

Prevalence of *Arcobacter* and *Campylobacter* on broiler carcasses during processing[☆]

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Abstract

Broiler carcasses ($n=325$) were sampled in a U.S. commercial poultry processing plant for the prevalence of *Arcobacter* and *Campylobacter* at three sites along the processing line: pre-scald, pre-chill and post-chill. Samples (75–125 broilers per site) were collected during five plant visits from August to October of 2004. *Arcobacter* was recovered from pre-scald carcasses more frequently (96.8%) than from pre-chill (61.3%) and post-chill carcasses (9.6%). *Campylobacter* was isolated from 92% of pre-scald carcasses, 100% of pre-chill carcasses, and 52% of post-chill carcasses. In total, *Arcobacter* was isolated from 55.1% (179 of 325), while *Campylobacter* was isolated from 78.5% (255 of 325) of the carcasses from the three collection sites. For *Arcobacter* identification, a species-specific multiplex PCR showed that *A. butzleri* was the most prevalent species (79.1%) followed by *A. cryaerophilus* 1B (18.6%). *A. cryaerophilus* 1A was found at low levels (2.3%). PCR identified the most common *Campylobacter* species as *C. jejuni* (87.6%) followed by *C. coli* (12.4%). Overall, significant contamination of broiler carcasses by *Arcobacter* was observed, although less than that found for *Campylobacter*. From pre-scald to post-chill, a far greater reduction in *Arcobacter* numbers was observed than for *Campylobacter*. Our results for *Arcobacter*, obtained from the same environment as the closely related pathogen *Campylobacter*, will aid in the development of control measures for this emerging pathogen.

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1. Introduction

Campylobacter is the most common cause of acute bacterial gastroenteritis in humans worldwide (Mead et al., 1999). The most important *Campylobacter* species associated with human illness are *C. jejuni* and *C. coli* (Wesley et al., 2000). *Arcobacter* spp. are gram-negative, aerotolerant organisms that are closely related to *Campylobacter*. *Arcobacter* infection can produce an illness similar to that caused by *Campylobacter* and other foodborne pathogens (Vandenberg et al., 2004). A taxo-

nomic study using DNA/rDNA and DNA/DNA hybridization, and electrophoretic protein profiles determined that the genus *Arcobacter* is comprised of five main groups (Vandamme et al., 1992a). *Arcobacter butzleri* and *A. cryaerophilus* (subgroups 1A and 1B), have been recognized as potential human pathogens with symptoms including abdominal pain, nausea, vomiting or fever, in addition to causing abortion in farm animals (Tee et al., 1988; Lerner et al., 1994; Hsueh et al., 1997; Vandamme et al., 1992b; van Driessche et al., 2003). Indeed, recent studies from Belgium and France identified *A. butzleri* as the fourth most common *Campylobacteraceae* species recovered from human stool samples submitted to clinical laboratories (Vandenberg et al., 2004; Prouzet-Mauléon et al., 2006). *Arcobacter skirrowii* has also been isolated from farm animals, and has been identified in cases of human illness involving chronic diarrhea (Mansfield and Forsythe, 2000; Kabeya et al.,

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2003b; Wybo et al., 2004). *Arcobacter nitrofigilis*, a nitrogen-fixing species found in the roots of salt marsh plants, has not been reported to cause infection in animals or humans. Another proposed species, *A. cibarius*, has recently been isolated from broiler carcasses (Houf et al., 2005). Its status as a potential pathogen is yet to be determined. While *Arcobacter* species are phenotypically similar to *Campylobacter* species, two notable features, aerotolerance and the ability to grow at lower (15–25 °C) temperatures, distinguish *Arcobacter* from *Campylobacter* (Lehner et al., 2005).

Campylobacter is a common contaminant of broiler carcasses in poultry processing plants (Atabay and Corry, 1997; Berrang and Dickens, 2000; Gonzalez et al., 2000; de Oliveira et al., 2001). Studies have demonstrated high levels of *Campylobacter* on broiler chickens from the farm (Stern et al., 1995) and from retail chickens (Zhao et al., 2001). Consequently, undercooked and raw poultry meats are common vehicles for the transmission of human campylobacteriosis. Considerable efforts have thus been made to reduce the levels of contamination of *Campylobacter* on processed poultry carcasses (Corry and Atabay, 2001). In contrast, a search of the literature revealed only one report pertaining to *Arcobacter* from a U.S. poultry plant (Johnson and Murano, 1999). Furthermore, little is known about how processing procedures in the U.S. may affect the prevalence of *Arcobacter* and *Campylobacter*. At present, the origin of *Arcobacter* contamination and the nature of its pathogenesis are still unknown. This is due in part to the lack of standardized isolation methods for *Arcobacter*. However, a number of studies on the development and comparison of media and enrichment broths for the recovery of *Arcobacter* from foods of animal origin such as chicken (Johnson and Murano, 1999; Houf et al., 2001; Eifert et al., 2003; Scullion et al., 2004), pork (Collins et al., 1996; Ohlendorf and Murano, 2002) and beef (de Boer et al., 1996; Golla et al., 2002) have been reported. Similarly, no single method for successfully isolating *Campylobacter* from all sample types has yet been developed, although the method of Stern et al. (1992) has been used successfully for detecting *C. jejuni* and *C. coli* in poultry. The choice of method depends on the expected level of *Campylobacter* in the sample examined and any competitive bacterial flora that may be present.

