

## Review on the scenario of *Campylobacter* in Malaysia

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### Article history:

Received: 7 March 2025

Received in revised form: 30 March 2025

Accepted: 1 April 2025

Available Online: 14 May 2025

### Keywords:

Antibiotic resistance,  
Campylobacter,  
Foodborne,  
Risk factors



### OPEN ACCESS

Citation: Jayasekara, M.K.J.K.P. and Dilan, A.S. (2025). Review on the scenario of *Campylobacter* in Malaysia. *Letters in Food Research*, 1(2), e25016. <https://doi.org/10.26656/lifr.1.e25016>

### Abstract

*Campylobacter* is a major zoonotic pathogen, primarily associated with foodborne illnesses worldwide and a leading cause of bacterial gastroenteritis in humans. *Campylobacter jejuni* and *Campylobacter coli* are the most commonly associated species. The epidemiology of *Campylobacter* infections is multifactorial, with transmission occurring primarily through the consumption of undercooked poultry, contaminated water, or unpasteurized dairy products. In Malaysia, the current scenario of *Campylobacter* prevalence remains a concern, with increasing reports of clinical cases of gastroenteritis attributed to this pathogen. Recent studies indicate a notable prevalence of *Campylobacter* in food commodities, particularly in poultry products, which are frequently contaminated. Additionally, *Campylobacter* is commonly found in various animal reservoirs, including poultry, cattle, and livestock, further contributing to its widespread occurrence in food products. The rising antibiotic resistance patterns in *Campylobacter*, especially to fluoroquinolones and macrolides, complicate treatment options and pose a public health threat. This resistance is primarily linked to the over and miss use of antibiotics in clinical setting, animal husbandry, highlighting the need for stringent surveillance and regulation of antimicrobial use. Detection methods for *Campylobacter* include traditional culturing techniques, molecular methods such as PCR, and immunological assays, each with distinct advantages and limitations. *Campylobacter* is known to thrive under specific conditions, and improper handling, storage, and cooking practices exacerbate the risk of contamination in food products. Effective prevention and control measures are critical to reducing *Campylobacter* prevalence, including good manufacturing practices, proper food handling, cooking, and pasteurization techniques, alongside public health initiatives focused on hygiene education. Future perspectives in the management of *Campylobacter* infections involve the development of novel detection methods, improved vaccine strategies for livestock, and enhanced global surveillance systems to monitor the evolution of resistance patterns. Collaborative efforts between government agencies, food industry stakeholders, and public health organizations are essential to curb the burden of *Campylobacter* infections and reduce associated health risks in Malaysia and beyond.

## 1. Introduction

Foodborne diseases have become a key public health issue worldwide with globalisation, advanced food production, dynamics in human demographics, as well as sociocultural behaviour. Food and waterborne diarrheal diseases account for the majority of illnesses and deaths in developing countries (Schlundt *et al.*, 2004). However, only 1 in 6 foodborne cases is presented to a general physician. Ultimately, national surveillance system captures only a number of cases that presented to a general physician (Wheeler *et al.*, 1999).

*Campylobacter* is one of the main biological hazards that lead to global foodborne infections. However, lots of reviews and data are available for developed countries (Silva *et al.*, 2011); there is a scarcity in the evaluation of the status of *Campylobacter* in developing and middle-income countries. It is essential to elucidate and understand the status of *Campylobacter* in Malaysia to reduce the burden of infection and to implement mitigation strategies. Further, this review illustrates the latest available data on microbiological, epidemiological, and clinical aspects of *Campylobacter*.

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### 1.1 Historical perspectives

In 1886, Theodor Escherich has observed a spiral non-cultivable organism in a stool sample from a child that eventually died of cholera. This might be the first observation of *Campylobacter* (Butzler, 2004; Skirrow, 2006). In May 1938, a milk-borne diarrheal outbreak occurred among 355 convicts in two neighbouring prisons in Illinois, United States. Though the cultures of stool samples were negative, broth cultures of blood samples from 13 patients showed growth of an organism similar to *Vibrio jejuni* and this outbreak considered as the first reported *Campylobacter* infection in humans caused by either *C. jejuni* or *C. coli* (Levy, 1946). The first human *Campylobacter* strain was isolated in the early 1970s by Dekyser et al. (1972) and Butzler et al. (1973) from blood and faeces of a woman with hemorrhagic enteritis in Brussel, Belgium. However, this work was not recognised until the development of Skirrow's selective growth media in 1977 that ultimately facilitated the routine isolation and detection of *Campylobacter* (Skirrow, 1977). Since then, the status quo of *Campylobacter* has been revealed and become one of the leading causes of foodborne pathogens in humans (Olson et al., 2008).

## 2. Classification

Sebald and Veron identified variation in DNA base content, metabolism, and growth requirement between the microaerophilic *V. fetus* group and *Vibrio* spp. Hence, in 1963, Sebald and Veron proposed a new genus

*Campylobacter* for *V. fetus* and *V. bubulus* (now named as *C. sputorum*). *Campylobacter* is a Greek word, which denotes curved rod (Sebald and Veron, 1963). Ten years later, Véron and Chatelain did a taxonomic revision for the genus *Campylobacter* including *C. fetus*, *C. coli*, *C. jejuni*, and *C. sputorum* (Véron and Chatelain, 1973).

The family *Campylobacteraceae* includes three genera namely, *Campylobacter*, *Arcobacter*, and *Sulfurospirillum* (Garrity et al., 2005). With the development of science and technology, there have been a number of taxonomic revisions in the genus *Campylobacter* (Vandamme and De Ley, 1991). The List of Prokaryotic names with Standing in Nomenclature has indicated 32 species and 13 subspecies within the genus *Campylobacter* (LPSN 2012).

### 2.1 Characteristics of *Campylobacter*

*Campylobacter* is a Gram-negative, non-spore forming, small, slender, spirally curved rods (0.2-0.8 × 0.5-5 µm) that form "S" or a "V" shape of gull-wings when group together. The single polar unsheathed flagellum located at one or both ends of the organism assists in the corkscrew-like motility. Unlike the other members, *C. gracilis* is non-motile while *C. showae* contains multiple flagella (Debruyne et al., 2008). *Campylobacter* inhabits the intestinal tract of warm-blooded animals. Table 1 summarises existing members of the genus *Campylobacter* and reservoirs.

Table 1. Members of the genus *Campylobacter* and reservoirs.

<i>Campylobacter</i> spp.	Hosts	Sites of isolation	References
<i>C. avium</i>	Poultry, turkey	Cecum	Rossi et al., 2009
<i>C. canadensis</i>	Whooping crane	Cloacal swabs	Inglis et al., 2007
	Cat	Faeces	Bruce et al., 1980
	Cat	Rectum	Andrzejewska et al., 2013
	Cattle	Faeces	Nielsen et al., 1997
	Cattle	Bile	Enokimoto et al., 2007
	Chicken	Faeces	Nielsen et al., 1997
	Dog	Faeces	Bruce et al., 1980
	Dog	Rectum	Andrzejewska et al., 2013
	Duck	Cloacal	Tsai and Hsiang, 2005
	Feral swine	Oral cavity, recto-anal	Jay-Russell et al., 2012
	Goat	Faeces	Salihu et al., 2009
	Horse	Faeces	Baserisalehi et al., 2007
	<i>C. coli</i>	Japanese Macaque	Faeces
Lamb		Faeces, Intestine	Stanley et al., 1998
Migratory birds		Faeces	Waldenstrom et al., 2002
Pig		Faeces	Nielsen et al., 1997
Rhesus Monkey		Rectal swabs	Andrade et al., 2007
Sheep		Faeces	Garcia et al., 2010
Turkey		Faeces	Wright et al., 2008
Wild birds		Faeces	Keller and Shriver, 2014
Cat		Saliva	Petersen et al., 2007
<i>C. concisus</i>		Human	Oral cavity
	Human	Saliva	Petersen et al., 2007
<i>C. corcagiensis</i> sp. nov.	Lion-tailed macaques	Faeces	Kozziel et al., 2014b
<i>C. cunicolorum</i>	Rabbit	Caeca contents	Zanoni et al., 2009
	Dog	Faeces	Chaban et al., 2010
<i>C. curvus</i>	Cattle	Faeces	Inglis and Kalischuk, 2004
	Dog	Faeces	Chaban et al., 2010
	Dog	Faeces	Chaban et al., 2010
<i>C. fetus</i>	Feral swine	Oral cavity, recto-anal	Jay-Russell et al., 2012
	Sheep	Faeces	Garcia et al., 2010
	Sheep	Foetus	Oporto and Hurtado, 2011
	Turtle, lizards, and snakes	Faeces	Wang et al., 2013

Table 1. Members of the genus *Campylobacter* and reservoirs. (cont')

<i>C. fetus</i> subsp. <i>Testudinum</i>	Reptiles	Faeces	Fitzgerald et al., 2014
<i>C. gracilis</i>	Dog	Faeces	Chaban et al., 2010
	Human	Saliva	Petersen et al., 2007
<i>C. hominis</i>	Human	Faeces	Lawson et al., 2001
<i>C. helveticus</i>	Cat	Faeces	Stanley et al., 1992
	Dog	Faeces	Chaban et al., 2010
	African elephant	Faeces	Misawa et al., 2000
	Cattle	Faeces	Inglis and Kalischuk, 2004
	Chimpanzee	Faeces	Misawa et al., 2000
	Dog	Faeces	Chaban et al., 2010
	Feral swine	Oral cavity, recto-anal	Jay-Russell et al., 2012
	Hamster	Intestine	Gebhart et al., 1985
	Japanese Macaque	Faeces	Misawa et al., 2000
	Lamb	Faeces, Intestine	Stanley et al., 1998
<i>C. hyointestinalis</i> , <i>C. hyointestinalis</i> subsp. <i>hyointestinalis</i> , and <i>C. hyointestinalis</i> subsp. <i>lawsonioid</i>	Lowland Gorilla	Faeces	Misawa et al., 2000
	Moluccan rusa deer	Faeces, ileum, caecum, colon and mesenteric lymph node	Hill et al., 1987
	Orang-utan	Faeces	Misawa et al., 2000
	Pig	Stomach	On et al., 1995
	Pig	Faeces	Oporto and Hurtado, 2011
	Sheep	Faeces	Oporto and Hurtado, 2011
	Northern elephant seal	Rectum	Stoddard et al., 2007
	Porpoise carcass ( <i>Phocoena Phocoena</i> )	Small intestine	Foster et al., 2004
	Southern American sea lion	Faeces	González et al., 2011
	Wild common seal ( <i>Phoca vitulina</i> )	Rectum	Foster et al., 2004
<i>C. insulaenigrae</i>	Blue Hare	Faeces	Rosef et al., 1983
	Cats	Faeces	Kaijser, 1981
	Cats	Rectum	Andrzejewska et al., 2013
	Cape hyrax	Faeces	Misawa et al., 2000
	Cattle	Faeces	Kaijser, 1981; 2004
	Cattle	Intestinal content	Munroe et al., 1983
	Cattle	Bile	Matsumoto et al., 2008
	Chicken	Faeces	Kaijser, 1981; Nielsen et al., 1997
	Chicken	Ceca, Cloacal, oviduct	Camarda et al., 2000
	Chilean Flamingo	Faeces	Misawa et al., 2000
	Chimpanzee	Faeces	Misawa et al., 2000
	Common peafowl	Faeces	Misawa et al., 2000
	Crow	Faeces	Keller et al., 2011
	Dog	Faeces	Kaijser, 1981; Chaban et al., 2010; Koene et al., 2004
	Dog	Rectum	Andrzejewska et al., 2013
	Duck	Cloacal	Tsai and Hsiang, 2005
	Fantail Pigeon	Faeces	Misawa et al., 2000
	Feral swine	Oral cavity, recto-anal	Jay-Russell et al., 2012
	Goat	Faeces	Salihu et al., 2009
	Gulls	Faeces	Keller et al., 2011
Horse	Faeces	Baserisalehi et al., 2007	
Lamb	Faeces, Intestine	Stanley et al., 1998	
Llama	Faeces	Misawa et al., 2000	
Migratory birds	Faeces	Waldenstrom et al., 2002	
Monkey	Faeces	Kalashnikova et al., 2002	
<i>C. jejuni</i> , <i>C. jejuni</i> subsp. <i>jejuni</i> , and <i>C. jejuni</i> subsp. <i>Doylei</i>	Northern elephant seal	Rectum	Stoddard et al., 2005
	Pig	Faeces	Kaijser, 1981; Nielsen et al., 1997
	Rhesus Monkey	Rectal swabs	Andrade et al., 2007
	Sheep	Faeces	Rosef et al., 1983; Garcia et al., 2010
	Turkey	Faeces	Wright et al., 2008
	Wild griffon vultures	Cloacal	Marin et al., 2014
	Cattle	Faeces	Inglis and Kalischuk, 2004
	Chinchillas	Faeces	Turowski et al., 2014
	Healthy abattoir workers	Faeces	Logan et al., 2000
	Feral swine	oral cavity, recto-anal	Jay-Russell et al., 2012
<i>C. lanienae</i>	Pig	Faeces	Sasaki et al., 2003
	Sheep	Faeces	Oporto and Hurtado, 2011

Table 1. Members of the genus *Campylobacter* and reservoirs. (cont')

