. skirrowii* isolates were tested for their susceptibilities to 5 antimicrobial agents.

[b]The grey shading indicates resistant isolates.

[c]%R, percentage of resistant isolates.

*Significant difference in resistance rates between *A. butzleri* and *A. cryaerophilus* isolates ($p<0.05$).

Table 14. Antimicrobial resistance of *A. butzleri* and *A. cryaerophilus* isolated from different meat types

Species[a]	Origin	No. of isolates	Percentage of isolates resistant to (%)[b]					%MDR[c]
			CIP	ERY	GEN	NAL	TET	
A. butzleri	Chicken	88	19.3	0.0	0.0	54.5	0.0	0.0
	Pork	65	26.2	1.5	3.1	70.8	0.0	0.0
	Beef	34	2.9	0.0	0.0	52.9	0.0	0.0
	Duck	38	10.5	2.6	0.0	82.0	0.0	0.0
A. cryaerophilus	Chicken	5	0.0	20.0	0.0	80.0	20.0	0.0
	Pork	3	0.0	0.0	0.0	33.3	0.0	0.0
	Beef	4	0.0	0.0	0.0	50.0	0.0	0.0
	Duck	2	0.0	50.0	0.0	100.0	0.0	0.0

[a]None of *A. skirrowii* was resistant to antimicrobial agents tested.

[b]CIP, ciprofloxacin; ERY, erythromycin; GEN, gentamicin; NAL, nalidixic acid; TET, tetracycline.

[C]%MDR, percentage of multidrug resistance.

Table 15. Resistance patterns of 244 *Arcobacter* isolates from retail meat in Bangkok

Resistance patterns	No. of resistant *Arcobacter* isolates (%)			
	A. butzleri (n=225)	*A. cryaerophilus* (n=15)	*A. skirrowii* (n=4)	Total (n=244)
NAL	100(44.4)	7(46.7)	0(0.0)	107 (43.9)
CIP-NAL	36(16.0)	0(0.0)	0(0.0)	36(14.8)
ERY-NAL	2(0.9)	2(13.3)	0(0.0)	4(1.6)
GEN-NAL	1(0.4)	0(0.0)	0(0.0)	1(0.4)
NAL-TET	0(0.0)	1(6.7)	0(0.0)	1(0.4)
CIP-NAL-GEN	1(0.4)	0(0.0)	0(0.0)	1(0.4)
No resistance	85 (37.8)	5 (33.3)	4 (100.0)	94 (38.5)

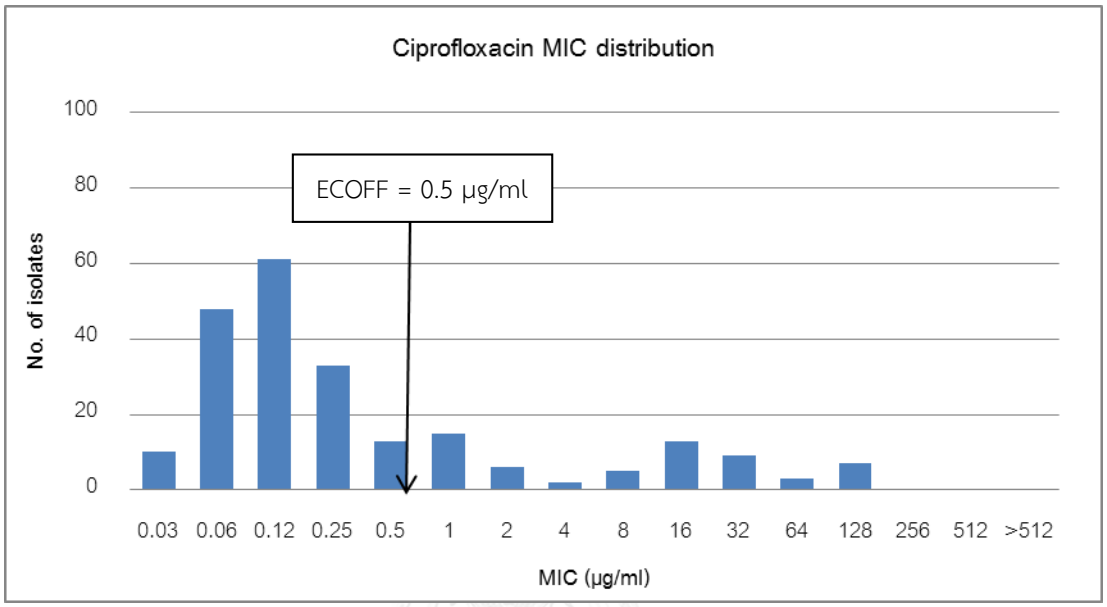

Figure 1. MIC distribution of 225 *A. butzleri* isolates tested against ciprofloxacin. ECOFF is defined as 2-fold dilutions higher than the modal MIC. In this study, the ECOFF for ciprofloxacin is 0.5 µg/ml. *A. butzleri* isolates with MICs above the ECOFF showed decreased susceptibility to this antimicrobial agent.

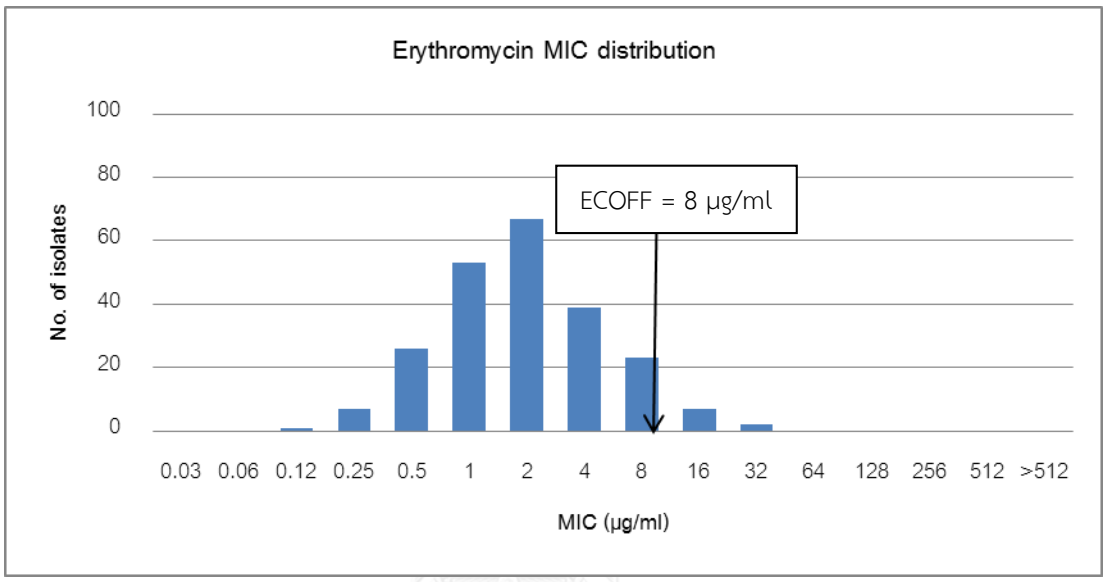

Figure 2. MIC distribution of 225 *A. butzleri* isolates tested against erythromycin. ECOFF is defined as 2-fold dilutions higher than the modal MIC. In this study, the ECOFF for erythromycin is 8 µg/ml. *A. butzleri* isolates with MICs above the ECOFF showed decreased susceptibility to this antimicrobial agent.

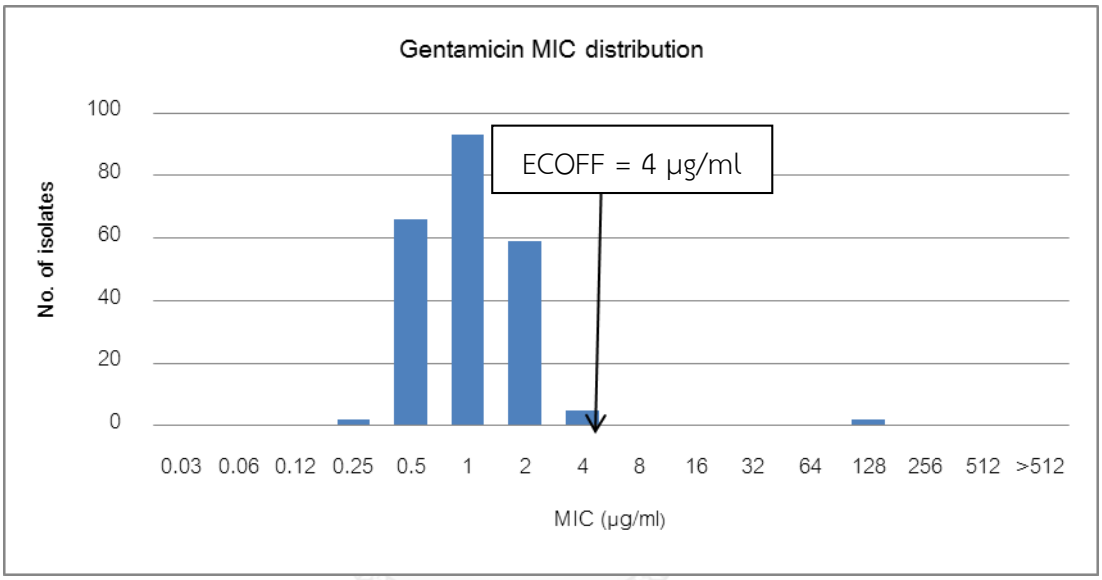

Figure 3. MIC distribution of 225 *A. butzleri* isolates tested against gentamicin. ECOFF is defined as 2-fold dilutions higher than the modal MIC. In this study, the ECOFF for gentamicin is 4 µg/ml. *A. butzleri* isolates with MICs above the ECOFF showed decreased susceptibility to this antimicrobial agent.