While *Campylobacter* is recognized as a major foodborne pathogen commonly associated with poultry, only within the last decade has *Arcobacter* began to receive attention as a potential human pathogen (for reviews see Wesley, 1996, 1997). The scant availability of data on *Arcobacter* from poultry processing environments in the U.S. prompted the present study, designed to compare the prevalence of *Arcobacter* and *Campylobacter* on broiler carcasses from a commercial poultry processing plant.

2. Materials and methods

2.1. Sample collection

Broiler carcasses were collected during a total of five plant visits from August to October of 2004 at a commercial poultry

processing plant. Carcasses were randomly chosen and collected by hand using new latex gloves for each carcass from three sites along the processing line: pre-scald, pre-chill, and post-chill. Twenty-five carcasses were collected at each site and all carcasses sampled were from the same broiler flock on each plant visit. On the first two plant visits, only the pre-scald and post-chill sites were sampled. Due to low isolate recovery from the post-chill site, the pre-chill site was added for the third through fifth plant visits. This yielded a total of 125 pre-scald carcass samples, 75 pre-chill samples and 125 post-chill samples. Samples were placed into sterile plastic bags that were sealed and covered with ice in coolers for transport to the laboratory. All carcasses were subjected to a whole carcass rinse. Briefly, feathered carcasses collected at the pre-scald site were shaken with 500 ml of sterile distilled water for 60 s. Carcasses collected at the pre-chill and post-chill sites were shaken with 100 ml of sterile distilled water for 60 s. The carcasses were then discarded, and the rinses were poured into 50 ml sterile specimen cups and refrigerated at 4 °C. Samples were placed into culture media within 1 h post-collection.

2.2. Isolation of *Arcobacter*

Direct plating and sample enrichment were both used to recover *Arcobacter* from carcass rinse samples. In preliminary studies (not shown), several different media combinations were tested, including Houf broth/Houf agar (Houf et al., 2001), JM (Johnson–Murano) broth/JM agar (Johnson and Murano, 1999), EMJH P-80 (Ellinghausen–McCullough–Johnson–Harris Polysorbate-80) broth (Ellis et al., 1977)/CVA (cefoperazone, vancomycin, and amphotericin B) agar (Collins et al., 1996), and Houf broth/CVA agar. We found that Houf broth/Houf agar produced very small colonies resulting in difficulty in selecting colonies. Plates from JM broth/JM agar were heavily contaminated with background flora, while the EMJH P-80/CVA agar method was not very selective for *Arcobacter*. However, Houf broth/CVA agar was quite selective for *Arcobacter* and produced the best overall results. Hence, this media combination was chosen for further *Arcobacter* studies.

For direct plating, 100 µl aliquots of carcass rinses were spread-plated on CVA agar containing 43 g/l Brucella agar (Hardy Diagnostics; Santa Maria, CA, USA), 0.5 g/l ferrous sulfate (Sigma; St. Louis, MO, USA), 0.2 g/l sodium bisulfate (Sigma), 0.5 g/l pyruvic acid (Sigma), 950 ml distilled water, 10 mg/l vancomycin (Sigma), 10 mg/l amphotecin B (Sigma), 33 mg/l cefoperazone (approx 80% purity; Sigma) and 50 ml lysed horse blood (Lampire Biological Laboratories; Pipersville, PA, USA). Serial 1:10 dilutions in PBS were also prepared and 100 µl aliquots of each dilution were spread-plated on CVA agar plates. All plates were incubated aerobically for 48 h at 25 °C. When *Arcobacter* colonies were detected on a plate, counts per ml were not calculated but rather one colony was chosen for further characterization.

To enhance recovery of *Arcobacter*, each sample was also subjected to an enrichment procedure in Houf broth (Houf et al., 2001). This allowed for the detection of cell numbers lower than the limit of detection for direct plating (10 cells/ml). For

enrichment, 1 ml of rinse was inoculated into 5 ml Houf broth containing 24 g/l *Arcobacter* broth (Oxoid; Ogdensburg, NY, USA), 0.5 g/l thioglycolic acid (Sigma), 0.5 g/l pyruvic acid (Sigma), 16 mg/l cefoperazone (Sigma), 100 mg/l 5-fluorouracil (ICN Biomedicals; Aurora, OH, USA), 10 mg/l amphotericin B (Sigma), 32 mg/l novobiocin (Sigma), 64 mg/l trimethoprim (Sigma), and 50 ml/l lysed horse blood. Enrichment broths were incubated aerobically at 25 °C for 48 h. When direct plates were negative for *Arcobacter*, a sterile swab was used to streak 0.1 ml of the corresponding enrichment broth onto CVA agar; plates were incubated aerobically at 25 °C for 48 h.