	Cattle	Faeces	Nielsen <i>et al.</i> , 1997	
	Chicken	Faeces	Nielsen <i>et al.</i> , 1997	
	Chilean Flamingo	Faeces	Misawa <i>et al.</i> , 2000	
	Dog	Faeces	Koene <i>et al.</i> , 2004	
<i>C. lari</i> , <i>C. lari</i> subsp. <i>lari</i> , and <i>C. lari</i> subsp. <i>concheus</i>	Dog	Saliva	Petersen <i>et al.</i> , 2007	
	Goat	Faeces	Salihu <i>et al.</i> , 2009	
	Lamb	Intestine	Stanley <i>et al.</i> , 1998	
	Migratory birds	Faeces	Waldenstrom <i>et al.</i> , 2002	
	Molluscs	Molluscs	Debruyne <i>et al.</i> , 2009	
	Northern elephant seal	Rectum	Stoddard <i>et al.</i> , 2005	
	Pig	Faeces	Nielsen <i>et al.</i> , 1997	
	<i>C. mucosalis</i>	Dog	Faeces	Chaban <i>et al.</i> , 2010
	<i>C. peloridis</i>	Molluscs	Molluscs	Debruyne <i>et al.</i> , 2009
	<i>C. rectus</i>	Dog	Saliva	Petersen <i>et al.</i> , 2007
	Dog	Faeces	Chaban <i>et al.</i> , 2010	
<i>C. showae</i>	Dog	Saliva	Petersen <i>et al.</i> , 2007	
	Dog	Faeces	Chaban <i>et al.</i> , 2010	
<i>C. sputorum</i> ,	Camel	Faeces	Baserisalehi <i>et al.</i> , 2007	
<i>C. sputorum</i> bv. <i>Sputorum</i> ,	Cattle	Faeces	Atabay and Corry, 1998	
<i>C. sputorum</i> bv. <i>faecalis</i> , and	Dog	Faeces	Chaban <i>et al.</i> , 2010	
<i>C. sputorum</i> bv.	Feral swine	oral cavity, recto-anal	Jay-Russell <i>et al.</i> , 2012	
<i>Paraureolyticus</i>	Goat	Faeces	Salihu <i>et al.</i> , 2009	
<i>C. subantarcticus</i>	Wild birds in sub-Antarctic region	Faeces	Debruyne <i>et al.</i> , 2010a	
<i>C. troglodytis</i>	Chimpanzee	Faeces	Kaur <i>et al.</i> , 2011	
	Cat	Faeces	Hald and Madsen, 1997	
<i>C. upsaliensis</i>	Dog	Faeces	Hald and Madsen, 1997	
	Goat	Faeces	Salihu <i>et al.</i> , 2009	
	Sheep	Faeces	Garcia <i>et al.</i> , 2010	
	Cat	Faeces	Koziel <i>et al.</i> , 2014a	
<i>C. ureolyticus</i>	Cattle	Milk	Koziel <i>et al.</i> , 2012	
	Dog	Faeces	Koziel <i>et al.</i> , 2014a	
	Pig	Faeces	Koziel <i>et al.</i> , 2014a	
<i>C. volucris</i>	Black-headed gull	Cloacal swabs	Debruyne <i>et al.</i> , 2010b	

In 2000, Parkhill and colleagues reported the *C. jejuni* NCTC 11168 whole genome sequence consisting of 1,641,481 base pairs (30.6% G+C) that are predicted to encode 1,654 proteins and 54 stable RNA species. In the genome, there are hypervariable sequences and homopolymeric genes encode for the biosynthesis or modification of surface structures that may facilitate the survival of *Campylobacter* (Parkhill *et al.*, 2000).

### 3. Epidemiology

*Campylobacter* is part of the normal flora of animals; hence, animal-origin food products can be easily contaminated during slaughtering and processing. In particular, poultry cecum and intestine naturally harbour numerous *Campylobacter* which can easily contaminate the chicken meat. Eating and handling of raw or undercooked poultry is a major source of *Campylobacter* infection in humans (Debruyne *et al.*, 2008). Meat, pork, and mutton can also be contaminated with *Campylobacter* with a comparatively low level. Consumption of raw milk is also a major risk for campylobacteriosis that contributes to most of the *Campylobacter* outbreaks. Additionally, contaminated water sources with *Campylobacter* via livestock faeces have led to outbreaks. Also, vegetables can be contaminated with *Campylobacter* due to the usage of poultry manure. Improper packaging and cross-contamination are the risk factors at the retail level. Improper handling can lead to cross-contaminations even

at the domestic level (Friedman *et al.*, 2004; Debruyne *et al.*, 2008).

The majority of the human *Campylobacter* cases are sporadic, thus difficult to diagnose or trace back to the source of infection. A small proportion of *Campylobacter* cases were lead to outbreaks (Samuel *et al.*, 2004). However, the epidemiology of campylobacteriosis is still puzzling (Engberg 2006). *Campylobacter* cases have reported from both developed and developing countries. The incidence of human infection in the temperate regions is higher than in the tropics. The large discrepancy among the incidence rate from different countries can be attributed to the differences in healthcare facilities, reporting systems, and methodology utilised for detection of *Campylobacter* (Olson *et al.*, 2008).

Though people of all ages can be affected by *Campylobacter* infection, advanced age and a lower socioeconomic status have been identified as risk factors for *Campylobacter* infection (WHO 2012). In developing countries, most incidences occur among children and the infection is endemic. Meanwhile, most of the *Campylobacter* outbreaks in developed countries are reported in elderly people associated with restaurants, schools, and holiday locations. A large proportion of *Campylobacter* patients in developing countries are either asymptomatic carriers or manifest only mild clinical signs such as watery and non-inflammatory

Table 2. Prevalence of *Campylobacter* in food commodities in Malaysia.

Study period	Locations	Samples	Total samples	Prevalence (%)				Microbial load	Reference
				<sup>a</sup> <i>Campy</i>	<sup>b</sup> <i>C. j</i>	<sup>c</sup> <i>C. c</i>	<i>C. j</i> / <i>C. c</i>		
January 2006 to August 2006	Wet markets and supermarkets in Serdang and Seri Kembangan, Malaysia	Chilled chicken parts	80	-	53.8	56.3	-	3->290 MPN/g	Usha et al., 2010
		Fresh chicken parts	80	-	92.5	80	-	3->2400 MPN/g	
February to September 2007	Wet markets and supermarkets in Hulu Langat	Raw chicken meat and marinated raw chicken (fresh)	94	51.0	51.0	-	-	ND	Ilida and Faridah, 2012
		Raw chicken meat and marinated raw chicken (chilled)	35	25.7	25.7	-	-	ND	
		Chicken-based products (frozen)	22	-	-	-	-	ND	
July 2007 to October 2007	Three supermarkets in Kuala Lumpur	Five types of sushi	150	26.6	82.46	0	-	3.6->1100 MPN/g	Tan et al., 2008
		Equipment (swabs)	72	40.3	-	-	-	<sup>d</sup> ND	
		Crates on arrival (faecal droppings)	72	83.3	-	-	-	ND	
November 2008 to April 2009	12 modern poultry processing plants in 6 states of Malaysia	Before inside-outside washing (neck skin)	72	80.6	-	-	-	ND.	Rejab et al., 2012
		After inside out washing (neck skin)	72	62.5	-	-	-	ND	
		Post chilling (neck skin)	72	38.9	-	-	-	ND	
			72						
NA	Three Supermarkets	Chilled chicken meat and by-products	93	70.7	91.4	34.4	-	<3-4600 MPN/g	Tang et al., 2010a
		Fresh chicken meat and by-products	92	91.4	70.7	20.7	-	<3-2400 MPN/g	
NA	Slaughterhouse in Selangor, Malaysia Hypermarket directly supplied by a processing plant in Selangor, Malaysia	Chicken skin and meat	150	84	74.7	0.7	8.7	ND	Tang et al., 2010 b
		Packed chicken	50	94	38	38	56	ND	
		Wet market in Selangor, Malaysia	50	78	70	70	8	ND	
		Hypermarket in Selangor, Malaysia	75	92	69.3	2.7	20	ND	
NA	Supermarket in Seri Kembangan, Selangor, Malaysia	Eight types of raw salad vegetables	102	51.9	40.7	35.2	-	0->2400 MPN/g	Chai et al., 2007
		Eight types of raw salad vegetables	108	67.7	67.7	65.7	-	0->2400 MPN/g	
		Eight types of raw salad vegetables	99	29.4	25.5	22.6	-	0-460 MPN/g	

<sup>a</sup>*Campy*: *Campylobacter* spp.; <sup>b</sup>*C. j*: *C. jejuni*; <sup>c</sup>*C. c*: *C. coli*; <sup>d</sup>ND: Not determined; NA: Not available

diarrhoea (Ketley 1997).

#### 4. Current Scenario of *Campylobacter* in Malaysia

##### 4.1 Clinical cases

Limited studies have been conducted to identify the cause of diarrheal infections in Malaysia. Lim *et al.* (1984) collected samples from inpatients and outpatients from the General Hospital Kuala Lumpur and patients from general practitioners nearby Kuala Lumpur to identify the prevalence of *Campylobacter jejuni* among diarrheic patients; and observed *C. jejuni* in 3.8% of 212 diarrheic children and 4.3% of 69 diarrheic adults. In the control groups, 2.6% prevalence of *C. jejuni* found in children but not in the adults (Lim *et al.*, 1984). Meanwhile, a cross-sectional observation study conducted to determine the causes of acute severe diarrhoea in children. The study comprised of 280 children (< 16 years old) with acute severe diarrhoea was the inpatient and outpatient that presented to the University Malaya Medical Centre (UMMC), Kuala Lumpur during 1978 to 1997 (Lee and Puthuchery 2002). Lee and Puthuchery (2002) concluded that *Campylobacter* was among the top five commonly isolated organisms with 5% prevalence in Malaysia.

##### 4.2 Prevalence of *Campylobacter* in food commodities

A number of studies have been conducted in Malaysia to identify the prevalence of *Campylobacter* in different food commodities (Table 2). One of the studies revealed that the prevalence of *Campylobacter* in

chicken and chicken by-products was ranged from 80% to 90% (Tang *et al.*, 2010a; Usha *et al.*, 2010). Chicken liver harboured the highest prevalence of *C. jejuni* (90.9%) whilst the low prevalence noted in bishops and feet. The number of *Campylobacter* cells in chicken ranged from <3 to 4600 MPN/g (Tang *et al.*, 2010a).

Along the chicken production process, the prevalence of *Campylobacter* were 84% in chicken skin and meat at the slaughterhouse while 94% prevalence was detected in final packed chicken (Tang *et al.*, 2010b). The predominant *Campylobacter* species isolated from chicken was *C. jejuni* and the proportion of this species was 74.7% for chicken skin and meat at slaughterhouse, 56% for packed chicken, 70% for chicken skin and meat at wet market, and 69.3% for chicken skin and meat at hypermarket (Tang *et al.*, 2010b). In addition to chicken, *Campylobacter* was detected in five types of sushi and eight types of salad vegetables in Malaysia.

##### 4.3 Prevalence of *Campylobacter* in animals

Many studies have been conducted in Malaysia to determine the prevalence of *Campylobacter* especially in poultry birds (Table 3). A survey on broiler faecal samples collected from ten different farms in Serdang, Selangor, Malaysia found 76.2% of *Campylobacter* prevalence and both *C. jejuni* and *C. coli* strains were isolated from those faecal samples (Saleha *et al.*, 2002). Yap *et al.* (2005) also indicated that 83.3% prevalence of *C. jejuni* in chicken flocks. Interestingly, the incidence of

Table 3. Prevalence of *Campylobacter* in animals.

Locations	Animals	Samples	Total samples	Prevalence (%)			Reference
				<i>Campylobacter</i> spp.	<i>C. jejuni</i>	<i>C. coli</i>	
Ten farms at five locations in Serdang, Malaysia	Broilers	Cecal contents, cloacal swabs	508	72.6	73.2	26.8	Saleha <i>et al.</i> , 2002
150 accredited broiler farms in Malaysia	Broilers	Faeces	150	70	83.8	-	Yap <i>et al.</i> , 2005
Selangor, Malaysia	House crow	Swabs from the intestine or cloacal	24	25.3	-	-	Ganapathy <i>et al.</i> , 2007
Farms in Selangor, Malaysia	Broilers in close house	Cloacal swabs	152	0	-	-	Tang <i>et al.</i> , 2010b
	Broilers in open house	Cloacal swabs	152	95	94	01	
A large animal ward and a cafeteria in a university in Serdang, Selangor and a poultry farm in Jenderam Hilir, Selangor, Malaysia	House flies	External body surface and internal content	60	5	1.6	3.3	Choo <i>et al.</i> , 2011
Six wet markets at six locations in Selangor, Malaysia	Chicken	Cloacal and cecal swabs	90	96.6	45.5	51.1	Mansouri-najand <i>et al.</i> , 2012
Three ostrich show farms in Malaysia	Ostrich	Cloacal and skin swabs	31	1.6	-	-	Yew <i>et al.</i> , 2012
Three goat farms in Selangor, Malaysia	Goat	Rectal swabs	60	9	8.33	6.67	Noh <i>et al.</i> , 2012
Three farms at Selangor, Malaysia	Duck	Cloacal swabs	75	99	22	77	Nor Fiza <i>et al.</i> , 2013

*Campylobacter* has been reported to be 95% in broilers kept in open houses comparatively none of the samples from broilers in the closed house contained *Campylobacter* (Tang et al., 2010b).

Apart from poultry, several studies have been conducted in Malaysia to investigate the occurrence of *Campylobacter* in other animal species. Twelve percent of Cloacal swabs obtained from ducks were positive for *Campylobacter*. Findings showed that *C. coli* was the most prevalent *Campylobacter* species recovered from ducks, for instance, *C. coli* has isolated from 77% of the duck Cloacal swabs while only 22% samples were positive for *C. jejuni* (Nor Fiza et al., 2013). The prevalence of *Campylobacter* in goats, ostrich, and wild birds were 9%, 1.6%, and 8.2%, respectively (Noh et al., 2012; Yew et al., 2012; Mustaffa et al., 2014). In addition, the prevalence of *C. coli* and *C. jejuni* in house flies were 3.3% and 1.6%, respectively (Choo et al., 2011).