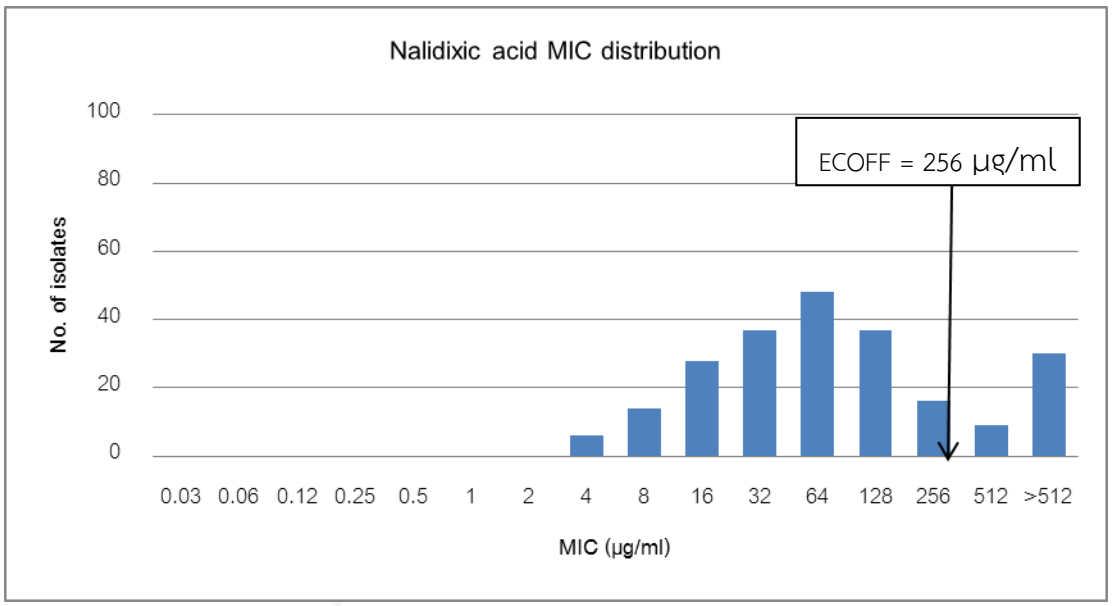

Figure 4. MIC distribution of 225 *A. butzleri* isolates tested against nalidixic acid. ECOFF is defined as 2-fold dilutions higher than the modal MIC. In this study, the ECOFF for nalidixic acid is 256 µg/ml. *A. butzleri* isolates with MICs above the ECOFF showed decreased susceptibility to this antimicrobial agent.

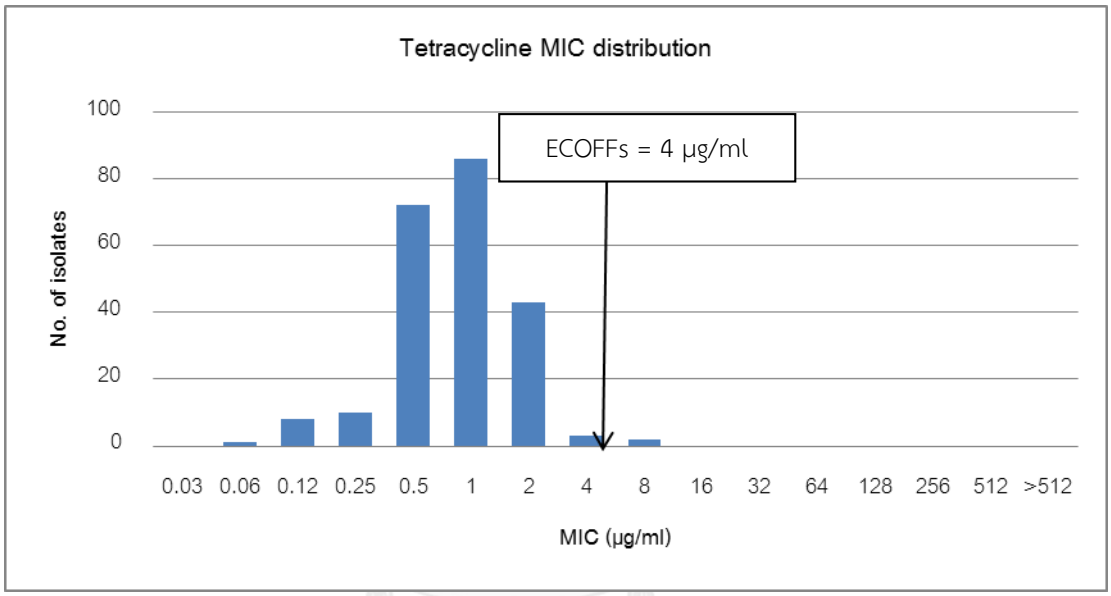

Figure 5. MIC distribution of 225 *A. butzleri* isolates tested against tetracycline. ECOFF is defined as 2-fold dilutions higher than the modal MIC. In this study, the ECOFF for tetracycline is 4 µg/ml. *A. butzleri* isolates with MICs above the ECOFF showed decreased susceptibility to this antimicrobial agent.

CHAPTER V

DISCUSSION

This study was conducted to determine the occurrence and antimicrobial susceptibility of *Campylobacter* and *Arcobacter* from a wide range of meat samples in supermarkets in Bangkok. The majority of duck (95.0%) and chicken meat (83.7%) in the present study was contaminated with *Campylobacter*. The high occurrence of *Campylobacter* in poultry meat was also reported in other studies such as France (76.0%), Italy (81.3%), and Ireland (84.3%) (Pezzotti et al., 2003; Madden et al., 2011; Guyard-Nicodeme et al., 2015). Compared to previous studies in our country, the contamination level in this study was much higher than those previously reported in Thailand, which revealed that the occurrence of *Campylobacter* in retail poultry ranged from 28.8-52.0% (Padungtod and Kaneene, 2005; Boonmar et al., 2007; Vindigni et al., 2007; Noppon et al., 2011). Such high contamination level in poultry meat may pose a greater risk for consumers. Compared to poultry meat, it is well documented that the occurrence of *Campylobacter* in red meat was generally lower (Whyte et al., 2004; Hannon et al., 2009; Zhao et al., 2010). It is not surprising that the occurrence of *Campylobacter* in pork and beef in this study was below 10.0%. Our findings are similar to those of other studies which revealed that the occurrence of *Campylobacter* in pork and beef was 9.1%-10.6% and 3.5%-10.1%, respectively (Wong et al., 2007; Korsak et al., 2015).

Generally, *C. jejuni* was the predominant *Campylobacter* species recovered from poultry meat and beef, while *C. coli* was more common in pork (Pezzotti et al., 2003; Hussain et al., 2007; Dadi and Asrat, 2008). In the present study, *C. jejuni* was the

most common *Campylobacter* species recovered from all meat types even in pork. Although a few studies found that *C. jejuni* was more prevalent in retail pork than *C. coli* (Wong et al., 2007; Korsak et al., 2015), most studies reported that around 90% of retail pork samples were contaminated with *C. coli* (Whyte et al., 2004; Padungtod et al., 2006; Hong et al., 2007; Noormohamed and Fakhr, 2013). Low level of co-contamination between different *Campylobacter* species found in this study was consistent with previous studies in Czech Republic and China, which showed that 2.3% of retail meat samples were co-contaminated with both *C. jejuni* and *C. coli* (Kolackova and Karpiskova, 2005; Ma et al., 2014).