#### 4.4 Antibiotic resistance patterns

Development of resistance to antibiotics and emergence of multi-drug resistant bacteria is a growing concern in the humans and animals. Extensive use and abuse of antibiotics for treatment, prophylaxis, and growth promotion have contributed for the emergence of these super bugs. Antibiotic resistant foodborne pathogens have become a current global public health concern which addressed in many forums (WHO 2012).

Antibiotic resistance profile of *Campylobacter* isolates from Malaysia has been assessed by several studies. A total of 98.7% and 92.2% of *Campylobacter* isolates recovered from chicken meat were resistant to erythromycin and tetracycline, respectively. More than 70% of the isolates were demonstrated resistance to quinolones, including nalidixic acid, norfloxacin, ciprofloxacin, and enrofloxacin (Tang et al., 2009). Usha et al. (2010) reported 100% resistance in *Campylobacter* strains isolated from chicken meat against ampicillin, cephalothin, and enrofloxacin. All the isolates were resistant to at least two tested antibiotics (Usha et al., 2010). Also, *Campylobacter* strains isolated from salad vegetables in Malaysia has revealed resistance to erythromycin (91.1%), tetracycline (85.7%), and enrofloxacin (80.4%), followed by multi-resistance to ten of the antibiotics (Chai et al., 2008).

Consistent with the food products, *Campylobacter* strains isolated from broilers showed 100% resistance to tetracycline followed by streptomycin (82.9%) (Saleha 2002). However, cephalothin resistance isolates (95.5%) was the highest in isolates from broilers while the second highest was to tetracycline (80.8%) while only 51.4% to erythromycin, 42.4% to enrofloxacin, and 24.4% to gentamicin (Mansouri-najand et al., 2012). Mustaffa et al. (2014) also reported that isolates from wild birds demonstrated 100% resistance to trimethoprim-sulfamethoxazole, while 83.3% and 33.3% resistance were towards cefotaxime and tetracycline, respectively.

## 5. Detection methods

### 5.1 Conventional methods

*Campylobacter* is a fastidious organism that hinders its detection in samples. Several methods were initially developed to isolate *Campylobacter* from clinical samples until the later enrichment and enumeration media formulated for isolation of *Campylobacter* in food. Clinical samples can directly plate onto selective media, but food samples require an additional enriched procedure prior subject to culture. The enrichment step facilitates multiplication of the low number of *Campylobacter* cells present in food samples and recovery of damaged cells (Jacobs-Reitsma et al., 2008).

There are several standard microbiological methods developed by International Standards Organisation (ISO), the US Food and Drug Association (FDA), and the UK Health Protection Agency (PHLS) for the isolation of thermotolerant *Campylobacter*. The first ISO method was developed in 1995 and revised in 2006, comprised of ISO 10272-1A for detection of *Campylobacter* in foods with low background count of non-campylobacters and/or with stressed *Campylobacter* and ISO 10272-1B for detection of *Campylobacter* in foods with high background count of non-campylobacters (Hunt et al., 1998; ISO 2006a, 2006b).

Table 4. Purposes and the common media used in each step of conventional culture method.

Step	Purposes
Enrichment	Broth: To resuscitate and recover injured <i>Campylobacter</i> cells
	Supplements: To suppress the growth of competing flora and inhibitory agents
First plating	Media: To detect the presence of <i>Campylobacter</i>
	Supplements: To improve recovery of <i>Campylobacter</i>
Second plating	To isolate pure <i>Campylobacter</i> strains

The general procedures in the standard methods include enrichment, selective first plating, and second plating on selective or non-selective agars. The enrichment is conducted at two phase with pre-enrichment at a lower temperature (37°C) for 4-6 h and followed by enrichment by further incubating for 24-48 h at 41.5°C (Hunt et al., 1998; ISO 2006a, 2006b). Then the enriched broth is cultured on selective agar and incubated at 41.5°C for 24-44 h under microaerophilic condition. Next, presumptive colonies are streaked on non-selective blood agar (Standards Australia, 2004) or selective agar (Hunt et al., 1998). The principles behind the usage of different steps in isolation of *Campylobacter* has illustrated in Table 4.

A number of selective enrichment broths have been developed to resuscitate and recover injured *Campylobacter* cells. These enrichment broths are composed of a basal medium supplied with antimicrobials (Jacobs-Reitsma et al., 2008). The commonly used broths and the supplements for the

Table 5. Broths and supplements that are commonly used for enrichment of *Campylobacter*.

Broth	Media	Supplements
Preston	Peptic digest of animal tissue, beef extract, sodium chloride	Polymyxin B, rifampicin, trimethoprim, cycloheximide
Bolton	Enzymatic digest of animal tissue, yeast extract, sodium carbonate lactalbumin hydrolysate, sodium pyruvate, hemin, sodium metabisulfite, sodium chloride, and $\alpha$ -ketoglutaric acid	Cefoperazone, vancomycin, trimethoprim, cycloheximide
Modified Bolton	Enzymatic digest of animal tissue, yeast extract, sodium carbonate lactalbumin hydrolysate, hemin, sodium pyruvate, sodium chloride, $\alpha$ -ketoglutaric acid, and sodium metabisulfite	Cefoperazone, vancomycin, trimethoprim, amphotericin B
Park and Sanders	Casein enzymic hydrolysate, peptic digest of animal tissue, yeast extract, dextrose, sodium citrate, sodium chloride, monohydrogen sodium sulphite, and sodium pyruvate	Cefoperazone, vancomycin, trimethoprim, cycloheximide
Exeter	Meat peptone, lactalbumin hydrolysate, yeast extract, sodium chloride, $\alpha$ -ketoglutaric acid, sodium carbonate, haemin, sodium metabisulphite, iron (II) sulphate, and sodium pyruvate	Cefoperazone, polymyxin B, vancomycin, amphotericin B

enrichment of *Campylobacter* are listed in Table 5. According to the ISO method, Bolton broth is used to enumerate *Campylobacter* from cooked or frozen samples (categorised under 1A) while Preston broth is used for raw chicken products, raw meats, and raw milk sample (categorised under 1B). The USFDA (Hunt *et al.*, 1998) and PHLS recommend the Bolton broth in their standards, while Preston broth was employed in Australian standards (Standards Australia 2004).

Casein or enzyme digest of animal tissue, yeast, and lactalbumin hydrolysate provide nutrient required for the growth of *Campylobacter*. Sodium metabisulfite and sodium pyruvate quench oxygens thereby improve the aerotolerance which facilitates the survival and recovery of *Campylobacter* in samples. Antimicrobial supplements added to the broth suppress the growth of surrounding microflora and improve recovery of *Campylobacter* (Jacobs-Reitsma *et al.*, 2008).

Recently, several enrichment broths have been developed for the isolation of *Campylobacter* such as Food Pathogen Enrichment (FPE) broth (Hayashi *et al.*, 2013), charcoal-cefoperazone-polymyxin B-deoxycholate (CCPD) broth (Chon *et al.*, 2013), Bolton enrichment broth supplemented with antimicrobial triclosan (T-Bolton broth) (Chon *et al.*, 2014), and Bolton broth with rifampicin (R-Bolton) broth (Kim *et al.*, 2015). All these media had higher detection sensitivity as compared to convention enrichment media (Table 6).

The selective media used for the isolation of *Campylobacter* are categorised into blood free media that contains charcoal and media supplemented with horse or rabbit blood. Both charcoal and blood inhibit the

lethal effect exerted by oxygen and light on *Campylobacter* (Fitzgerald *et al.*, 2014). The media that supplemented with animal blood includes Butzler agar (Butzler *et al.*, 1973), Skirrow agar (Skirrow 1977), Blaser agar (Blaser *et al.*, 1978), Preston agar (Bolton and Robertson 1982), and Campy-Cefex agar (Stern *et al.*, 1992). In the earlier time, all the *Campylobacter* media contained blood, but later Bolton and colleagues (Bolton and Coates 1983; Bolton *et al.*, 1984a; Bolton *et al.*, 1984b; Hutchinson and Bolton 1984) discovered charcoal could be an effective substitute for the function of blood in the media. Thereafter, blood free *Campylobacter* media group has evolved and include modified cefoperazone charcoal deoxycholate agar (mCCDA) (Hutchinson and Bolton 1984), Karmali agar (Karmali *et al.*, 1986), cefoperazone amphotericin teicoplanin agar (CAT) (Corry and Atabay 1997), and Campy-Line agar (Line 2001).

Chromogenic media has been recently introduced for isolation of *Campylobacter*, including Campy Food ID agar for isolation of *Campylobacter* from food and environmental samples, Brilliance CampyCount agar for isolation of *C. jejuni* and *C. coli* from poultry, and CASA for isolation of *Campylobacter* in meat, poultry products, and in environmental samples. Ahmed *et al.* (2012) examined the performance of these chromogenic media using 483 suspected *Campylobacter* isolates and reported 100% colony confirmation rate for CASA. However, the colony confirmation rate of Campy Food ID agar and Brilliance CampyCount agar were lower than conventional agars, modified charcoal cefoperazone-deoxycholate agar (mCCDA) and Campy-Cefex (Ahmed *et al.*, 2012). When compared to conventional

Table 6. Enrichment media for *Campylobacter* isolation.

Broth	Media	Supplements	Detection sensitivity	References
FPE	Soybean-casein digest, Na-Pyruvate, Lab-Lemco Meat Extract, NaHSO <sub>3</sub> , L-Cystine-HCl, hemin, and K <sub>2</sub> HPO <sub>4</sub>	Polymyxin B, trimethoprim, cycloheximide, and rifampicin	80%	Hayashi <i>et al.</i> , 2013
CCPD	Nutrient broth No. 2, bacteriological charcoal, casein hydrolysate, sodium deoxycholate, ferrous sulfate, and sodium pyruvate	Bacteriological charcoal, polymyxin B, cefoperazone, trimethoprim, vancomycin, and amphotericin	76.3%	Chon <i>et al.</i> , 2013
T-Bolton broth	Bolton broth	Triclosan	71.3%	Chon <i>et al.</i> , 2014
R-Bolton	Bolton broth	Rifampicin	99.2%	Kim <i>et al.</i> , 2015

Table 7. Biochemical properties of some common *Campylobacter*.

Characteristic	<i>C. jejuni</i>	<i>C. jejuni</i> subsp. <i>doylei</i>	<i>C. coli</i>	<i>C. lari</i>	<i>C. fetus</i> subsp. <i>fetus</i>	<i>C. upsaliensis</i>
Growth at 25°C	–	±	–	–	+	–
Growth at 35–37°C	+	+	+	+	+	+
Growth at 42°C	+	+	+	+	+	+
Nitrate reduction	+	–	+	+	+	+
H <sub>2</sub> S, lead acetate strip	+	+	+	+	+	+
Catalase	+	+	+	+	+	–
Oxidase	+	+	+	+	+	+
Motility (wet mount)	+	+	+	+	+	+
Hippurate hydrolysis	+	+	–	–	–	–
Nalidixic acid	S	S	S	R	R	S
Cephalothin	R	R	R	R	S	S

+: positive; -: negative; S: sensitive; R: resistance

Source: Hunt et al., 1998

media, chromogenic media has a higher possibility to differentiate *Campylobacter* from surrounding microflora and reduce time and cost. Future studies are required on the applicability of chromogenic media for isolation of *Campylobacter* from clinical and highly contaminated samples, enhancement of the specificity, sensitivity, and recovery of isolation.

Plumer et al. (1962) first used the membrane filtration technique to isolate *C. fetus* from bulls. Later, membrane filters were used for isolation of *Campylobacter* from human clinical samples (Steele and McDermott 1984). For isolation of *Campylobacter* from faecal samples, cellulose acetate and polycarbonate (PC) filters (pore size of 0.60–0.65 µm) were used in different studies (Nielsen et al., 2013, Nielsen et al., 2015) while 0.45 µm cellulose (Speegle et al., 2009) and 0.45 µm pore size cellulose triacetate (Bi et al., 2013) membrane filters have applied in isolation of *Campylobacter* in chicken meat. The 0.60–0.65 µm pore size filters have higher sensitivity while 0.45 µm filters have higher possibility to minimise unintentional transfer of competitive flora onto the culture media (Man 2011). The PC membranes have shown to be superior to routinely used cellulose acetate filters (Nielsen et al., 2013). The Enrichment of samples prior to usage of membrane filtration improves higher recovery of *Campylobacter* cells. The membrane filtration technique is very useful to obtain pure cultures (Speegle et al., 2009) and to improve the isolation of *Campylobacter* (Jokinen et al., 2012; Bi et al., 2013).

### 5.2 Identification methods

Species identification of thermophilic *Campylobacter* by biochemical tests is tedious (Weino et al., 2003). Hippurate hydrolysis is the only test available to differentiate *C. jejuni* from *C. coli*. However, this procedure can lead to misidentification because of hippurate-variable or hippurate-negative *C. jejuni* strains are available (Waino et al., 2003). Biochemical properties of commonly isolated *Campylobacter* are summarised in Table 7.

Other methods which are used to identify and confirm *Campylobacter* are latex agglutination tests, Microscreen (Lucron), INDX-Campy (Biotrading), Dryspot *Campylobacter* Test (Oxoid), and BBL-

Campslide (BD) (Jacobs-Reitsma et al., 2008).