Like *Campylobacter*, *Arcobacter* was more common in poultry meat than in red meat. In the present study, the highest occurrence of *Arcobacter* was detected in duck (97.5%) and chicken (90.4%). The high occurrence of *Arcobacter* in retail chicken was previously reported in Turkey (68.0%), Northern Ireland (62.0%), Spain (64.3%) and Thailand (59.0%-100.0%) (Morita et al., 2004; Scullion et al., 2006; Aydin et al., 2007; Vindigni et al., 2007; Collado et al., 2009; Bodhidatta et al., 2013). The high prevalence of *Arcobacter* in poultry meat is likely due to fecal contamination during slaughter processes (Van Driessche and Houf, 2007). Because *A. butzleri* is able to grow at 10°C, which is the normal temperature of slaughterhouses, and form biofilms on the surface of slaughterhouse equipment (Kjeldgaard et al., 2009), this organism can persist in the slaughterhouse environment for long period of time and may spread to carcass during processing (Rasmussen et al., 2013). In addition to poultry meat, 68.0% of pork samples in this study were contaminated with *Arcobacter*. Similar occurrence of *Arcobacter* in retail pork (54.0% - 68.3%) was also found in studies carried out in Belgium and Thailand (Collado et al., 2009; Bodhidatta et al., 2013). On the other hand, a study

conducted in Japan found that only 7.0% of pork samples were contaminated with *Arcobacter* (Kabeya et al., 2004). The occurrence of *Arcobabacter* in beef in our study (35.6%) was quite similar to those reported in Belgium (31.3%) and Malaysia (38.0%) (Aydin et al., 2007; Collado et al., 2009; Shah et al., 2011).

A. butzleri was the most common *Arcobacter* species found in this study, followed by *A. skirrowii* and *A. cryaerophilus*. Previous studies also reported that *A. butzleri* was the predominant *Arcobacter* species recovered from retail meat, while *A. Skirrowii* was less common (Kabeya et al., 2004; Ho et al., 2008; Rahimi et al., 2012). Since *A. butzleri* grows faster than *A. cryaerophilus* and *A. skirowii*, this may explain the high recovery rate of *A. butzleri* from retail meat in many studies (Corry et al., 2003). Co-contamination with different *Arcobacter* species in retail meat was observed in several studies (Kabeya et al., 2004; De Smet et al., 2010; Rahimi et al., 2012). Although previous studies (Kabeya et al., 2004; Rahimi et al., 2012; Rahimi, 2014) displayed low level of mix species infection (0.4%-2.1%), 31.5% of meat samples particularly poultry meat in our study were contaminated with two or more species of *Arcobacter*.

Two types of meat products including store brand and conventional brand were sold in 9 major supermarket chains in this study. Store brand was cut and packaged at retail store, while conventional brand was readily cut and packaged in large-scale processing plants, which have higher hygienic standard than small-scale facilities where store brand was originated from. Interestingly, 90.0% of contaminated pork in this study was store brand and most of them were from chain C. The high contamination rate of *Campylobacter* in store brand is likely due to less proper hygienic measures in small scale-slaughterhouses. It should be noted that the implementation of proper hygienic measures is necessary for reducing cross-

contamination in meat products. In contrast to *Campylobacter*, the high *Arcobacter* contamination rate in pork was found in both store brand and conventional brand. Because *Arcobacter* can persist in slaughterhouses after disinfection and may cross-contaminate carcasses during processing, this may be an explanation why the high contamination of *Arcobacter* in pork obtained from store brand and conventional brand was observed in the present study.

In this study, most of meat samples tested contained a relatively low number of *Campylobacter* (2.3 MPN/g). The low concentration of *Campylobacter* in retail meat was also reported by other authors. For instance, Scherer et al. (2006) and Wong et al. (2007) found that most contaminated meat in Germany and New Zealand had count of below 0.3 MPN/g. On the other hand, Chokboonmongkol et al. (2013) revealed that 13.3% of broiler skin samples were contaminated with *Campylobacter* at the level of >2,400 MPN/g. Likewise, Sison et al. (2014) found that 25.0% of chicken samples from wet markets in Philippines were contaminated with *Campylobacter* at the level of >2,400 MPN/g. Although most studies revealed that the concentration of *Campylobacter* in retail meat was relatively low, it should be noted that small amount of *Campylobacter* contaminated in retail meat can cause disease if raw or undercooked contaminated meat was consumed.

In the present study, *Campylobacter* isolates were examined for their susceptibility to clinically important antibiotics. The high prevalence of ciprofloxacin resistance (74.0%) was observed in this study, followed by nalidixic acid resistance (67.9%) and tetracycline resistance (58.0%). This finding is consistent with previously reports in Thailand (Bodhidatta et al., 2013; Chokboonmongkol et al., 2013). Bodhidatta et al. (2013) and Chokboonmongkol et al. (2013) revealed that at least 80.0% and

around 40.0%-60.0% of *Campylobacter* isolates from food samples were resistant to ciprofloxacin and tetracycline, respectively. Besides Thailand, the high frequency of ciprofloxacin and tetracycline resistance was also found in other Asian and European countries. In China, Ma et al. (2014) reported that ciprofloxacin and tetracycline resistance in broiler meat was almost 100.0%. Furthermore, 59.5% and 40.6% of *Campylobacter* isolates from chicken meat in Europe were also resistant to ciprofloxacin and tetracycline, respectively (EFSA, 2014[a]). The possible explanation of high ciprofloxacin and nalidixic acid resistance in this study may be due to the use of fluoroquinolones for therapeutic purposes in livestock production in Thailand in the past decade. It should be noted that fluoroquinolone-resistant *Campylobacter* may persist in the absence of antibiotic selection pressure and transfer to human through contaminated food (Zhang et al., 2003; Luangtongkum et al., 2009).

Since macrolides, such as erythromycin, are the first-line drug of choice for treatment of campylobacteriosis, the occurrence of macrolide resistance in *Campylobacter* in retail meat is particularly of concern. It is well known that higher occurrence of macrolide resistance was generally found in *C. coli* than *C. jejuni* (Silva et al., 2011). In this study, we found that 1.9% of *C. jejuni* and 28.0% of *C. coli* isolates from retail meat were resistant to erythromycin. This finding is consistent with EFSA summary report which demonstrated that the frequency of erythromycin resistance in *C. jejuni* and *C. coli* isolates from chicken meat was 1.8% and 16.5%, respectively (EFSA, 2014[a]). The high occurrence of erythromycin-resistant *C. coli* particularly *C. coli* isolates from pork may be associated with the extensive use of macrolide, such as tylosin in swine production (Engberg et al., 2001; Juntunen et al., 2010). In our study, a majority of *Campylobacter* isolates were susceptible to gentamicin. This finding is similar to the

results of most studies which indicated that the occurrence of gentamicin resistance in *Campylobacter* isolates from retail meat was around 0.0%-8.0% (Padungtod et al., 2006; Son et al., 2007; Thakur et al., 2010; Ghimire et al., 2014; Noormohamed and Fakhr, 2014). With regard to co-resistance between ciprofloxacin and erythromycin, several studies found that co-resistance to both antimicrobial agents ranged from 0.0% to 26.0% (Ge et al., 2003; Nobile et al., 2013; EFSA, 2014[a]). Consistent with other studies, 6.9% of *Campylobacter* isolates in the present study were resistant to both ciprofloxacin and erythromycin.

The most common antimicrobial resistance among *Arcobacter* isolates in this study was nalidixic acid resistance (61.5%), followed by ciprofloxacin resistance (16.0%).This finding is similar to the previous study in our laboratory, which reported that 74.6% of chicken isolates from fresh markets and supermarkets in Bangkok were resistant to nalidixic acid (Phasipol et al., unpublished data). In contrast, the prevalence of nalidixic acid resistance in other regions was relatively low worldwide (Son et al., 2007; Rahimi, 2014; Zacharow et al., 2015). Compared to *Campylobacter*, *Arcobacter* isolates in this study had much lower resistance rates to ciprofloxacin and tetracycline. The low occurrence of ciprofloxacin resistance was previously reported in several countries such as Iran (1.4%), US (4.3%) and Poland (17.0%) (Son et al., 2007; Rahimi, 2014; Zacharow et al., 2015). Consistent with other studies, less than 5.0% of *Arcobacter* isolates from retail meat in this study were resistant to erythromycin, gentamicin and tetracycline (Son et al., 2007; Rahimi, 2014). In the absence of standardized method and clinical breakpoints for *Arcobacter*, antibiotic susceptibility data among different studies were difficult to compare. Therefore, standardized methods for antimicrobial susceptibility testing and resistance breakpoints of

Arcobacter should be established. In the meantime, monitoring of antimicrobial resistance in *Arcobacter* in each country, where antimicrobial resistance situation is different, should be performed by using epidemiological cut-off values.

CONCLUSION AND SUGGESTION

The present study demonstrated that retail poultry meat sold in supermarkets in Bangkok was frequently contaminated with *Campylobacter* and *Arcobacter*, whereas retail beef and pork were mainly contaminated with *Arcobacter*. These findings suggest that consumption of undercooked poultry or other meats poses a risk to consumers. In this study, *Campylobacter* positive samples mostly contained a contamination level of 2.3 MPN/g. Occurrence and enumeration data of these organisms can be used as part of quantitative risk assessment to estimate the risk of *Campylobacter* and *Arcobacter* infection from consumption of retail meat.

Many *Campylobacter* isolates examined were resistant to multiple antimicrobial agents. The high occurrence of ciprofloxacin, nalidixic acid and tetracycline resistance was observed in *Campylobacter*, while *Arcobacter* only exhibited high resistance to nalidixic acid. This finding suggests that antibiotic-resistant foodborne pathogens including *Campylobacter* and *Arcobacter* may be transmitted to humans via foods of animal origin and cause prolonged illness in humans.

To reduce or prevent the risk of *Campylobacter* and *Arcobacter* infection, it is essential to improve hygienic measures along food chain as well as increase consumer's knowledge on proper food handling and cooking. With regard to the high occurrence of antimicrobial resistance of these organisms, monitoring program should be established to prevent the spread of antimicrobial resistance among foodborne pathogens as well as promote prudent use of antimicrobial agents in livestock production. Further studies should focus on genetic relatedness of *Campylobacter* and *Arcobacter* among food-producing animals, retail meat and clinical samples to

elucidate the source and route of *Campylobacter* and *Arcobacter* infection and to prevent the spread of these organisms in food chain.

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APPENDIX

APPENDIX A

Culture media used for *Arcobacter* and *Campylobacter* isolation

1. *Arcobacter* enrichment broth (CM0965; Oxoid)

Typical formula	(gm/litre)
Peptone	18.0
Yeast extract	1.0
Sodium chloride	5.0

pH 7.2 ± 0.2 @ 25°C

2. CAT supplement

Antimicrobial agents	(mg/litre)
Cefoperazone	16.0
Amphotericin B	20.0
Teicoplanin	8.0

3. Nutrient broth no. 2 (CM0067; Oxoid)

Typical Formula	(gm/litre)
'Lab-Lemco' Powder	10.0
Peptone	10.0
Sodium chloride	5.0

pH 7.5 ± 0.2 @ 25°C

4. *Campylobacter* enrichment supplement (Exeter)

Antimicrobial agents	(mg/litre)
Amphotericin B	2
Cefoperazone	15
Polymyxin B	2500 IU
Rifampicin	5
Trimethoprim	10

5. *Campylobacter* growth supplement

Typical Formula	(mg/litre)
Sodium pyruvate	250
Sodium metabisulphite	250
Ferrous sulphate	250

* Complete Exeter Broth includes nutrient broth No. 2, lysed horse blood, *Campylobacter* growth supplement and *Campylobacter* selective supplement.

6. *Campylobacter* blood-free selective agar base (mCCDA) (CM0739; Oxoid)

Typical Formula	(gm/litre)
Nutrient Broth No.2	25.0
Bacteriological charcoal	4.0
Casein hydrolysate	3.0
Sodium desoxycholate	1.0
Ferrous sulphate	0.25
Sodium pyruvate	0.25
Agar	12.0

pH 7.4 ± 0.2 @ 25°C

7. CCDA selective supplement

Antimicrobial agents	mg/litre
Cefoperazone	32
Amphotericin B	10

APPENDIX B

Table B-1. Interpretation of semi-quantitative test results as described by ISO 10272-3: 2010/AC: 2011

Sample Quantity (g)	**Growth of confirmed *Campylobacter* spp.**						
10^{1}	-	+	+	+	+	+	+
10^{0}	-	-	+	+	+	+	+
10^{-1}	-	-	-	+	+	+	+
10^{-2}	-	-	-	-	+	+	+
10^{-3}	-	-	-	-	-	+	+
10^{-4}	-	-	-	-	-	-	+
MPN/g	0	0.23	2.3	23	230	2,400	∞

If all samples tested are negative, the results would be interpreted as MPN = 0/g (upper confidence limit, T_1 0.33/g); if all samples tested are positive, the results would be interpreted as MPN = ∞ (lower confidence limit, T_0 580/g).

APPENDIX C

Table C-1 Antimicrobial susceptibility and source of *Campylobacter* spp. isolated from retail meat in supermarkets in Bangkok

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
1	A	C1	*C. jejuni*	Chicken	8	64	128	0.5	2	CIP-NAL-TET
2	A	C2	*C. jejuni*	Chicken	16	64	0.25	0.25	2	CIP-NAL
3	A	C28	*C. jejuni*	Chicken	0.03	2	32	0.25	0.5	TET
4	A	C39	*C. jejuni*	Chicken	8	32	64	0.25	0.5	CIP-TET
5	A	C57	*C. jejuni*	Chicken	0.06	2	<0.06	0.25	0.5	Susceptible
6	A	C58	*C. jejuni*	Chicken	32	128	2	0.25	1	CIP-NAL
7	A	C67	*C. jejuni*	Chicken	8	128	64	0.5	0.5	CIP-NAL-TET
8	A	C68	*C. jejuni*	Chicken	8	64	64	0.25	0.5	CIP-NAL-TET
9	A	C73	*C. jejuni*	Chicken	0.06	4	0.125	0.25	1	Susceptible
10	A	C74	*C. jejuni*	Chicken	16	32	16	0.25	1	CIP-TET
11	A	C75	*C. jejuni*	Chicken	1	16	32	32	8	TET-GEN
12	A	C76	*C. jejuni*	Chicken	8	64	<0.06	0.125	0.25	CIP-NAL
13	A	C81	*C. jejuni*	Chicken	0.06	4	0.125	0.25	0.5	Susceptible
14	A	C82	*C. jejuni*	Chicken	0.125	8	0.25	1	1	Susceptible
15	A	C83	*C. jejuni*	Chicken	0.125	4	0.125	0.5	0.5	Susceptible
16	A	C84	*C. jejuni*	Chicken	0.03	4	0.125	0.25	0.5	Susceptible
17	A	C85	*C. jejuni*	Chicken	0.06	4	<0.06	0.25	0.5	Susceptible
18	A	C86	*C. jejuni*	Chicken	0.03	2	<0.06	0.25	0.125	Susceptible
19	A	C93	*C. jejuni*	Chicken	8	128	16	0.25	0.5	CIP-NAL-TET
20	A	C94	*C. jejuni*	Chicken	16	128	16	0.5	0.5	CIP-NAL-TET
21	A	C95	*C. jejuni*	Chicken	4	128	32	0.5	0.5	CIP-NAL-TET
22	A	C96	*C. jejuni*	Chicken	8	128	32	0.5	2	CIP-NAL-TET

Table C-1 Antimicrobial susceptibility and source of *Campylobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
23	A	C99	*C. jejuni*	Chicken	16	128	64	0.5	1	CIP-NAL-TET
24	A	C100	*C. coli*	Chicken	0.03	8	0.25	0.5	2	Susceptible
25	A	C101	*C. jejuni*	Chicken	0.06	8	4	0.25	1	Susceptible
26	A	C102	*C. jejuni*	Chicken	0.06	4	2	0.25	1	Susceptible
27	A	C103	*C. jejuni*	Chicken	16	128	<0.06	0.5	1	CIP-NAL
28	A	C104	*C. jejuni*	Chicken	0.016	1	<0.06	0.125	0.5	Susceptible
29	A	P1	*C. jejuni*	Pork	16	32	1	0.5	>512	CIP-ERY
30	B	C3	*C. jejuni*	Chicken	0.03	8	128	0.5	1	TET
31	B	C4	*C. jejuni*	Chicken	16	128	64	0.25	1	CIP-NAL-TET
32	B	C23	*C. jejuni*	Chicken	16	128	32	0.25	0.5	CIP-NAL-TET
33	B	C24	*C. jejuni*	Chicken	16	64	0.125	0.5	0.5	CIP-NAL
34	B	C43	*C. jejuni*	Chicken	8	64	64	0.25	0.5	CIP-NAL-TET
35	B	C51	*C. jejuni*	Chicken	16	128	32	0.5	1	CIP-NAL-TET
36	B	C52	*C. jejuni*	Chicken	4	32	32	0.125	0.5	CIP-TET
37	B	C61	*C. jejuni*	Chicken	16	64	0.125	0.5	0.5	CIP-NAL
38	B	C62	*C. jejuni*	Chicken	8	128	0.125	0.5	0.125	CIP-NAL
39	B	C65	*C. jejuni*	Chicken	0.06	64	0.5	0.125	0.5	NAL
40	B	C77	*C. jejuni*	Chicken	0.03	2	8	0.25	0.125	Susceptible
41	B	C87	*C. jejuni*	Chicken	8	64	8	0.125	0.25	CIP-NAL
42	B	C88	*C. jejuni*	Chicken	8	128	16	0.25	1	CIP-NAL-TET
43	B	C91	*C. jejuni*	Chicken	8	128	32	0.25	0.5	CIP-NAL-TET
44	B	C92	*C. jejuni*	Chicken	8	128	64	0.25	0.5	CIP-NAL-TET