### 5.3 Conventional methods used in Malaysia

Bolton broth and mCCDA system have been commonly employed in Malaysia for culturing and isolating *Campylobacter* in faecal and food samples with or without the addition of blood and supplements (Table 8). The gas generating packs were used for generating microaerophilic conditions (Saleha et al., 2002; Chai et al., 2007; Tan et al., 2008; Usha et al., 2010; Tang et al., 2010; Mansouri-najand et al., 2012; Rejab et al., 2012). Apart from biochemical tests, Mast ID™ Camp Identification System (Mast Diagnostics) (Saleha et al., 2002; Mansouri-najand et al., 2012) and Latex agglutination test (Oxoid, Dry Spot *Campylobacter* Test) (Rejab et al., 2012) were used for *Campylobacter* identification while molecular methods were used for confirmation (Chai et al., 2007; Tan et al., 2008; Usha et al., 2010; Tang et al., 2010).

### 5.4 Rapid methods

Enzyme-linked immunosorbent assay (ELISA or EIA) techniques are available for detection of *Campylobacter* in clinical and food samples. Sandwich assays are the most popular immunoassay technique used to detect foodborne pathogens including multi-well micro plates, dipsticks, paddles, membranes, or other solid matrices (Liu et al., 2009; Reiter et al., 2010). A modification of EIA, lateral flow immunochromatography composed of a dipstick or plastic casing was used for rapid diagnosis of pathogens. Lateral flow immunoassay is a simple, cost-effective, stable and rapid, but the detection limit is lower as compared to EIA (Granato et al., 2010). Sensitivity and specificity can be a limitation of EIA methods, and therefore, positive results have to confirm by the conventional culture method (Myers et al., 2011).

Oyofe and colleagues were the pioneers in using polymerase chain reaction (PCR) assay for identification of *Campylobacter* (Oyofe et al., 1992). Since then, the PCR technique has become an efficient method for detection of *Campylobacter*. The introduction of a multiplex PCR assay has assisted in detecting more than one species of bacteria (Persson and Olsen 2005; Oyarzabal et al., 2007; Zhou et al., 2011). To date, PCR

Table 8. Bacterial culture media used in Malaysia for isolation of *Campylobacter*.

Types of samples	Enrichment broth	Supplements	Isolation media	Supplements	References
Cecal contents, cloacal swabs, and cecal swabs	No		CCDA (Oxoid)	CCDA selective supplement (Oxoid)	Saleha et al., 2002 Mansouri-najand et al., 2012
Cloacal swabs, environmental samples, poultry feed and water	Brucella broth (BBL)	Cefoperazone, amphotericin B, sodium pyruvate, sodium metabisulphite, ferrous sulphate	CCDA (Oxoid)	Cefoperazone, amphotericin B	Saleha, 2004
Raw chicken meat, chicken based products, and chilled chicken meat	Bolton Broth (Oxoid)	Bolton Broth Supplement, 5% Laked Horse Blood (Oxoid)	CCDA (Oxoid)	CCDA selective supplement (Oxoid)	Ilida and Faridah, 2012
Sushi	Bolton Broth (Merck)	Bolton Supplement (Merck), 5% lysed horse blood	mCCDA (Merck)	mCCDA (Merck) supplements	Tan et al., 2008
Fresh chicken and chilled chicken meat	Bolton Broth (Merck)	Bolton Supplement (Merck), 5% lysed horse blood	mCCDA (Merck)	mCCDA (Merck) supplements	Tang et al., 2009 Tang et al., 2010 Usha et al., 2010 Chai et al., 2009
Neck skin/faeces	Bolton broth (Oxoid)	5% lysed horse blood, polymyxin B, rifampicin, trimethoprim and cycloheximide	mCCDA (Oxoid) and Karmali agar (Oxoid)	Sodium pyruvate, cefoperazone, vanco-mycin, vanco-mycin, amphotericin	Rejab et al., 2012
Chicken faeces			Filtration system 5% sheep blood agar (Bloxwich, Singapore)		Yap et al., 2005

methods have been widely used in Malaysia to detect *Campylobacter*, including *Campylobacter* genus, *C. jejuni* and *C. coli* using 16S ribosomal RNA, *hipO*, and *ceuE* genes, respectively (Table 9).

Compared to conventional PCR, the real-time PCR (RT-PCR) assays are specific, sensitive, and can quantify target concentration. The closed-tube system of RT-PCR minimises the risks of cross-contamination. In addition, the RT-PCR does not require any gel electrophoresis as in the conventional PCR assays. Several RT-PCR assays have been developed for identification of *Campylobacter* including *C. jejuni* in food (Salis et al., 2003), *C. jejuni* in chicken rinse (Cheng and Griffiths 2003), *C. jejuni* in poultry, milk, and environmental water (Yang et al., 2003), *C. jejuni* in poultry faeces and cecum (Rudi et al., 2004), and *C. jejuni* in chicken rinse (Debretson et al., 2007). Multiplex RT-PCR has also developed for detection of *C. jejuni*, *C. coli*, *C. lari*, *C. upsaliensis*, *C. helveticus*, and *C. hyointestinalis* in chicken faeces (Lund et al., 2004), *C. jejuni* and *C. coli* in clinical and human faeces (LaGier et al., 2004), *C. jejuni* and *C.*

*lanienae* (Inglis and Kalischuk 2004), *C. jejuni*, *C. coli*, *C. lari*, and *C. upsaliensis* in pig faeces (Jensen et al., 2005), *C. jejuni* and *C. coli* in chicken (Hong et al., 2007). Recently, a rapid, sensitive and simple loop-mediated isothermal amplification (LAMP) assay method has been developed for detection of *C. jejuni* and *C. coli* in human faeces (Yamazaki et al., 2008), *C. fetus* (Yamazaki et al., 2009a), *C. jejuni* and *C. coli* in chicken (Yamazaki et al., 2009b).

#### 5.6 Risk factors related to survival and growth of *Campylobacter* in foods

*Campylobacter* spp. are fastidious organisms that require specific growth conditions, such as 3–5% oxygen, 3–10% carbon dioxide, and 85% nitrogen gas. All *Campylobacter* are able to grow at 37°C. Thermophilic *Campylobacter* including *C. coli*, *C. jejuni*, *C. upsaliensis*, and *C. lari* have the optimum growth at 42°C whereas *C. consisus*, *C. curvas*, and *C. fetus* are non-thermophilic *Campylobacter*. The growth rate of *C. jejuni* drastically reduces in temperatures below 30°C.

Table 9. PCR methods used in Malaysia for identification of *Campylobacter*.

Types of samples	Targeted species	Targeted gene	References
	<i>Campylobacter</i> (genus)	16S ribosomal RNA	Chai et al., 2007; Tan et al., 2008; Chai et al., 2009; Tang et al., 2009; Tang et al., 2010
Sushi, chicken meat, and vegetables	<i>C. jejuni</i>	<i>hipO</i> gene	Chai et al., 2007; Tan et al., 2008; Chai et al., 2009; Tang et al., 2009; Tang et al., 2010; Usha et al., 2010
	<i>C. coli</i>	<i>ceuE</i> gene	Chai et al., 2007; Tan et al., 2008; Chai et al., 2009; Tang et al., 2009; Tang et al., 2010; Usha et al., 2010

*Campylobacter ureolyticus* requires hydrogen supply and is unable to grow above 37°C. The osmotic pressure more or less than 2% NaCl concentration, dryness, and pH less than 4.9 hinder the growth of *Campylobacter* (Vandamme et al., 2010).

The microenvironment of the chicken skin and refrigeration conditions facilitate survival of *Campylobacter* (Debruyne et al., 2008; Pires et al., 2010; Taylor et al., 2013). The appearance of *Campylobacter* varies with the age of the culture. In older cultures, *Campylobacter* cells become spherical or coccoidal form which characterise as viable but non-culturable state (VBNC). In unfavourable environments, the *Campylobacter* survives in this VBNC state (Rollins and Colwell 1986). According to some studies, *C. jejuni* was able to survive for more than 4 h at 27°C and 60–62% relative humidity on either clean or soiled food contact surfaces (De Cesare et al., 2003). Previous study also showed that *C. jejuni* and *C. coli* were capable of surviving on raw chicken meat and skin stored at 4°C and –20°C (El-Shibiny et al., 2009).

### 5.7 Prevention and control measures

Naturally, *Campylobacter* are harboured in the intestinal tract of poultry, livestock, pet animals, and wildlife. Consequently, preventing the entry of *Campylobacter* into the animal origin food is rather challenging. Prevention measures can apply at each level of food production system. There is a great focus on preventing contamination at the farm level, especially in poultry. Three main approaches can be used for prevention of *Campylobacter* contamination at the farm level:

- 1) Decrease environmental exposure
- 2) Increase host resistance
- 3) Decrease or eliminate of *Campylobacter* in animals

Through recognising the associated risk factors and minimising exposure can reduce *Campylobacter* contamination at the farm level (Lin 2009). Various methods have been used to increase host resistance. Several vaccines have been developed against *Campylobacter*. However, the vaccines should be immunogenic and prevent *Campylobacter* colonisation in poultry but should not be pathogenic to humans. Competitive expulsion (CE) cultures (Stern et al., 2001; Mead 2002), probiotics (Willis and Redi 2008), bacteriophages (Wagenaar et al., 2005; Carvalho et al., 2010) and bacteriocins (Svetoch et al., 2005; Svetoch et al., 2008) have shown promising results in controlling *Campylobacter* in poultry.

The most effective approach to reducing *Campylobacter* contamination in animal origin food is to prevent faecal contamination during the slaughtering. The combination of steam with ultrasound (Musavian et al., 2014) and electrolysed oxidising water with lactic acid (Rasschaert et al., 2011) has reduced

*Campylobacter* contaminant levels without changing the organoleptic properties. A mixture of acidic calcium sulphate, lactic acid, ethanol, sodium dodecyl sulphate, polypropylene glycol (Zhao and Doyle, 2006) and a combination of trisodium phosphate with capric acid sodium salt (Koolman et al., 2014) were able to reduce *Campylobacter* contamination level. Also, grape phenolic plant extract has reduced *Campylobacter* contamination in food (Mingo et al., 2014).

General measures such as avoiding consumption of raw milk, milk products, and untreated water can minimise exposure to *Campylobacter*. Before consumption, chicken and meat should be thoroughly cooked. Also, food products that commonly consumed raw, including vegetables and fruits should be thoroughly cleaned. Proper handling, preparation, and storage of food can also prevent *Campylobacter* contamination. Findings indicated that air chilling, water chilling, and freezing packed chicken have reduced *Campylobacter* contamination during poultry processing (Rosenquist et al., 2006). Crust freezing (CF) was effective in reducing *C. jejuni* on raw chicken (Haughton et al., 2012).

### Conclusion

In general, conventional microbiological procedures for enrichment, isolation, and identification of *Campylobacter* in samples take around five days (ISO 1995). Since the standard methods used for detection of *Campylobacter* are laborious, tedious and expensive; rapid, sensitive, accurate, and cost-effective methods have been introduced for detection of *Campylobacter* in clinical, food, and environmental samples. For clinical samples, early identification of the causative agent is necessary for the commencement of appropriate treatment and specifically for *Campylobacter* to notify the status of outbreaks. Detection of *Campylobacter* in food and environmental samples are essential in order to trace back to the source of infection and control the risk. Recovery of *Campylobacter* can be compromised when using more selective chromogenic media. Some techniques itself can lead to reducing recovery of *Campylobacter* spp. including *C. upsaliensis*. Still, there is room for improvement of sensitivity, specificity, and recovery in the techniques used for isolation of *Campylobacter*. Laboratory methods have to be standardised and validated. Enhancing and upgrading the available species identification and subtyping methods are necessary for surveillance and diagnosis of causative agent, especially in outbreaks.

Clear identification of risk factors through conducting risk assessment is necessary for implementing various strategies to reduce exposure to *Campylobacter*. Hence, factors related to dynamics in the colonisation of broiler flocks with *Campylobacter* have to be further evaluated. Recognising and implementing multiple interventions to reduce the bacterial load through a stepwise approach along the pre-

and post-harvest stages are necessary. Conducting risk assessment focusing on source attribution studies including various sources and multiple exposure pathways are pivotal. Apart from poultry, focusing on all possible exposure pathways can assist in the elimination of the disease. Incorporating *Campylobacter* into the routine national public health surveillance systems can help identify the true disease burden in Malaysia and deliver information essential for policy decision making.

### Conflict of interest

The author declares no conflict of interest.