Table C-1 Antimicrobial susceptibility and source of *Campylobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
45	B	D1	*C. coli*	Duck	16	128	0.25	0.5	2	CIP-NAL
46	B	D2	*C. jejuni*	Duck	0.03	2	<0.06	0.25	0.5	Susceptible
47	B	D4	*C. jejuni*	Duck	0.125	4	16	0.25	0.5	TET
48	B	D5	*C. jejuni*	Duck	16	128	32	0.5	1	CIP-NAL-TET
49	B	D6	*C. jejuni*	Duck	0.06	4	1	0.25	1	Susceptible
50	B	D7	*C. jejuni*	Duck	16	128	64	0.25	1	CIP-NAL-TET
51	B	D9	*C. coli*	Duck	16	128	64	0.5	2	CIP-NAL-TET
52	B	D10	*C. coli*	Duck	0.06	4	16	0.5	0.25	TET
53	B	D11	*C. coli*	Duck	16	128	64	0.5	2	CIP-NAL-TET
54	B	D12	*C. coli*	Duck	8	64	16	0.5	2	CIP-NAL-TET
55	B	D13	*C. coli*	Duck	16	128	1	0.5	2	CIP-NAL
56	B	D14	*C. coli*	Duck	16	128	0.5	0.5	4	CIP-NAL
57	B	D15	*C. jejuni*	Duck	0.03	4	32	0.5	0.25	TET
58	B	D16	*C. coli*	Duck	16	128	64	0.5	2	CIP-NAL-TET
59	B	D17	*C. coli*	Duck	16	128	128	0.5	2	CIP-NAL-TET
60	B	D18	*C. coli*	Duck	16	128	128	0.5	2	CIP-NAL-TET
61	B	D19	*C. jejuni*	Duck	4	256	64	0.5	0.5	CIP-NAL-TET
62	B	D20	*C. jejuni*	Duck	8	128	<0.06	0.5	256	CIP-NAL-ERY
63	B	D21	*C. jejuni*	Duck	8	256	128	0.25	0.5	CIP-NAL-TET
64	B	D22	*C. jejuni*	Duck	4	64	32	0.25	0.25	CIP-NAL-TET
65	B	D23	*C. jejuni*	Chicken	8	128	128	0.25	0.5	CIP-NAL-TET
66	B	D24	*C. jejuni*	Duck	4	64	32	0.25	0.25	CIP-NAL-TET

Table C-1 Antimicrobial susceptibility and source of *Campylobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
67	B	D25	*C. jejuni*	Duck	0.06	4	1	0.5	0.5	Susceptible
68	B	D26	*C. jejuni*	Duck	16	256	0.125	1	1	CIP-NAL
69	B	D27	*C. jejuni*	Duck	32	128	0.5	1	2	CIP-NAL
70	B	D28	*C. jejuni*	Duck	16	128	0.125	0.5	1	CIP-NAL
71	B	D29	*C. jejuni*	Duck	16	256	0.125	0.5	1	CIP-NAL
72	B	D30	*C. jejuni*	Duck	16	128	<0.06	0.5	1	CIP-NAL
73	B	D32	*C. jejuni*	Duck	0.06	8	0.5	0.5	0.5	Susceptible
74	B	D33	*C. jejuni*	Duck	16	128	128	0.25	1	CIP-NAL-TET
75	B	D34	*C. jejuni*	Duck	8	128	32	0.5	1	CIP-NAL-TET
76	B	D35	*C. jejuni*	Duck	4	64	<0.06	0.5	0.25	CIP-NAL
77	B	D36	*C. jejuni*	Duck	4	128	32	0.5	0.5	CIP-NAL-TET
78	B	D38	*C. jejuni*	Duck	16	128	32	0.5	1	CIP-NAL-TET
79	B	P4	*C. coli*	Pork	32	128	256	2	>512	CIP-NAL-TET-ERY
80	B	P61	*C. jejuni*	Pork	16	256	128	0.5	1	CIP-NAL-TET
81	C	C5	*C. coli*	Chicken	16	64	64	0.5	0.5	CIP-NAL-TET
82	C	C6	*C. jejuni*	Chicken	16	256	64	0.5	2	CIP-NAL-TET
83	C	C25	*C. jejuni*	Chicken	8	128	64	0.5	0.5	CIP-NAL-TET
84	C	C26	*C. jejuni*	Chicken	0.03	2	64	0.25	0.25	TET
85	C	C37	*C. jejuni*	Chicken	8	32	128	0.25	0.5	CIP-TET
86	C	C38	*C. jejuni*	Chicken	8	32	128	0.25	0.5	CIP-TET
87	C	C53	*C. coli*	Chicken	8	64	0.25	0.25	0.5	CIP-NAL
88	C	C54	*C. jejuni*	Chicken	0.06	4	0.25	0.5	1	Susceptible

Table C-1 Antimicrobial susceptibility and source of *Campylobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (μg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
89	C	C59	*C. coli*	Chicken	64	128	32	0.25	1	CIP-NAL-TET
90	C	C60	*C. jejuni*	Chicken	8	64	32	0.5	128	CIP-NAL-TET-ERY
91	C	C79	*C. jejuni*	Chicken	8	128	16	0.25	0.125	CIP-NAL-TET
92	C	C80	*C. coli*	Chicken	32	128	64	>128	>512	CIP-NAL-TET-GEN-ERY
93	C	P5	*C. jejuni*	Pork	32	64	64	>128	>512	CIP-NAL-TET-GEN-ERY
94	C	P6	*C. coli*	Pork	16	256	0.125	0.5	0.5	CIP-NAL
95	C	P25	*C. jejuni*	Pork	32	256	256	0.5	0.5	CIP-NAL-TET
96	C	P53	*C. jejuni*	Pork	4	4	2	0.5	0.5	CIP
97	C	P54	*C. coli*	Pork	32	128	64	1	>512	CIP-NAL-TET-ERY
98	C	P80	*C. jejuni*	Pork	8	128	64	0.5	512	CIP-NAL-TET-ERY
99	D	C19	*C. jejuni*	Chicken	0.125	4	64	0.5	0.5	TET
100	D	C20	*C. jejuni*	Chicken	0.06	4	<0.06	0.5	0.5	Susceptible
101	D	C63	*C. jejuni*	Chicken	0.06	4	0.125	0.5	1	Susceptible
102	D	C64	*C. jejuni*	Chicken	0.125	8	0.125	0.5	1	Susceptible
103	D	C71	*C. coli*	Chicken	16	64	64	0.5	2	CIP-NAL-TET
104	D	C72	*C. coli*	Chicken	16	64	64	0.5	2	CIP-NAL-TET
105	E	C9	*C. jejuni*	Chicken	16	128	128	0.5	0.5	CIP-NAL-TET
106	E	C10	*C. jejuni*	Chicken	4	128	<0.06	0.25	1	CIP-NAL
107	E	C35	*C. jejuni*	Chicken	32	128	128	0.5	0.5	CIP-NAL-TET
108	E	C36	*C. jejuni*	Chicken	16	128	<0.06	0.5	0.5	CIP-NAL
109	E	C45	*C. jejuni*	Chicken	8	64	<0.06	0.25	0.25	CIP-NAL
110	E	C46	*C. jejuni*	Chicken	8	32	<0.06	0.25	0.25	CIP