### References

- Ahmed, R., León-Velarde, C.G. and Odumeru, J.A. (2012). Evaluation of novel agars for the enumeration of *Campylobacter* spp. in poultry retail samples. *Journal of Microbiological Methods*, 88(2), 304-310. <https://doi.org/10.1016/j.mimet.2011.12.011>
- Andrade, M.C.R., Gabeira, S.C.D.O. Abreu-Lopes, D., Esteves, W.T.C., Vilardo, M.D.C.B., Thome, J., Cabello, P.H. and Lauria-Filgueiras, A.L. (2007). Circulation of *Campylobacter* spp. in rhesus monkeys *Macaca mulatta* held in captivity: a longitudinal study. *Memórias do Instituto Oswaldo Cruz*, 102, 53-57. <https://doi.org/10.1590/s0074-02762007000100008>
- Andrzejewska, M., Szczepańska, B., Klawe, J.J., Śpica, D. and Chudzińska, M. (2013). Prevalence of *Campylobacter jejuni* and *Campylobacter coli* species in cats and dogs from Bydgoszcz Poland region. *Polish Journal of Veterinary Science*, 16, 115-120. <https://doi.org/10.2478/pjvs-2013-0016>
- Atabay, H.I. and Corry, J.E.L. (1998). The isolation and prevalence of *Campylobacters* from dairy cattle using a variety of methods. *Journal of Applied Microbiology*, 84, 733-740. <https://doi.org/10.1046/j.1365-2672.1998.00402.x>
- Baserisalehi, M., Bahador, N. and Kapadnis, B.P. (2007). Isolation and characterization of *Campylobacter* spp. from domestic animals and poultry in south of Iran. *Pakistan Journal of Biological Science*, 10, 1519-1524. <https://10.3923/pjbs.2007.1519.1524>
- Bi, S.L., Shi, L., Yan, H. and Meng, H.C. (2013). Comparison of various culture methods (Skirrow medium, a blood-free medium and a filtration system enriched in Bolton and Preston broths) for isolation of *Campylobacter* spp. from raw meat samples. *Annals of Microbiology*, 63, 179-185. <https://doi.org/10.1007/s13213-012-0459-y>
- Blaser, M., Powers, B., Cravens, J. and Wang, W.L. (1978). *Campylobacter* enteritis associated with canine infection. *Lancet*, 312, 979-981. [https://doi.org/10.1016/s0140-6736\(78\)92541-2](https://doi.org/10.1016/s0140-6736(78)92541-2)
- Bolton, F.J. and Coates, D. (1983). Development of a blood-free *Campylobacter* medium: screening tests on basal media and supplements, and the ability of selected supplements to facilitate aerotolerance. *Journal of Applied Bacteriology*, 54, 115-125. <https://doi.org/10.1111/j.1365-2672.1983.tb01308.x>
- Bolton, F.J., Coates, D. and Hutchinson, D.N. (1984a). The ability of *Campylobacter* media supplements to neutralize photochemically induced toxicity and hydrogen peroxide. *Journal of Applied Bacteriology*, 56, 151-157. <https://doi.org/10.1111/j.1365-2672.1984.tb04707.x>
- Bolton, F.J., Hutchinson, D.N. and Coates, D. (1984b). Blood-free selective medium for isolation of *Campylobacter jejuni* from faeces. *Journal of Clinical Microbiology*, 19, 169-171. <https://doi.org/10.1128/jcm.19.2.169-171.1984>
- Bolton, F.J. and Robertson, L. (1982). A selective medium for isolating *Campylobacter jejuni* /*coli*. *Journal of Clinical Pathology*, 35, 462-467. <https://doi.org/10.1136/jcp.35.4.462>
- Bruce, D., Zochowski, W. and Fleming, G.A. (1980). *Campylobacter* infections in cats and dogs. *Veterinary Records*, 107, 200-201. <https://doi.org/10.1136/vr.107.9.200>
- Butzler, J.P., Dekeyser, P., Detrain, M. and Dehaen, F. (1973). Related vibrio in stools. *The Journal of Pediatrics*, 82, 493-495. [https://doi.org/10.1016/s0022-3476\(73\)80131-3](https://doi.org/10.1016/s0022-3476(73)80131-3)
- Butzler, J.P. (2004). *Campylobacter*, from obscurity to celebrity. *Clinical Microbiology and Infection*, 10, 868-876. <https://doi.org/10.1111/j.1469-0691.2004.00983.x>
- Camarda, A., Newell, D.G., Nasti, R. and Di Modugno, G. (2000). Genotyping *Campylobacter jejuni* strains isolated from the gut and oviduct of laying hens. *Avian Diseases*, 44, 907-912. <https://doi.org/10.2307/1593065>
- Carbonero, A., Paniagua, J., Torralbo, A., Arenas-Montes, A., Borge, C. and García-Bocanegra, I. (2014). *Campylobacter* infection in wild artiodactyl species from southern Spain: Occurrence, risk factors and antimicrobial susceptibility. *Comparative Immunology, Microbiology and Infectious Diseases*, 37, 115-121. <https://doi.org/10.1016/j.cimid.2014.01.001>
- Chaban, B., Ngeleka, M. and Hill, J.E. (2010). Detection and quantification of 14 *Campylobacter* species in pet dogs reveals an increase in species richness in faeces of diarrheic animals. *BMC Microbiology*, 10, 73. <https://doi.org/10.1186/1471-2180-10-73>
- Chai, L.C., Robin, T., Ragavan, U.M., Gunsalam, J.W., Bakar, F.A., Ghazali, F.M., Son, R. and Kumar, M.P. (2007). Thermophilic *Campylobacter* spp. in salad vegetables in Malaysia. *International Journal of Food Microbiology*, 117, 106-111. <https://doi.org/10.1016/j.ijfoodmicro.2007.02.014>
- Cheng, Z. and Griffiths, M.W. (2003). Rapid detection of *Campylobacter jejuni* in chicken rinse water by melting-peak analysis of amplicons in real-time polymerase chain reaction. *Journal of Food Protection*, 66, 1343-1352. <https://doi.org/10.4315/0362-028X-66.8.1343>
- Chon, J.W., Kim, H., Kim, H.S. and Seo, K.H. (2013). Improvement of modified charcoal-cefoperazone-deoxycholate agar by addition of potassium clavulanate for detecting *Campylobacter* spp. in chicken carcass rinse. *International Journal of Food Microbiology*, 165, 7-10.

- <https://doi.org/10.1016/j.ijfoodmicro.2013.04.006>
- Choo, L. C., Saleha, A.A., Wai, S.S. and Fauziah, N. (2011). Isolation of *Campylobacter* and *Salmonella* from houseflies (*Musca domestica*) in a university campus and a poultry farm in Selangor, Malaysia. *Tropical Biomedicine*, 28, 16-20. Retrieved from <https://pubmed.ncbi.nlm.nih.gov/21602764/>
- Corry, J.E. and Atabay, H.I. (1997). Comparison of the productivity of cefoperazone amphotericin teicoplanin (CAT) agar and modified charcoal cefoperazone deoxycholate (mCCD) agar for various strains of *Campylobacter*, *Arcobacter* and *Helicobacter pullorum*. *International Journal of Food Microbiology*, 38, 201-209. [https://doi.org/10.1016/s0168-1605\(97\)00105-0](https://doi.org/10.1016/s0168-1605(97)00105-0)
- De Cesare, A., Sheldon, B.W., Smith, K.S. and Jaykus, L.A. (2003). Survival and persistence of *Campylobacter* and *Salmonella* species under various organic loads on food contact surfaces. *Journal of Food Protection*, 66, 1587-1594. <https://doi.org/10.4315/0362-028x-66.9.1587>
- Debretson, A., Habtemariam, T., Wilson, S., Nganwa, D. and Yehualaeshet, T. (2007). Real-time PCR assay for rapid detection and quantification of *Campylobacter jejuni* on chicken rinses from poultry processing plant. *Molecular and Cellular Probes*, 21, 177-181. <https://doi.org/10.1016/j.mcp.2006.10.006>
- Debruyne L., Gevers, D. and Van-damme, P. (2008). Taxonomy of the family *Campylobacteraceae*. In *Campylobacter* (3<sup>rd</sup> ed.), ed. Nachamkin, I., Szymanski, C.M. and Blaser, M.J. p. 3-25. Washington DC: ASM Press.
- Debruyne, L., On, S.L., De Brandt, E. and Vandamme, P. (2009). Novel *Campylobacter lari*-like bacteria from humans and molluscs: description of *Campylobacter peloridis* sp. nov, *Campylobacter lari* subsp. *concheus* subsp. nov and *Campylobacter lari* subsp. *lari* subsp. nov. *International Journal of Systematic and Evolutionary Microbiology*, 59, 1126-1132. <https://doi.org/10.1099/ijs.0.000851-0>
- Debruyne, L., Broman, T., Bergström, S., Olsen, B., On, S.L. and Vandamme, P. (2010a). *Campylobacter subantarcticus* sp. nov, isolated from birds in the sub-Antarctic region. *International Journal of Systematic and Evolutionary Microbiology*, 60, 815-819. <https://doi.org/10.1099/ijs.0.011056-0>
- Debruyne L, Broman, T., Bergström, S., Olsen, B., On, S.L. and Vandamme, P. (2010b). *Campylobacter volucris* sp. nov, isolated from black-headed gulls *Larus ridibundus*. *International Journal of Systematic and Evolutionary Microbiology*, 60, 1870-1875. <https://doi.org/10.1099/ijs.0.013748-0>
- Dekeyser, P., Gossuin-Detrain, M., Butzler, J.P. and Sternon, J. (1972). Acute enteritis due to related vibrio: first positive stool cultures. *Journal of Infectious Diseases*, 125, 390-392. <https://doi.org/10.1093/infdis/125.4.390>
- El-Shibiny, A., Connerton, P. and Connerton, I. (2009). Survival at refrigeration and freezing temperatures of *Campylobacter coli* and *Campylobacter jejuni* on chicken skin applied as axenic and mixed inoculums. *International Journal of Food Microbiology*, 131, 197-202. <https://doi.org/10.1016/j.ijfoodmicro.2009.02.024>
- Engberg, J. (2006). Contributions to the epidemiology of *Campylobacter* infections. *Danish Medical Bulletin*, 53, 361-389. Retrieved from <https://pubmed.ncbi.nlm.nih.gov/17150145/>
- Enokimoto, M., Kubo, M., Bozono, Y., Mieno, Y. and Misawa, N. (2007). Enumeration and identification of *Campylobacter* species in the liver and bile of slaughtered cattle. *International Journal of Food Microbiology*, 118, 259-263. <https://doi.org/10.1556/EuJMI.2012.1.11>
- Fitzgerald, C., Tu, Z.C., Patrick, M., Stiles, T., Lawson, A.J., Santovenia, M., Gilbert, M.J., van Bergen, M., Joyce, K., Pruckler, J., Stroika, S., Duim, B., Miller, W.G., Loparev, V.L., Sinnige, J.C., Fields, P.I., Tauxe, R.V., Blaser, M.J. and Wagenaar, J.A. (2014). Description of *Campylobacter fetus* subsp. *testudinum* subsp. nov, isolated from humans and reptiles. *International Journal of Systematic and Evolutionary Microbiology*, 64, 2944-2948. <https://doi.org/10.1099/ijs.0.057778-0>
- Foster, G., Holmes, B., Steigerwalt, A.G., Lawson, P.A., Thorne, P., Byrer, D.E., Ross, H.M., Xerry, J., Thompson, P.M. and Collins, M.D. (2004). *Campylobacter insulaenigrae* sp. nov., isolated from marine mammals. *International Journal of Systematic and Evolutionary Microbiology*, 54, 2369-2373. <https://doi.org/10.1099/ijs.0.63147-0>
- Friedman, C.R., Hoekstra, R.M., Samuel, M., Marcus, R., Shiferaw, S.B., Reddy, S., Ahuja, S.D., Helfrick, D.L., Hardnett, F., Carter, M., Anderson, B. and Tauxe, R.V. (2004). Risk factors for sporadic *Campylobacter* infection in the United States: a case-control study in FoodNet sites. *Clinical Infectious Diseases*, 38, S285-S296. <https://doi.org/10.1086/381598>
- Ganapathy, K., Saleha, A.A., Jaganathan, M., Tan, C.G., Chong, C.T., Tang, S.C., Ideris, A., Dare, M. and Bradbury, J.M. (2007). Survey of *Campylobacter*, *Salmonella* and *Mycoplasmas* in house crows *Corvus splendens* in Malaysia. *Veterinary Record*, 160, 622-624. <https://doi.org/10.1136/vr.160.18.622>
- Garcia, A.B., Steele, W.B. and Taylor, D.J. (2010). Prevalence and carcass contamination with *Campylobacter* in sheep sent for slaughter in Scotland. *Journal of Food Safety*, 30, 237-250. <https://doi.org/10.1111/j.1745-4565.2009.00203.x>
- Garrity, G.M., Bell, J.A. and Lilburn, T. (2005). Order I. *Campylobacterales* ord. nov. In *The Bergey's Manual of*