Table C-1 Antimicrobial susceptibility and source of *Campylobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
111	E	C55	*C. jejuni*	Chicken	16	128	64	0.25	0.5	CIP-NAL-TET
112	E	P9	*C. jejuni*	Pork	8	64	0.5	0.5	0.25	CIP-NAL
113	F	C13	*C. jejuni*	Chicken	0.125	4	0.5	0.5	0.5	Susceptible
114	F	C14	*C. jejuni*	Chicken	0.125	4	0.25	0.5	1	Susceptible
115	F	C21	*C. jejuni*	Chicken	8	128	8	0.5	0.5	CIP-NAL
116	F	C22	*C. jejuni*	Chicken	16	256	64	0.5	0.5	CIP-NAL-TET
117	F	C47	*C. jejuni*	Chicken	8	32	32	0.5	0.5	CIP-TET
118	F	C48	*C. jejuni*	Chicken	8	64	0.125	0.25	0.5	CIP-NAL
119	G	C11	*C. coli*	Chicken	32	128	64	0.5	2	CIP-NAL-TET
120	G	C31	*C. jejuni*	Chicken	0.06	4	<0.06	0.5	0.5	Susceptible
121	G	C32	*C. jejuni*	Chicken	16	128	32	0.25	0.5	CIP-NAL-TET
122	G	C49	*C. jejuni*	Chicken	16	128	64	0.25	0.5	CIP-NAL-TET
123	G	C50	*C. jejuni*	Chicken	16	128	64	0.25	0.5	CIP-NAL-TET
124	H	C15	*C. jejuni*	Chicken	16	128	128	0.25	0.5	CIP-NAL-TET
125	H	C16	*C. coli*	Chicken	64	128	256	0.5	2	CIP-NAL-TET
126	H	C30	*C. jejuni*	Chicken	16	32	64	0.25	0.5	CIP-TET
127	H	B16	*C. jejuni*	Beef	8	128	128	0.5	0.5	CIP-NAL-TET
128	I	C17	*C. jejuni*	Chicken	8	64	64	0.25	0.5	CIP-NAL-TET
129	I	C18	*C. jejuni*	Chicken	0.125	64	0.125	0.5	1	NAL
130	I	C33	*C. jejuni*	Chicken	32	128	128	0.5	2	CIP-NAL-TET
131	I	C34	*C. coli*	Chicken	16	128	128	0.5	>512	CIP-NAL-TET-ERY

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
1	A	C39	*A. butzleri*	Chicken	0.06	16	1	0.5	2	Susceptible
2	A	C57	*A. butzleri*	Chicken	0.125	32	0.5	0.5	2	Susceptible
3	A	C58-0	*A. butzleri*	Chicken	0.06	64	1	0.5	2	NAL
4	A	C58-1	*A. cryaerophilus*	Chicken	1	128	2	2	2	NAL
5	A	C67	*A. butzleri*	Chicken	0.125	64	1	0.5	2	NAL
6	A	C68	*A. butzleri*	Chicken	0.06	32	1	1	2	Susceptible
7	A	C74	*A. butzleri*	Chicken	0.125	64	0.5	0.5	2	NAL
8	A	C75	*A. butzleri*	Chicken	0.06	32	1	0.5	2	Susceptible
9	A	C76	*A. butzleri*	Chicken	4	4	0.25	0.5	1	Susceptible
10	A	C81	*A. butzleri*	Chicken	16	>512	1	1	1	CIP-NAL
11	A	C82	*A. butzleri*	Chicken	0.03	16	0.5	0.5	2	Susceptible
12	A	C83	*A. butzleri*	Chicken	0.125	64	1	0.5	4	NAL
13	A	C84	*A. butzleri*	Chicken	16	>512	1	2	4	CIP-NAL
14	A	C85	*A. butzleri*	Chicken	0.06	128	0.25	0.5	0.5	NAL
15	A	C86	*A. butzleri*	Chicken	0.03	8	0.125	0.5	1	Susceptible
16	A	C89	*A. butzleri*	Chicken	0.125	64	1	0.5	0.5	NAL
17	A	C93	*A. butzleri*	Chicken	0.06	32	0.5	2	1	Susceptible
18	A	C94	*A. butzleri*	Chicken	0.03	32	0.125	0.5	1	Susceptible
19	A	C95	*A. butzleri*	Chicken	0.25	64	2	1	8	NAL
20	A	C96	*A. butzleri*	Chicken	0.125	64	1	2	4	NAL
21	A	C97	*A. butzleri*	Chicken	16	>512	0.5	1	2	CIP-NAL
22	A	C98	*A. butzleri*	Chicken	32	>512	2	2	16	CIP-NAL

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
23	A	C99	*A. butzleri*	Chicken	16	>512	0.5	0.5	1	CIP-NAL
24	A	C100	*A. butzleri*	Chicken	0.125	128	0.5	0.5	4	NAL
25	A	C101	*A. butzleri*	Chicken	0.125	128	1	1	2	NAL
26	A	C103	*A. butzleri*	Chicken	32	>512	0.5	0.25	4	CIP-NAL
27	A	C104	*A. butzleri*	Chicken	0.125	64	0.5	0.5	4	NAL
28	A	P2	*A. butzleri*	Pork	1	128	1	1	4	NAL
29	A	P27	*A. butzleri*	Pork	16	256	2	1	2	CIP-NAL
30	A	P39	*A. butzleri*	Pork	16	>512	1	1	2	CIP-NAL
31	A	P40	*A. butzleri*	Pork	0.125	128	4	1	2	NAL
32	A	P58	*A. butzleri*	Pork	0.125	128	4	1	4	NAL
33	A	P67	*A. butzleri*	Pork	0.06	8	0.125	1	1	Susceptible
34	A	P68	*A. butzleri*	Pork	0.125	128	1	2	4	NAL
35	A	P74	*A. butzleri*	Pork	8	512	0.5	1	0.5	CIP-NAL
36	A	P81	*A. butzleri*	Pork	0.125	16	0.5	1	0.5	Susceptible
37	A	P82	*A. butzleri*	Pork	0.125	32	1	1	1	Susceptible
38	A	P83	*A. butzleri*	Pork	0.06	8	0.5	1	0.5	Susceptible
39	A	P84	*A. cryaerophilus*	Pork	0.25	8	1	0.5	2	Susceptible
40	A	P86	*A. butzleri*	Pork	32	512	1	1	1	CIP-NAL
41	A	P95	*A. butzleri*	Pork	64	>512	1	1	2	CIP-NAL
42	A	P97	*A. butzleri*	Pork	0.5	>512	1	1	4	NAL
43	A	P98	*A. butzleri*	Pork	0.125	32	0.5	2	2	Susceptible
44	A	P99	*A. butzleri*	Pork	0.25	32	1	1	16	Susceptible

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
45	B	P100	*A. cryaerophilus*	Pork	0.125	64	2	1	2	NAL
46	B	P104	*A. butzleri*	Pork	0.125	16	0.5	1	1	Susceptible
47	B	B1	*A. butzleri*	Beef	0.125	32	1	2	16	Susceptible
48	B	B2	*A. butzleri*	Beef	0.125	64	2	1	16	NAL
49	B	B27	*A. butzleri*	Beef	0.25	128	2	1	2	NAL
50	B	B28	*A. butzleri*	Beef	0.125	8	0.5	1	0.5	Susceptible
51	B	B68	*A. butzleri*	Beef	0.25	16	1	2	1	Susceptible
52	B	B75	*A. butzleri*	Beef	0.06	64	0.25	2	1	NAL
53	B	B76	*A. butzleri*	Beef	0.125	64	2	2	8	NAL
54	B	B86	*A. butzleri*	Beef	0.25	32	1	1	0.25	Susceptible
55	B	B89	*A. butzleri*	Beef	0.25	256	0.5	2	4	NAL
56	B	B90	*A. butzleri*	Beef	0.25	16	1	2	2	Susceptible
57	B	B98	*A. butzleri*	Beef	0.125	32	2	2	2	Susceptible
58	B	B103	*A. butzleri*	Beef	1	256	2	4	4	NAL
59	B	B104	*A. butzleri*	Beef	0.25	16	1	2	2	Susceptible
60	B	C3	*A. butzleri*	Chicken	0.06	16	0.5	0.5	2	Susceptible
61	B	C4-0	*A. butzleri*	Chicken	0.125	128	1	0.5	2	NAL
62	B	C4-1	*A. cryaerophilus*	Chicken	0.5	64	2	1	8	NAL
63	B	C23	*A. butzleri*	Chicken	0.06	32	1	0.5	2	Susceptible
64	B	C24-0	*A. butzleri*	Chicken	0.06	32	0.5	0.5	1	Susceptible
65	B	C24-1	*A. cryaerophilus*	Chicken	0.25	32	2	2	4	Susceptible
66	B	C43-0	*A. butzleri*	Chicken	32	>512	0.5	1	2	CIP-NAL