- Systematic Bacteriology, The Proteobacteria, Part C (2<sup>nd</sup> ed., vol 2), ed. Garrity, G., Brenner, D.J. Staley, J.T., Krieg, N.R., Boone, D.R., De Vos, P., Goodfellow, M., Rainey, F.A. and Schleifer, K.H. p. 1145-1160. New York: Springer Publishing.
- Gebhart, C.J., Edmonds, P., Ward, G.E., Kurtz, H.J. and Brenner, D.J. (1985). *Campylobacter hyointestinalis* sp. nov: a new species of *Campylobacter* found in the intestines of pigs and other animals. *Journal of Clinical Microbiology*, 21, 715-720. <https://doi.org/10.1128/jcm.21.5.715-720.1985>
- González, M., Villanueva, M.P., Debruyne, L., Vandamme, P. and Fernández, H. (2011). *Campylobacter insulaenigrae*: first isolation report from South American sea lion (*Otaria flavescens*). *Brazilian Journal of Microbiology*, 42, 261-265. <https://doi.org/10.1590/S1517-83822011000100033>
- Granato, P.A., Chen, L., Holiday, I., Rawling, R.A., Novak-Weekley, S.M., Quinlan, T. and Musser, K.A. (2010). Comparison of premier CAMPY enzyme immunoassay (EIA), ProSpecT *Campylobacter* EIA, and ImmunoCard STAT! CAMPY tests with culture for laboratory diagnosis of *Campylobacter* enteric infections. *Journal of Clinical Microbiology*, 48, 4022-4027. <https://doi.org/10.1128/JCM.00486-10>
- Hald, B. and Madsen, M. (1997). Healthy puppies and kittens as carriers of *Campylobacter* spp., with special reference to *Campylobacter upsaliensis*. *Journal of Clinical Microbiology*, 35, 3351-3352. <https://doi.org/10.1128/jcm.35.12.3351-3352.1997>
- Houghton, P.N., Lyng, J., Cronin, D., Fanning, S. and Whyte, P. (2012). Effect of crust freezing applied alone and in combination with ultraviolet light on the survival of *Campylobacter* on raw chicken. *Food Microbiology*, 32, 147-151. <https://doi.org/10.1016/j.fm.2012.05.004>
- Hayashi, M., Kubota-Hayashi, S., Natori, T., Mizuno, T., Miyata, M., Yoshida, S., Zhang, J., Kawamoto, K., Ohkusu, K., Makino, S. and Ezaki, T. (2013). Use of blood-free enrichment broth in the development of a rapid protocol to detect *Campylobacter* in twenty-five grams of chicken meat. *International Journal of Food Microbiology*, 163, 41-46. <https://doi.org/10.1016/j.ijfoodmicro.2013.02.007>
- Hill, B.D., Thomas, R.J. and Mackenzie, A.R. (1987). *Campylobacter hyointestinalis* associated enteritis in Moluccan rusa deer *Cervus timorensis* subsp. *moluccensis*. *Journal of Comparative Pathology*, 97, 687-694. [https://doi.org/10.1016/0021-9975\(87\)90080-6](https://doi.org/10.1016/0021-9975(87)90080-6)
- Hong, J., Jung, W.K., Kim, J.M., Kim, S.H., Koo, H.C., Ser, J. and Park, Y.H. (2007). Quantification and differentiation of *Campylobacter jejuni* and *Campylobacter coli* in raw chicken meats using a real-time PCR method. *Journal of Food Protection*, 70, 2015-2022. <https://doi.org/10.4315/0362-028x-70.9.2015>
- Hutchinson, D.N. and Bolton, F.J. (1984). Improved blood free selective medium for the isolation of *Campylobacter jejuni* from faecal specimens. *Journal of Clinical Pathology*, 37, 956. <https://doi.org/10.1136/jcp.37.8.956-b>
- Hunt, J.M., Abeyat, C. and Tran, T. (1998). *Campylobacter*. In FDA Bacteriological Analytical Manual (8<sup>th</sup> ed.), ed. Hunt, J.M., Abeyta, C. and Tran, T. Washington DC: U.S. Food and Drug Administration. Retrieved 30 June 2017 from <https://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm072616.htm>
- Ilida, M.N. and Faridah, M.S. (2012). Prevalence of *Campylobacter jejuni* in chicken meat and chicken-based products. *Journal of Tropical Agriculture and Food Science*, 40, 63-69. Retrieved from [jtafs/40-1/Campylobacter jejuni.pdf](http://jtafs.mardi.gov.my/jtafs/40-1/Campylobacter%20jejuni.pdf)
- Inglis, G.D., Hoar, B.M., Whiteside, D.P. and Morck, D.W. (2007). *Campylobacter canadensis* sp. nov, from captive whooping cranes in Canada. *International Journal of Systematic and Evolutionary Microbiology*, 57, 2636-2644. <https://doi.org/10.1099/ijs.0.65061-0>
- Inglis, G.D. and Kalischuk, L.D. (2004). Direct quantification of *Campylobacter jejuni* and *Campylobacter lanienae lanienae* in faeces of cattle by real-time quantitative PCR. *Applied and Environmental Microbiology*, 70, 2296-2306. <https://doi.org/10.1128/AEM.70.4.2296-2306.2004>
- ISO (International Organisation for Standardization). (1995). ISO 10272: 1995 E, Microbiology of Food and Animal Feeding Stuffs – Horizontal Method for Detection of Thermotolerant *Campylobacter*. Geneva, Switzerland: International Organization for Standardization.
- ISO (International Organisation for Standardization). (2006a). ISO 10272-1, Microbiology of Food and Animal Feeding Stuffs – Horizontal Method for Detection and Enumeration of *Campylobacter* spp.–Part 1: Enrichment Method. Geneva, Switzerland: International Organization for Standardization.
- ISO (International Organisation for Standardization). (2006b). ISO 10272-1, Microbiology of Food and Animal Feeding Stuffs – Horizontal Method for Detection and Enumeration of *Campylobacter* spp.–Part 2: Enumeration Method. Geneva, Switzerland: International Organization for Standardization.
- Jacobs-Reitsma, W., U. Lyhs, J. Wagenaar, I. Nachamkin, C.M. Szymanski, and M.J. Blaser. 2008. *Campylobacter* in the food supply. In *Campylobacter* (3<sup>rd</sup> ed.), ed. Nachamkin, I., Szymanski, C.M. and Blaser, M.J. p. 627-644. Washington DC: ASM Press.
- Jay-Russell, M.T., Bates, A., Harden, L., Miller, W.G. and Mandrell, R.E. (2012). Isolation of *Campylobacter* from feral swine (*Sus scrofa*) on the ranch associated with the 2006 *Escherichia coli* O157:H7 spinach outbreak investigation in California. *Zoonoses Public Health*, 59, 314-319. <https://doi.org/10.1111/j.1863-2378.2012.01465.x>
- Jensen, A.N., Andersen, M.T., Dalsgaard, A., Baggesen, D.L. and Nielsen, E.M. (2005). Development of real-time PCR and hybridization methods for detection and identification of thermophilic *Campylobacter* spp. in pig faecal samples. *Journal of Applied Microbiology*, 99, 292-300. <https://doi.org/10.1111/j.1365-2672.2005.02616.x>

- Jokinen, C.C., Koot, J.M., Carrillo, C.D., Gannon, V.P., Jardine, C.M., Mutschall, S.K., Topp, E. and Taboada, E.N. (2012). An enhanced technique combining pre-enrichment and passive filtration increases the isolation efficiency of *Campylobacter jejuni* and *Campylobacter coli* from water and animal fecal samples. *Journal of Microbiological Methods*, 91, 506-513. <https://doi.org/10.1016/j.mimet.2012.09.005>
- Kaijser, B. (1981). Isolation of *Campylobacter jejuni* from domestic animals and pets: probable origin of human infection. *Journal of Infection*, 3, 37-40. [https://doi.org/10.1016/s0163-4453\(81\)92261-1](https://doi.org/10.1016/s0163-4453(81)92261-1)
- Kalashnikova, V.A., Dzhikidze, E.K., Stasilevich, Z.K. and Chikobava, M.G. (2002). Detection of *Campylobacter jejuni* in healthy monkeys and monkeys with enteric infections by PCR. *Bulletin Experimental Biology and Medicine*, 134, 299-300. <https://doi.org/10.1023/a:1021528122942>
- Karmali, M.A., Simor, A.E., Roscoe, M., Fleming, P.C., Smith, S.S. and Lane, J. (1986). Evaluation of a blood-free, charcoal-based, selective medium for the isolation of *Campylobacter* organisms from faeces. *Journal of Clinical Microbiology*, 23, 456-459. <https://doi.org/10.1128/jcm.23.3.456-459.1986>
- Kaur, T., Singh, J., Huffman, M.A., Petrželková, K.J., Taylor, N.S., Xu, S. and Fox, J.G. (2011). *Campylobacter troglodytis* sp. nov, isolated from faeces of human-habituated wild chimpanzees (*Pan troglodytes schweinfurthii*) in Tanzania. *Applied and Environmental Microbiology*, 77, 2366-2373. <https://doi.org/10.1128/AEM.01840-09>
- Keller, J.I. and Shriver, W.G. (2014). Prevalence of three *Campylobacter* species, *C. jejuni*, *C. coli*, and *C. lari*, using multilocus sequence typing in wild birds of the mid-Atlantic region, USA. *Journal of Wildlife Diseases*, 50, 31-41. <https://doi.org/10.7589/2013-06-136>
- Keller, J.I., Shriver, W.G., Waldenström, J., Griekspoor, P. and Olsen, B. (2011). Prevalence of *Campylobacter* in wild birds of the mid-Atlantic region, USA. *Journal of Wildlife Diseases*, 47, 750-754. <https://doi.org/10.7589/0090-3558-47.3.750>
- Ketley, J.M. (1997). Pathogenesis of enteric infection by *Campylobacter*. *Microbiology*, 143, 5-21. <https://doi.org/10.1099/00221287-143-1-5>
- Koene, M.G.J., Houwers, D.J., Dijkstra, J.R., Duim, B. and Wagenaar, J.A. (2004). Simultaneous presence of multiple *Campylobacter* species in dogs. *Journal of Clinical Microbiology*, 42, 819-821. <https://doi.org/10.1128/JCM.42.2.819-821.2004>
- Koolman, L., Whyte, P., Meade, J., Lyng, J. and Bolton, D. (2014). Use of chemical treatments applied alone and in combination to reduce *Campylobacter* on raw poultry. *Food Control*, 46, 299-303. <https://doi.org/10.1016/j.foodcont.2014.05.041>
- Koziel, M., Lucey, B., Bullman, S., Corcoran, G.D. and Sleator, R.D. (2012). Molecular-based detection of the gastrointestinal pathogen *Campylobacter ureolyticus* in unpasteurized milk samples from two cattle farms in Ireland. *Gut Pathology*, 4, 14. <https://doi.org/10.1186/1757-4749-4-14>
- Koziel, M., Corcoran, G.D., Sleator, R.D. and Lucey, B. (2014a). Detection and molecular analysis of *Campylobacter ureolyticus* in domestic animals. *Gut Pathology*, 61, 9. <https://doi.org/10.1186/1757-4749-6-9>
- Koziel, M., Doherty, P., Vandamme, P., Corcoran, G.D., Sleator, R.D. and Lucey, B. (2014b). *Campylobacter corcagiensis* sp. nov, isolated from faeces of captive lion-tailed macaques (*Macaca silenus*) in Ireland. *International Journal of Systematic and Evolutionary Microbiology*, 64, 2878-83. <https://doi.org/10.1099/ijs.0.063867-0>
- Kim, S.A., Lee, Y.M., Hwang, I.G., Kang, D.H., Woo, G.J. and Rhee, M.S. (2009). Eight enrichment broths for the isolation of *Campylobacter jejuni* from inoculated suspensions and ground pork. *Letters in Applied Microbiology*, 49, 620-626. <https://doi.org/10.1111/j.1472-765X.2009.02714.x>
- LaGier, M.J., Joseph, L.A., Passaretti, T.V., Musser, K.A. and Cirino, N.M. (2004). A real-time multiplexed PCR assay for rapid detection and differentiation of *Campylobacter jejuni* and *Campylobacter coli*. *Molecular and Cellular Probes*, 18, 275-282. <https://doi.org/10.1016/j.mcp.2004.04.002>
- Lawson, A.J., On, S.L., Logan, J.M. and Stanley, J. (2001). *Campylobacter hominis* sp. nov, from the human gastrointestinal tract. *International Journal of Systematic and Evolutionary Microbiology*, 51, 651-660. <https://doi.org/10.1099/00207713-51-2-651>
- Lee, W.S. and Puthuchery, S.D. (2002). Bacterial enteropathogens isolated in childhood diarrhoea in Kuala Lumpur-the changing trend. *The Medical Journal of Malaysia*, 57, 24-30. Retrieved from <https://pubmed.ncbi.nlm.nih.gov/14569714/>
- Levy, A.J. (1946). A gastro-enteritis outbreak probably due to a bovine strain of vibrio. *Yale Journal of Biology and Medicine*, 18, 243-258. Retrieved from <https://pubmed.ncbi.nlm.nih.gov/21019769/>
- Lim, Y.S., Jegathesan, M. and Wong, Y.H. (1984). *Campylobacter jejuni* as a cause of diarrhoea in Kuala Lumpur. *The Medical Journal of Malaysia*, 39(4), 285-288. Retrieved from <https://www.e-mjm.org/1984/v39n4/campylobacter-jejuni-and-diarrhoea.pdf>
- Lin, J. (2009). Novel approaches for *Campylobacter* control in poultry. *Foodborne Pathogens and Disease*, 6, 755-765. <https://doi.org/10.1089/fpd.2008.0247>
- Line, J.E. (2001). Development of a selective differential agar for isolation and enumeration of *Campylobacter* spp. *Journal of Food Protection*, 64, 1711-1715. <https://doi.org/10.4315/0362-028x-64.11.1711>
- LPSN (List of Prokaryotic names with Standing in Nomenclature). (2012). Genus *Campylobacter* Retrieved 30 June 2017 from <http://www.bacterio.net/campylobacter.html>
- Liu, L., Hussain, S.K., Miller, R.S. and Oyarzabal, O.A. (2009). Research note: efficacy of mini VIDAS for the