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
67	B	C43-2	*A. cryaerophilus*	Chicken	1	64	32	2	2	NAL-TET
68	B	C44	*A. butzleri*	Chicken	0.25	64	1	2	1	NAL
69	B	C51	*A. butzleri*	Chicken	0.125	128	2	0.5	4	NAL
70	B	C52	*A. butzleri*	Chicken	0.125	128	2	0.5	4	NAL
71	B	C61	*A. butzleri*	Chicken	0.06	64	1	0.5	2	NAL
72	B	C62	*A. butzleri*	Chicken	0.06	4	0.25	1	1	Susceptible
73	B	C65	*A. butzleri*	Chicken	0.25	128	2	0.5	2	NAL
74	B	C66	*A. skirrowii*	Chicken	0.06	16	0.125	1	0.5	Susceptible
75	B	C77	*A. butzleri*	Chicken	0.125	64	1	0.5	2	NAL
76	B	C78	*A. butzleri*	Chicken	0.125	64	1	1	2	NAL
77	B	C87	*A. butzleri*	Chicken	0.06	32	0.5	0.5	1	Susceptible
78	B	C88	*A. butzleri*	Chicken	0.125	16	0.5	1	4	Susceptible
79	B	C91	*A. butzleri*	Chicken	0.06	64	1	1	2	NAL
80	B	C92	*A. butzleri*	Chicken	0.06	4	0.125	0.25	0.125	Susceptible
81	B	P3	*A. butzleri*	Pork	0.125	64	0.5	0.5	2	NAL
82	B	P4	*A. butzleri*	Pork	32	>512	0.5	0.5	8	CIP-NAL
83	B	P23	*A. butzleri*	Pork	0.125	64	1	2	8	NAL
84	B	P43	*A. butzleri*	Pork	0.125	64	0.5	>128	2	NAL-GEN
85	B	P44	*A. butzleri*	Pork	0.125	128	1	2	2	NAL
86	B	P51	*A. butzleri*	Pork	2	128	2	2	32	NAL-ERY
87	B	P52	*A. butzleri*	Pork	2	256	2	1	2	NAL
88	B	P61	*A. butzleri*	Pork	0.25	256	2	1	8	NAL

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
89	B	P65	*A. butzleri*	Pork	0.25	32	0.5	2	8	Susceptible
90	B	P66	*A. butzleri*	Pork	0.25	256	2	2	8	NAL
91	B	P87	*A. butzleri*	Pork	0.5	128	1	2	2	NAL
92	B	P88	*A. butzleri*	Pork	0.125	128	1	1	2	NAL
93	B	P91	*A. butzleri*	Pork	1	256	2	1	4	NAL
94	B	B3	*A. cryaerophilus*	Beef	0.125	16	2	1	2	Susceptible
95	B	B43-0	*A. butzleri*	Beef	1	16	1	2	4	Susceptible
96	B	B43-2	*A. cryaerophilus*	Beef	0.25	64	2	2	2	NAL
97	B	B44-0	*A. butzleri*	Beef	0.25	64	0.5	2	8	NAL
98	B	B44-1	*A. cryaerophilus*	Beef	0.25	32	2	2	2	Susceptible
99	B	B51	*A. butzleri*	Beef	0.25	128	2	2	4	NAL
100	B	B52	*A. butzleri*	Beef	0.25	32	1	2	8	Susceptible
101	B	B92	*A. butzleri*	Beef	128	>512	2	2	4	CIP-NAL
102	B	D1	*A. butzleri*	Duck	1	256	8	1	32	NAL-ERY
103	B	D2	*A. butzleri*	Duck	2	128	1	0.5	2	NAL
104	B	D3	*A. butzleri*	Duck	2	128	1	1	2	NAL
105	B	D4	*A. butzleri*	Duck	0.03	16	0.5	1	0.5	Susceptible
106	B	D5	*A. butzleri*	Duck	1	128	2	1	2	NAL
107	B	D6	*A. butzleri*	Duck	128	>512	1	1	1	CIP-NAL
108	B	D7	*A. butzleri*	Duck	2	256	2	1	2	NAL
109	B	D9	*A. butzleri*	Duck	0.06	128	1	1	1	NAL
110	B	D10	*A. butzleri*	Duck	1	128	1	1	2	NAL

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
111	B	D11	*A. butzleri*	Duck	1	128	1	1	2	NAL
112	B	D12	*A. butzleri*	Duck	0.5	256	0.5	1	0.5	NAL
113	B	D13-0	*A. butzleri*	Duck	0.5	32	0.5	1	1	Susceptible
114	B	D13-1	*A. cryaerophilus*	Duck	0.5	512	2	2	8	NAL
115	B	D14-0	*A. butzleri*	Duck	1	128	4	1	8	NAL
116	B	D14-1	*A. cryaerophilus*	Duck	0.5	64	2	1	32	NAL-ERY
117	B	D15	*A. butzleri*	Duck	0.06	64	0.5	2	1	NAL
118	B	D16	*A. butzleri*	Duck	1	64	1	2	4	NAL
119	B	D17	*A. butzleri*	Duck	1	32	1	1	2	Susceptible
120	B	D18	*A. butzleri*	Duck	0.5	128	0.5	1	2	NAL
121	B	D19	*A. butzleri*	Duck	0.5	8	0.5	1	0.25	Susceptible
122	B	D20	*A. butzleri*	Duck	0.06	8	1	1	0.5	Susceptible
123	B	D21	*A. butzleri*	Duck	0.5	16	1	2	1	Susceptible
124	B	D22	*A. butzleri*	Duck	1	128	1	1	2	NAL
125	B	D23	*A. butzleri*	Duck	64	>512	2	2	1	CIP-NAL
126	B	D24	*A. butzleri*	Duck	0.25	256	2	2	4	NAL
127	B	D25	*A. butzleri*	Duck	0.06	8	0.5	1	0.25	Susceptible
128	B	D26	*A. butzleri*	Duck	0.25	256	2	2	8	NAL
129	B	D27	*A. butzleri*	Duck	0.25	8	1	1	2	Susceptible
130	B	D29	*A. butzleri*	Duck	0.25	256	2	2	8	NAL
131	B	D30	*A. butzleri*	Duck	0.25	128	2	1	8	NAL
132	B	D31	*A. butzleri*	Duck	0.125	128	1	1	2	NAL

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
133	B	D32	*A. butzleri*	Duck	0.25	256	2	2	4	NAL
134	B	D33	*A. butzleri*	Duck	0.06	32	2	1	2	Susceptible
135	B	D34	*A. butzleri*	Duck	0.125	64	2	1	8	NAL
136	B	D35	*A. butzleri*	Duck	0.5	64	2	2	4	NAL
137	B	D36	*A. butzleri*	Duck	0.5	32	2	0.5	1	Susceptible
138	B	D37	*A. butzleri*	Duck	8	>512	1	2	0.5	CIP-NAL
139	B	D38	*A. butzleri*	Duck	0.125	128	2	2	8	NAL
140	B	D39	*A. butzleri*	Duck	1	256	2	2	4	NAL
141	B	D40	*A. butzleri*	Duck	8	512	0.5	1	0.25	CIP-NAL
142	C	C5	*A. butzleri*	Chicken	0.03	16	0.25	1	1	Susceptible
143	C	C6	*A. butzleri*	Chicken	0.03	16	0.5	0.5	0.5	Susceptible
144	C	C25-0	*A. butzleri*	Chicken	0.06	64	0.5	0.5	4	NAL
145	C	C25-1	*A. cryaerophilus*	Chicken	0.125	64	1	2	32	NAL-ERY
146	C	C26	*A. butzleri*	Chicken	0.06	32	1	0.5	1	Susceptible
147	C	C37	*A. butzleri*	Chicken	0.06	32	1	0.5	2	Susceptible
148	C	C38	*A. butzleri*	Chicken	0.06	32	1	0.5	1	Susceptible
149	C	C53	*A. butzleri*	Chicken	0.06	4	0.5	1	0.25	Susceptible
150	C	C54	*A. butzleri*	Chicken	0.06	4	0.5	0.5	0.25	Susceptible
151	C	C59	*A. butzleri*	Chicken	0.06	64	1	0.5	2	NAL
152	C	C60	*A. butzleri*	Chicken	0.06	64	1	1	2	NAL
153	C	C70	*A. butzleri*	Chicken	0.06	64	0.5	1	4	NAL
154	C	C79	*A. butzleri*	Chicken	0.125	32	0.5	0.5	1	Susceptible