- detection of *Campylobacter* spp. from retail broiler meat enriched in Bolton broth with or without the supplementation of blood. *Journal of Food Protection*, 72, 2428-2432. <https://doi.org/10.4315/0362-028x-72.11.2428>
- Logan, J.M., Burnens, A., Linton, D., Lawson, A.J. and Stanley, J. (2000). *Campylobacter lanienae* sp. nov, a new species isolated from workers in an abattoir. *International Journal of Systematic and Evolutionary Microbiology*, 50, 865-872. <https://doi.org/10.1099/00207713-50-2-865>
- Lund, M., Nordentoft, S., Pedersen, K. and Madsen, M. (2004). Detection of *Campylobacter* spp. in chicken fecal samples by real-time PCR. *Journal of Clinical Microbiology*, 42, 5125-5132. <https://doi.org/10.1128/JCM.42.11.5125-5132.2004>
- Man, S.M. (2011). The clinical importance of emerging *Campylobacter* species. *Nature Reviews Gastroenterology and Hepatology*, 8, 669-685. <https://doi.org/10.1038/nrgastro.2011.191>
- Marin, C., Palomeque, M.D., Marco-Jiménez, F. and Vega, S. (2014). Wild Griffon Vultures (*Gyps fulvus*) as a source of *Salmonella* and *Campylobacter* in eastern Spain. *PLoS One*, 9, e94191. <https://doi.org/10.1371/journal.pone.0094191>
- Matsumoto, N., Taniwaki, T., Kinuta, M. and Murase, T. (2008). Isolation of *Campylobacter jejuni* and coliform bacilli from bile and liver obtained from slaughter cattle in western Japan. *Journal of Food Protection*, 71, 1228-1231. <https://doi.org/10.4315/0362-028x-71.6.1228>
- Mead, G.C. (2002). Factors affecting intestinal colonisation of poultry by *Campylobacter* and role of microflora in control. *World's Poultry Science Journal*, 58, 169-178. <https://doi.org/10.1079/WPS20020016>
- Mingo, E., Carrascosa, A.V., Pascual-Teresa, S.D. and Martínez-Rodríguez, A.J. (2014). Grape phenolic extract potentially useful in the control of antibiotic resistant strains of *Campylobacter*. *Advances in Microbiology*, 4, 73-80. <https://doi.org/10.4236/aim.2014.42012>
- Misawa, N., Shinohara, S., Satoh, H., Itoh, H., Shinohara, K., Shimomura, K. Kondo, F. and Itoh, K. (2000). Isolation of *Campylobacter* species from zoo animals and polymerase chain reaction-based random amplified polymorphism DNA analysis. *Veterinary Microbiology*, 71, 59-68. [https://doi.org/10.1016/s0378-1135\(99\)00156-x](https://doi.org/10.1016/s0378-1135(99)00156-x)
- Munroe, D.L., Prescott, J.F. and Penner, J.K. (1983). *Campylobacter jejuni* and *Campylobacter coli* serotypes isolated from chickens, cattle, and pigs. *Journal of Clinical Microbiology*, 18, 877-881. <https://doi.org/10.1128/jcm.18.4.877-881.1983>
- Musavian, H.S., Krebs, N.H., Nonboe, U., Corry, J.E. and Purnell, G. (2014). Combined steam and ultrasound treatment of broilers at slaughter: a promising intervention to significantly reduce numbers of naturally occurring *Campylobacter*s on carcasses. *International Journal of Food Microbiology*, 176, 23-28. <https://doi.org/10.1016/j.ijfoodmicro.2014.02.001>
- Myers, A.L., Jackson, M.A. and Selvarangan, R. (2011). False-positive results of *Campylobacter* rapid antigen testing. *The Pediatric Infectious Disease Journal*, 30, 542. <https://doi.org/10.1097/INF.0b013e31821524db>
- Nielsen, H.L., Ejlertsen, T. and Nielsen, H. (2015). Polycarbonate filtration technique is noninferior to mCCDA for isolation of *Campylobacter* species from stool samples. *Diagnostic Microbiology and Infectious Disease*, 83, 11-12. <https://doi.org/10.1016/j.diagmicrobio.2015.05.008>
- Nielsen, H.L., Engberg, J., Ejlertsen, T. and Nielsen, H. (2013). Comparison of polycarbonate and cellulose acetate membrane filters for isolation of *Campylobacter concisus* from stool samples. *Diagnostic Microbiology and Infectious Disease*, 76, 549-550. <https://doi.org/10.1016/j.diagmicrobio.2013.05.002>
- Nielsen, E.M., Engberg, J. and Madsen, M. (1997). Distribution of serotypes of *Campylobacter jejuni* and *C. coli* from Danish patients, poultry, cattle and swine. *FEMS Immunology and Medical Microbiology*, 19, 47-56. <https://doi.org/10.1111/j.1574-695X.1997.tb01071.x>
- Nor Faiza, S., Saleha, A.A., Jalila, A. and Fauziah, N. (2013). Research Note Occurrence of *Campylobacter* and *Salmonella* in ducks and duck eggs in Selangor, Malaysia. *Tropical Biomedicine*, 30, 55-158. Retrieved from <https://pubmed.ncbi.nlm.nih.gov/23665722/>
- Noh, M., Shakira, N. and Aziz, S.A. (2012). Occurrence of *Campylobacter* spp. and *Arcobacter* spp. in goats. In *Proceedings of the 7<sup>th</sup> Seminar in Veterinary Sciences*, pp 114. <https://doi.org/10.1089/153036602321131913>
- Mustaffa, S.S., Saleha, A.A. and Jalila, A. (2014). Occurrence of antibiotic resistant *Salmonella* and *Campylobacter* in wild birds. *Journal of Veterinary Malaysia*, 26, 17-19. <https://doi.org/10.21161/mjm.xxxxx>
- Olson, C.K., Ethelberg, S., Van Pelt, W. and Tauxe, R.V. (2008). Epidemiology of *Campylobacter jejuni* infections in industrialized nations. In *Campylobacter* (3<sup>rd</sup> ed.), ed. Nachamkin, I., Szymanski, C.M. and Blaser, M.J. p. 163-189. Washington DC: ASM press. <https://doi.org/10.1128/9781555815554.ch9>
- On, S.L., Bloch, B., Holmes, B., Hoste, B. and Vandamme, P. (1995). *Campylobacter hyointestinalis* subsp. *lawsonii* subsp. nov, isolated from the porcine stomach, and an emended description of *Campylobacter hyointestinalis*. *International Journal of Systematic and Evolutionary Microbiology*, 45, 76,774. <https://doi.org/10.1099/00207713-45-4-767>
- Oporto, B. and Hurtado, A. (2011). Emerging thermotolerant *Campylobacter* species in healthy ruminants and swine. *Foodborne Pathogens and Disease*, 8, 807-813. <https://doi.org/10.1089/fpd.2010.0803>
- Oyarzabal, O.A., Backert, S., Nagaraj, S., Miller, M., Hussain, R.S. and Oyarzabal, E.A. (2007). Efficacy of supplemented buffered peptone water for the isolation of *Campylobacter jejuni* and *C. coli* from broiler retail products. *Journal of Microbiological Methods*, 69, 129-136. <https://doi.org/10.1016/j.mimet.2006.12.011>
- Oyofe, B.A., Thornton, S.A., Burr, D.H., Trust, T.J., Pavlovskis, O.R. and Guerry, P. (1992). Specific detection

- of *Campylobacter jejuni* and *Campylobacter coli* by using polymerase chain reaction. *Journal of Clinical Microbiology*, 30, 2613-2619. <https://doi.org/10.1128/jcm.30.10.2613-2619.1992>
- Parkhill, J., Wren, B.W., Mungall, K., Ketley, J.M., Churcher, C., Basham, D., Chillingworth, T., Davies, R.M., Feltwell, T., Holroyd, S. and Jagels, K. (2000). The genome sequence of the food-borne pathogen *Campylobacter jejuni* reveals hypervariable sequences. *Nature*, 403, 665-668. <https://doi.org/10.1038/35001088>
- Persson, S. and Olsen, K.E. (2005). Multiplex PCR for identification of *Campylobacter coli* and *Campylobacter jejuni* from pure cultures and directly on stool samples. *Journal of Medical Microbiology*, 54, 1043-1047. <https://doi.org/10.1099/jmm.0.46203-0>
- Petersen, R.F., Harrington, C.S., Kortegaard, H.E. and On, S.L.W. (2007). A PCR-DGGE method for detection and identification of *Campylobacter*, *Helicobacter*, *Arcobacter* and related Epsilonbacteria and its application to saliva samples from humans and domestic pets. *Journal of Applied Microbiology*, 103, 2601-2615. <https://doi.org/10.1111/j.1365-2672.2007.03515.x>
- Pires, S.M., Vigre, H., Makela, P. and Hald, T. (2010). Using outbreak data for source attribution of human salmonellosis and *Campylobacteriosis* in Europe. *Foodborne Pathogens and Disease*, 7, 1351-1361. <https://doi.org/10.1089/fpd.2010.0564>
- Plumer, G.J., Duvall, W.C. and Shepler, V.M. (1962). A preliminary report on a new technic for isolation of *Vibrio fetus* from carrier bulls. *The Cornell Veterinarian*, 52, 110-122.
- Rasschaert, G., Piessens, V., Scheldeman, P., Leleu, S., Stals, A., Herman, L., Heyndrickx, M. and Messens, W. (2011). Efficacy of electrolyzed oxidizing water and lactic acid on the reduction of *Campylobacter* on naturally contaminated broiler carcasses during processing. *Poultry Science*, 92, 1077-1084. <https://doi.org/10.3382/ps.2012-02771>
- Reiter, M.G., López, C., Jordano, R. and Medina, L.M. (2010). Comparative study of alternative methods for food safety control in poultry slaughterhouses. *Food Analytical Methods*, 3, 253-260. <https://doi.org/10.1007/s12161-010-9129-5>
- Rejab, S.B.M., Zessin, K.H., Fries, R. and Patchanee, P. (2012). *Campylobacter* in chicken carcasses and slaughterhouses in Malaysia. *Southeast Asian Journal of Tropical Medicine and Public Health*, 43, 96-104. Retrieved from [https://www.researchgate.net/publication/232526160\\_Campylobacter\\_in\\_chicken\\_carcasses\\_and\\_slaughterhouses\\_in\\_Malaysia](https://www.researchgate.net/publication/232526160_Campylobacter_in_chicken_carcasses_and_slaughterhouses_in_Malaysia)
- Rollins, D.M. and Colwell, R.R. (1986). Viable but nonculturable stage of *Campylobacter jejuni* and its role in survival in the natural aquatic environment. *Applied and Environmental Microbiology*, 52, 531-538. <https://doi.org/10.1128/aem.52.3.531-538.1986>
- Rosef, O., Gondrosen, B., Kapperud, G. and Underdal, B. (1983). Isolation and characterization of *Campylobacter jejuni* and *Campylobacter coli* from domestic and wild mammals in Norway. *Applied and Environmental Microbiology*, 46, 855-859. <https://doi.org/10.1128/aem.46.4.855-859.1983>
- Rosenquist, H., Sommer, H.M., Nielsen, N.L. and Christensen, B.B. (2006). The effect of slaughter operations on the contamination of chicken carcasses with thermotolerant *Campylobacter*. *International Journal of Food Microbiology*, 108, 226-232. <https://doi.org/10.1016/j.ijfoodmicro.2005.12.007>
- Rossi, M., Debruyne, L., Zanoni, R.G., Manfreda, G., Revez, J. and Vandamme, P. (2009). *Campylobacter avium* sp. nov., a hippurate-positive species isolated from poultry. *International Journal of Systematic and Evolutionary Microbiology*, 59, 2364-2369. <https://doi.org/10.1099/ijs.0.007419-0>
- Rudi, K., Høidal, H.K., Katla, T., Johansen, B.K., Nordal, J. and Jakobsen, K.S. (2004). Direct real-time PCR quantification of *Campylobacter jejuni* in chicken fecal and cecal samples by integrated cell concentration and DNA purification. *Applied and Environmental Microbiology*, 70, 790-797. <https://doi.org/10.1128/AEM.70.2.790-797.2004>
- Sails, A.D., Fox, A.J., Bolton, F.J., Wareing, D.R. and Greenway, D.L. (2003). A real-time PCR assay for the detection of *Campylobacter jejuni* in foods after enrichment culture. *Applied and Environmental Microbiology*, 69, 1383-1390. <https://doi.org/10.1128/AEM.69.3.1383-1390.2003>
- Saleha, A.A. (2002). Isolation and characterization of *Campylobacter jejuni* from broiler chickens in Malaysia. *International Journal of Poultry Science*, 1, 94-97. <https://doi.org/10.3923/ijps.2002.94.97>
- Salihu, M.D., Junaidu, A.U., Oboegbulem, S.I., Egwu, G.O., Tambuwal, F.M. and Yakubu, Y. (2009). Prevalence of *Campylobacter* species in apparently healthy goats in Sokoto state Northwestern Nigeria. *African Journal of Microbiology Research*, 3, 572-574. Retrieved from <http://www.academicjournals.org/ajmr>
- Samuel, M.C., Vugia, D.J., Shallow, S., Marcus, R., Segler, S., McGovern, T., Kassenborg, H., Reilly, K., Kennedy, M., Angulo, F. and Tauxe, R.V. (2004). Epidemiology of sporadic *Campylobacter* infection in the United States and declining trend in incidence, FoodNet 1996-1999. *Clinical Infectious Diseases*, 38, S165-S174. <https://doi.org/10.1086/381583>
- Sasaki, Y., Fujisawa, T., Ogikubo, K., Ohzono, T., Ishihara, K. and Takahashi, T. (2003). Characterization of *Campylobacter lanienae* from pig faeces. *Journal of Veterinary Medical Science*, 65, 129-131. <https://doi.org/10.1292/jvms.65.129>
- Schlundt, J., Toyofuku, H., Jansen, J. and Herbst, S.A. (2004). Emerging food-borne zoonoses. *Scientific and Technical Review of the Office International des Epizooties*, 23, 513-534. <https://doi.org/10.20506/rst.23.2.1506>

- Sebald, M. and Veron, M. (1963). DNA base content in the classification of vibrios. *Annales de l'Institut Pasteur*, 105, 897-910. Retrieved from <https://pubmed.ncbi.nlm.nih.gov/14098102/>
- Speegle, L., Miller, M.E., Backert, S. and Oyarzabal, O.A. (2009). Use of cellulose filters to isolate *Campylobacter* spp. from naturally contaminated retail broiler meat. *Journal of Food Protection*, 72, 2592-2596. <https://doi.org/10.4315/0362-028x-72.12.2592>
- Silva, J., Leite, D., Fernandes, M., Mena, C., Gibbs, P.A. and Teixeira, P. (2011). *Campylobacter* spp. as a foodborne pathogen: a review. *Frontiers in Microbiology*, 2, 1-12. <https://doi.org/10.3389/fmicb.2011.00200>
- Skirrow, M.B. (1977). *Campylobacter* enteritis: a "new" disease. *British Medical Journal*, 2, 9-11. <https://doi.org/10.1136/bmj.2.6078.9>
- Skirrow, M.B. (2006). John McFadyean and the centenary of the first isolation of *Campylobacter* species. *Clinical Infectious Diseases*, 43, 1213-1217. <https://doi.org/10.1086/508201>
- Standards Australia. (2004). AS 5013.6-2004: Food microbiology. Method 6: Examination for specific organisms—*Campylobacter*. Sydney, Australia: Standards Australia.
- Stanley, K.N., Wallace, J.S., Currie, J.E., Diggle, P.J. and Jones, K. (1998). Seasonal variation of thermophilic *Campylobacters* in lambs at slaughter. *Journal of Applied Microbiology*, 84, 1111-1116. <https://doi.org/10.1046/j.1365-2672.1998.00450.x>
- Stanley, J., Burnens, A.P., Linton, D., On, S.L.W., Costas, M. and Owen, R.J. (1992). *Campylobacter helveticus* sp. nov, a new thermophilic species from domestic animals: characterization and cloning of a species-specific DNA probe. *Journal of General Microbiology*, 138, 2293-2303. <https://doi.org/10.1099/00221287-138-11-2293>
- Steele, T.W. and McDermott, S.N. (1984). The use of the membrane filters applied directly to the surface of agar plates for the isolation of *Campylobacter jejuni* from faeces. *Pathology*, 16, 263-265. <https://doi.org/10.3109/00313028409068535>
- Stern, N.J., Cox, N.A., Bailey, J.S., Berrang, M.E. and Musgrove, M.T. (2001). Comparison of mucosal competitive exclusion and competitive exclusion treatment to reduce *Salmonella* and *Campylobacter* sp. colonization in broiler chickens. *Poultry Science*, 80, 156-160. <https://doi.org/10.1093/ps/80.2.156>
- Stoddard, R.A., Gulland, F.M., Atwill, E.R., Lawrence, J., Jang, S. and Conrad, P.A. (2005). *Salmonella* and *Campylobacter* spp. in northern elephant seals, California. *Emerging Infectious Diseases*, 11, 1967-1969. <https://doi.org/10.3201/eid1112.050752>
- Stoddard, R.A., Miller, W.G., Foley, J.E., Lawrence, J., Gulland, F.M., Conrad, P.A. and Byrne, B.A. (2007). *Campylobacter insulaenigrae* isolates from northern elephant seals (*Mirounga angustirostris*) in California. *Applied and Environmental Microbiology*, 73, 1729-1735. <https://doi.org/10.1128/AEM.01816-06>
- Svetoch, E.A., Eruslanov, B.V., Perelygin, V.V., Mitsevich, E.V., Mitse-vich, I.P., Borzenkov, V.N., Levchuk, V.P., Svetoch, O.E., Kovalev, Y.N., Stepanshin, Y.G., Siragusa, G.R., Seal, B.S. and Stern, N.J. (2008). Diverse antimicrobial killing by *Enterococcus faecium* E 50-52 bacteriocin. *Journal of Agricultural and Food Chemistry*, 56, 1942-1948. <https://doi.org/10.1021/jf073284g>
- Svetoch, E.A., Stern, N.J., Eruslanov, B.V., Kovalev, N.Y., Volodina, L.I., Perelygin, V.V., Mitsevich, E.V., Mitsevich, I.P., Pokhilenko, V.D., Borzenkov, V.N., Levchuk, V.P., Svetoch, O.E. and Kudriavtseva, T.Y. (2005). Isolation of *Bacillus circulans* and *Paenibacillus polymyxa* strains inhibitory to *Campylobacter jejuni* and characterization of associated bacteriocins. *Journal of Food Protection*, 68,11-17. <https://doi.org/10.4315/0362-028x-68.1.11>
- Tan, Y.F., Chai, L.C., Ghazali, F.M., Son, R. and Haresh, K.K. (2008). Prevalence of *Campylobacter* spp. in retailed ready-to-eat sushi. *International Food Research Journal*, 15, 331-336. Retrieved from [http://www.ifrj.upm.edu.my/15%20\(3\)%202008/11.%20Tan%20Y.F.pdf](http://www.ifrj.upm.edu.my/15%20(3)%202008/11.%20Tan%20Y.F.pdf)
- Tang, J.Y.H., Ghazali, F.M., Saleha, A.A., Nakaguchi, Y., Nishibuchi, M. and Son, R. (2010a). MPN-PCR enumeration of *Campylobacter* spp. in raw chicken meats and by-products. *Frontiers of Agriculture in China*, 4, 501-506. <https://doi.org/10.1007/s11703-010-1042-6>
- Tang, J.Y.H., Aziz, S.A., Abu, J.A., Ghazali, F.M., Chilek, T.Z.T., Ahmad, N., Sandra, A., Nishibuchi, M. and Son, R. (2010b). Thermophilic *Campylobacter* spp. occurrence on chickens at farm, slaughterhouse and retail. *International Journal of Poultry Science*, 9, 134-138. <https://doi.org/10.3923/ijps.2010.134.138>
- Tang, J.Y.H., Ghazali, F.M., Aziz, S.A., Nishibuchi, M. and Son, R. (2009). Comparison of thermophilic *Campylobacter* spp. occurrence in two types of retail chicken samples. *International Food Research Journal*, 16, 277-288. Retrieved from <http://psasir.upm.edu.my/id/eprint/13706/1/13706.pdf>
- Tanner, A.C.R., Dzik, J.L., Ebersole, J.L. and Socransky, S.S. (1987). *Wolinella recta*, *Campylobacter concisus*, *Bacteroides gracilis*, and *Eikenella corrodens* from periodontal lesions. *Journal of Periodontal Research*, 22, 327-330. <https://doi.org/10.1111/j.1600-0765.1987.tb01593.x>
- Taylor, E.V., Herman, K.M., Ailes, E.C., Fitzgerald, C., Yoder, J.S., Mahon, B.E. and Tauxe, R.V. (2013). Common source outbreaks of *Campylobacter* infection in the USA, 1997-2008. *Epidemiology and Infection*, 141, 987-996. <https://doi.org/10.1017/S0950268812001744>
- Turowski, E.E., Shen, Z., Ducore, R.M., Parry, N.M.A., Kirega, A., Dewhirst, F.E. and Fox, J.G. (2014). Isolation of a *Campylobacter lanienae*-like bacterium from laboratory chinchillas (*Chinchilla laniger*). *Zoonoses Public Health*, 61(8), 571-580. <https://doi.org/10.1111/zph.12107>
- Usha, M.R., Maarof, F., Robin, T., Chai, L.C., Cheah, Y.K., Ghazali, F.M. and Son, R. (2010). Occurrence and

- antibiotic resistance of *Campylobacter jejuni* and *Campylobacter coli* in retail broiler chicken. *International Food Research Journal*, 17, 247-255. Retrieved from [www.ifrj.upm.edu.my/17\\_02\\_2010/IFRJ-2010-247-255\\_Son\\_Malaysia\(S\)\[1\].pdf](http://www.ifrj.upm.edu.my/17_02_2010/IFRJ-2010-247-255_Son_Malaysia(S)[1].pdf)
- Vandamme, P. and De Ley, J. (1991). Proposal for a new family, *Campylobacteraceae*. *International Journal of Systematic and Evolutionary Microbiology*, 41, 451-455. <https://doi.org/10.1099/00207713-41-3-451>
- Veron, M. and Chatelain, R. (1973). Taxonomic study of the genus *Campylobacter* Sebald and Véron and designation of the neotype strain for the type species, *Campylobacter fetus* (Smith and Taylor) Sebald and Véron. *International Journal of Systematic and Evolutionary Microbiology*, 23, 122-134. <https://doi.org/10.1099/00207713-23-2-122>
- Wagenaar, J.A., Van Bergen, M.A., Mueller, M.A., Wassenaar, T.M. and Carlton, R.M. (2005). Phage therapy reduces *Campylobacter jejuni* colonization in broilers. *Veterinary Microbiology*, 1093, 275-283. <https://doi.org/10.1016/j.vetmic.2005.06.002>
- Waino, M., Bang, D.D., Lund, M., Nordentoft, S., Andersen, J.S., Pedersen, K. and Madsen, M. (2003). Identification of *Campylobacter* isolated from Danish broilers by phenotypic tests and species-specific PCR assays. *Journal of Applied Microbiology*, 95, 649-655. <https://doi.org/10.1046/j.1365-2672.2003.01996.x>
- Waldenström, J., Broman, T., Carlsson, I., Hasselquist, D., Achterberg, R.P., Wagenaar, J.A. and Olsen, B. (2002). Prevalence of *Campylobacter jejuni*, *Campylobacter lari*, and *Campylobacter coli* in different ecological guilds and taxa of migrating birds. *Applied and Environmental Microbiology*, 68, 5911-5917. <https://doi.org/10.1128/AEM.68.12.5911-5917.2002>
- Wang, C.M., W.Y. Shia, W.Y., Jhou, Y.J. and Shyu, C.L. (2013). Occurrence and molecular characterization of reptilian *Campylobacter fetus* strains isolated in Taiwan. *Veterinary Microbiology*, 164, 67-76. <https://doi.org/10.1016/j.vetmic.2013.01.008>
- Weino, M., Bang, D.D., Lund, M., Nordentoft, S., Andersen, J.S., Pedersen, K. and Madsen, M. (2003). Identification of *Campylobacter* isolated from Danish broilers by phenotypic tests and species specific PCR assays. *Journal of Applied Microbiology*, 95, 649-655. <https://doi.org/10.1046/j.1365-2672.2003.01996.x>
- Wheeler, J.G., Sethi, D., Cowden, J.M., Wall, P.G., Rodrigues, L.C., Tompkins, D.S., Hudson, M.J. and Roderick, P.J. (1999). Study of infectious intestinal disease in England: rates in the community, presenting to general practice, and reported to national surveillance. *British Medical Journal*, 318, 1046-1050. <https://doi.org/10.1136/bmj.318.7190.1046>
- Willis, W.L. and Reid, L. (2008). Investigating the effects of dietary probiotic feeding regimens on broiler chicken production and *Campylobacter jejuni* presence. *Poultry Science*, 874, 606-611. <https://doi.org/10.3382/ps.2006-00458>
- WHO (World Health Organization). (2012). The Global View of Campylobacteriosis. Report of an Expert Consultation. Geneva, Switzerland: World Health Organization. Retrieved from <https://www.who.int/publications/item/9789241564601>
- Wright, S.L., D.K. Carver, D.K., Siletzky, R.M., Romine, S., Morrow, W.E.M. and Kathariou, S. (2008). Longitudinal study of prevalence of *Campylobacter jejuni* and *Campylobacter coli* from turkeys and swine grown in close proximity. *Journal of Food Protection*, 71, 1791-1796. <https://doi.org/10.4315/0362-028X-71.9.1791>
- Yamazaki, W., Taguchi, M., Ishibashi, M., Kitazato, M., Nukina, M., Misawa, N. and Inoue, K. (2008). Development and evaluation of a loop-mediated isothermal amplification assay for rapid and simple detection of *Campylobacter jejuni* and *Campylobacter coli*. *Journal of Medical Microbiology*, 57, 444-451. <https://doi.org/10.1099/jmm.0.47688-0>
- Yamazaki, W., Taguchi, M., Ishibashi, M., Nukina, M., Misawa, N. and Inoue, K. (2009a). Development of a loop-mediated isothermal amplification assay for sensitive and rapid detection of *Campylobacter fetus*. *Veterinary Microbiology*, 1363, 393-396. <https://doi.org/10.1016/j.vetmic.2008.11.018>
- Yamazaki, W., Taguchi, M., Kawai, T., Kawatsu, K., Sakata, J., Inoue, K. and Misawa, N. (2009b). Comparison of loop-mediated isothermal amplification assay and conventional culture methods for detection of *Campylobacter jejuni* and *Campylobacter coli* in naturally contaminated chicken meat samples. *Applied and Environmental Microbiology*, 75, 1597-1603. <https://doi.org/10.1128/AEM.02004-08>
- Yang, C., Jiang, Y., Huang, K., Zhu, C. and Yin, Y. (2003). Application of real-time PCR for quantitative detection of *Campylobacter jejuni* in poultry, milk and environmental water. *FEMS Immunology Medical Microbiology*, 38, 265-271. [https://doi.org/10.1016/S0928-8244\(03\)00168-8](https://doi.org/10.1016/S0928-8244(03)00168-8)
- Yap, H.H., Cardona, C.J. and Carpenter, T.E. (2005). Prevalence and risk factors associated with *Campylobacter* species in chickens imported into Singapore. *Singapore Journal of Primary Industries*, 32, 70-79. <https://doi.org/10.1016/j.ijfoodmicro.2010.11.003>
- Yew, E.L., Aziz, S.A. and Abu, J. (2012). Detection of *Campylobacter* and *Salmonella* in ostrich. *Jurnal Veterinar Malaysia*, 24, 6-8. Retrieved from <https://www.mavma.org.my/jvm/2012-volume-24-issue-no-1-2-june-dec>
- Zanoni, R.G., Debruyne, L., Rossi, M., Revez, J. and Vandamme, P. (2009). *Campylobacter cuniculorum* sp. nov, from rabbits. *International Journal of Systematic and Evolutionary Microbiology*, 59, 1666-1671. <https://doi.org/10.1099/ijs.0.007286-0>
- Zhao, T. and Doyle, M.P. (2006). Reduction of *Campylobacter jejuni* on chicken wings by chemical treatments. *Journal of Food Protection*, 69, 762-767. <https://doi.org/10.4315/0362-028x-69.4.762>
- Zhou, P., Hussain, S.K., Liles, M.R., Arias, C.R., Backert, S., Kieninger, J.R. and Oyarzabal, O.A. (2011). A simplified and cost-effective enrichment protocol for the isolation of

*Campylobacter* spp. from retail broiler meat without microaerobic incubation. *BMC Microbiology*, 11, 175. <https://doi.org/10.1186/1471-2180-11-175>