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
155	C	C80	*A. butzleri*	Chicken	0.06	4	0.5	1	1	Susceptible
156	C	P5	*A. butzleri*	Pork	0.125	64	0.5	0.5	8	NAL
157	C	P6	*A. butzleri*	Pork	0.06	16	0.5	1	1	Susceptible
158	C	P25	*A. butzleri*	Pork	0.125	32	0.5	2	1	Susceptible
159	C	P26	*A. butzleri*	Pork	0.25	512	2	1	16	NAL
160	C	P37	*A. butzleri*	Pork	8	512	0.06	1	0.5	CIP-NAL
161	C	P38-0	*A. butzleri*	Pork	16	>512	0.5	128	1	CIP-NAL-GEN
162	C	P38-3	*A. cryaerophilus*	Pork	0.5	64	2	1	1	NAL
163	C	P53	*A. butzleri*	Pork	1	64	1	2	0.5	NAL
164	C	P54	*A. butzleri*	Pork	0.125	16	1	1	0.5	Susceptible
165	C	P59	*A. butzleri*	Pork	0.25	>512	2	1	8	NAL
166	C	P60	*A. butzleri*	Pork	128	512	1	2	4	CIP-NAL
167	C	P69	*A. butzleri*	Pork	1	32	2	1	1	Susceptible
168	C	P70	*A. butzleri*	Pork	16	>512	8	1	4	CIP-NAL
169	C	P79	*A. butzleri*	Pork	16	>512	0.5	2	1	CIP-NAL
170	C	P80	*A. butzleri*	Pork	2	128	2	2	2	NAL
171	C	B26	*A. butzleri*	Beef	0.125	8	1	0.5	0.5	Susceptible
172	C	B37	*A. butzleri*	Beef	0.125	64	1	2	1	NAL
173	C	B38	*A. butzleri*	Beef	0.25	16	0.5	1	8	Susceptible
174	C	B60	*A. butzleri*	Beef	0.25	32	1	2	4	Susceptible
175	C	B79	*A. butzleri*	Beef	0.25	64	1	1	8	NAL
176	D	C7	*A. butzleri*	Chicken	32	>512	0.5	0.5	2	CIP-NAL

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
177	D	C8	*A. butzleri*	Chicken	32	>512	0.5	0.5	1	CIP-NAL
178	D	C19	*A. butzleri*	Chicken	0.06	32	0.5	0.5	0.5	Susceptible
179	D	C20	*A. skirrowii*	Chicken	0.03	16	0.25	0.5	0.5	Susceptible
180	D	C42	*A. butzleri*	Chicken	0.03	16	0.5	0.5	0.5	Susceptible
181	D	C63	*A. butzleri*	Chicken	0.125	32	1	0.5	1	Susceptible
182	D	C64	*A. butzleri*	Chicken	0.06	64	1	0.5	2	NAL
183	D	C71	*A. butzleri*	Chicken	16	512	0.5	1	2	CIP-NAL
184	D	C72	*A. butzleri*	Chicken	0.125	32	1	2	1	Susceptible
185	D	P64	*A. butzleri*	Pork	0.25	16	1	0.5	8	Susceptible
186	E	C9	*A. butzleri*	Chicken	0.06	8	0.125	0.5	0.5	Susceptible
187	E	C10	*A. butzleri*	Chicken	0.06	8	0.125	0.5	0.5	Susceptible
188	E	C35	*A. butzleri*	Chicken	0.03	16	0.5	0.5	0.5	Susceptible
189	E	C36	*A. butzleri*	Chicken	16	512	0.25	1	1	CIP-NAL
190	E	C45	*A. butzleri*	Chicken	4	32	1	1	4	Susceptible
191	E	C55	*A. butzleri*	Chicken	0.125	64	1	2	1	NAL
192	E	C56	*A. skirrowii*	Chicken	0.125	32	0.25	4	0.5	Susceptible
193	E	P9	*A. butzleri*	Pork	0.06	64	0.5	0.5	4	NAL
194	E	P35	*A. butzleri*	Pork	0.125	64	1	2	0.5	NAL
195	E	P36	*A. butzleri*	Pork	8	512	0.5	1	1	CIP-NAL
196	E	P45	*A. butzleri*	Pork	0.125	16	0.125	1	1	Susceptible
197	E	P46	*A. butzleri*	Pork	0.125	64	0.25	1	0.25	NAL
198	E	P56	*A. butzleri*	Pork	64	>512	1	1	2	CIP-NAL

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
199	E	B36	*A. butzleri*	Beef	0.125	64	0.25	2	1	NAL
200	E	B45	*A. butzleri*	Beef	0.25	256	2	2	8	NAL
201	E	B46	*A. butzleri*	Beef	0.25	128	1	2	1	NAL
202	F	C13	*A. butzleri*	Chicken	0.125	128	1	0.5	4	NAL
203	F	C14	*A. butzleri*	Chicken	0.06	32	0.25	0.5	2	Susceptible
204	F	C21-0	*A. butzleri*	Chicken	0.06	16	0.5	1	1	Susceptible
205	F	C21-1	*A. skirrowii*	Chicken	0.06	8	0.5	2	0.5	Susceptible
206	F	C22	*A. butzleri*	Chicken	16	>512	0.5	1	1	CIP-NAL
207	F	C47	*A. butzleri*	Chicken	32	>512	0.5	0.5	1	CIP-NAL
208	F	C48	*A. butzleri*	Chicken	0.25	128	2	0.5	4	NAL
209	F	P21	*A. butzleri*	Pork	0.125	16	0.5	1	0.5	Susceptible
210	F	P47	*A. butzleri*	Pork	0.125	16	0.5	1	1	Susceptible
211	F	B21	*A. butzleri*	Beef	0.125	64	1	1	16	NAL
212	F	B22	*A. butzleri*	Beef	0.125	16	0.5	1	1	Susceptible
213	G	C11	*A. butzleri*	Chicken	0.06	32	1	0.5	2	Susceptible
214	G	C31	*A. butzleri*	Chicken	0.06	8	0.5	0.5	2	Susceptible
215	G	C32	*A. butzleri*	Chicken	16	>512	0.25	1	0.5	CIP-NAL
216	G	C49	*A. butzleri*	Chicken	0.06	64	1	0.5	2	NAL
217	G	P12	*A. butzleri*	Pork	0.125	32	1	0.5	2	Susceptible
218	G	P31	*A. butzleri*	Pork	0.25	128	2	2	4	NAL
219	G	P32	*A. butzleri*	Pork	128	>512	1	4	0.5	CIP-NAL
220	G	P49	*A. butzleri*	Pork	0.125	64	1	1	4	NAL

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
221	G	P50	*A. butzleri*	Pork	0.125	64	0.5	1	2	NAL
222	G	B31	*A. cryaerophilus*	Beef	0.5	64	2	4	8	NAL
223	G	B32	*A. butzleri*	Beef	0.5	32	1	2	8	Susceptible
224	H	C15	*A. butzleri*	Chicken	0.06	64	0.5	0.5	4	NAL
225	H	C16	*A. butzleri*	Chicken	0.03	16	0.5	1	8	Susceptible
226	H	C29	*A. butzleri*	Chicken	0.125	128	0.5	2	4	NAL
227	H	C30	*A. butzleri*	Chicken	0.25	64	1	0.5	2	NAL
228	H	P15	*A. butzleri*	Pork	0.03	16	0.5	0.5	0.5	Susceptible
229	H	P16	*A. butzleri*	Pork	0.06	8	0.125	1	1	Susceptible
230	H	P29	*A. cryaerophilus*	Pork	0.125	32	1	2	2	Susceptible
231	H	P30	*A. butzleri*	Pork	128	>512	1	2	1	CIP-NAL
232	H	B15	*A. butzleri*	Beef	0.125	128	2	1	2	NAL
233	H	B16	*A. butzleri*	Beef	0.125	8	0.5	1	0.5	Susceptible
234	H	B29	*A. butzleri*	Beef	0.125	64	1	1	16	NAL
235	H	B30	*A. butzleri*	Beef	0.5	64	2	2	4	NAL
236	I	C17	*A. butzleri*	Chicken	0.06	16	0.5	0.5	2	Susceptible
237	I	C18	*A. butzleri*	Chicken	0.125	32	1	1	2	Susceptible
238	I	C33	*A. butzleri*	Chicken	0.06	128	0.5	0.5	4	NAL
239	I	C34	*A. butzleri*	Chicken	32	>512	0.5	0.5	2	CIP-NAL
240	I	P17	*A. butzleri*	Pork	0.5	64	1	4	1	NAL
241	I	P18	*A. butzleri*	Pork	0.06	64	0.5	0.5	2	NAL
242	I	P33	*A. butzleri*	Pork	128	>512	2	2	1	CIP-NAL

Table C-2 Antimicrobial susceptibility and source of *Arcobacter* spp. isolated from retail meat in supermarkets in Bangkok (continued)

No.	Supermarket chain	Strain ID	Species	Type of meat	MICs (µg/ml)					Resistance pattern
					CIP	NAL	TET	GEN	ERY	
243	I	P34	*A. butzleri*	Pork	128	>512	2	2	2	CIP-NAL
244	I	B34	*A. butzleri*	Beef	0.5	32	1	2	1	Susceptible

VITA

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