From each positive plate resulting from direct plating or enrichment, one typical *Arcobacter* colony was subcultured twice on BBA (Brucella agar supplemented with 5% (vol/vol) lysed horse blood) to ensure clonality. Presumptive identification of *Arcobacter* was performed by microscopic examination of wet mounts of colonies using phase contrast optics. A total of 179 isolates were collected from the sampled carcasses. For frozen storage, an isolated colony was subcultured twice on BBA. Isolates were stored at –70 °C in Wang's freezing medium (Wang et al., 1980) containing 15% (vol/vol) glycerol.

2.3. Isolation of *Campylobacter*

CVA agar has also proven efficient for isolating *Campylobacter* (Zimbro and Power, 2003), and pre-scald samples were isolated by direct plating using the same method as described for *Arcobacter* with the exception that the plates were incubated at 42 °C in a microaerobic atmosphere (5% O₂, 10% CO₂, and 85% N₂). For pre-chill and post-chill carcass rinse samples, both direct plating and sample enrichment were used to recover *Campylobacter*. For *Campylobacter* enrichment, 1 ml of rinse was placed in 5 ml Bolton broth (Bolton et al., 1984) containing 27.6 g/l *Campylobacter* enrichment broth (Acumedia; Baltimore, MD, USA), 5% (vol/vol) lysed horse blood (Lampire) and Bolton broth selective supplement (Oxoid). Enrichment cultures were incubated microaerobically for 24 h at 42 °C. As with *Arcobacter*, when direct plates were negative for *Campylobacter* 0.1 ml of the corresponding Bolton broth was spread onto CVA agar and these plates were incubated microaerobically for 48 h at 42 °C.

From each positive plate resulting from direct plating or enrichment, one typical *Campylobacter* colony was subcultured twice on BBA. For presumptive identification, wet mounts of suspected *Campylobacter* colonies were examined using phase contrast microscopy. A total of 255 *Campylobacter* isolates were collected from the sampled carcasses, and were stored at –70 °C in Wang's freezing medium (Wang et al., 1980) containing 15% (vol/vol) glycerol.

2.4. Identification of *Arcobacter*

Reference strains of *Arcobacter*, including *A. buzleri* (ATCC 49616), *A. cryaerophilus* 1A (ATCC 43158), *A. cryaerophilus* 1B (ATCC 49615), and *A. skirrowii* (ATCC 51132) were used as controls. Reference strains and all presumptive *Arcobacter* isolates were incubated aerobically on BBA at 25 °C for 48 h.

Of the 179 *Arcobacter* strains collected from the broiler carcasses, 177 (98.9%) were recoverable from frozen storage and were re-grown for species identification. The *Arcobacter* spp. multiplex PCR of Kabeya et al. (2003a) was modified and used for species identification. Based on preliminary experiments (data not shown), the concentrations of template DNA, PCR primers, Taq DNA polymerase and dNTPs were adjusted to improve reproducibility of the assay. The cycling program of the PCR was also modified. Template DNA was prepared using a commercial DNA extraction kit (Gentra Systems; Minneapolis, MN, USA). The DNA concentration was adjusted to 25 ng/μl using λ_{260 nm} measured in a Beckman DU 640 spectrophotometer (Beckman Instruments; Fullerton, CA, USA). The 50 μl PCR reaction mixture contained 25 ng of DNA template, 50 pmol each of PCR primers N.c.1A and ARCO-U, 10 pmol each of N.c.1B, N.butz, and N.ski, 0.5 U of Jump Start™ Taq DNA polymerase (Sigma), 0.8 mM of dNTPs (Amersham; Warrington, UK), 10 mM Tris–HCl (pH 8.3), 50 mM KCl, and 1.5 mM MgCl₂. Nuclease-free water was added to adjust the final reaction volume to 50 μl. The sequences (5'–3') of the primers used in this PCR are: ARCO-U (*Arcobacter*), TTCGCTTGCGCTG ACATCAT; N.c.1A (*A. cryaerophilus* 1A), ACCGAAGCTTTA GATTTCGAATTTATTTCG; N.c.1B (*A. cryaerophilus* 1B), GGA CTTGCTCCAAAAGCTGAAG; N.butz (*A. butzleri*), AGCG TTCTATTTCAGCGTAGAAGATGT; N.ski (*A. skirrowii*), CGA GGTCACGGATGGAAGTG. Amplification was performed in a thermal cycler (MJ Research; Watertown, MA, USA; PTC-200) using the following program: initial denaturation at 94 °C for 10 min, followed by 30 amplification cycles consisting of denaturation for 30 s at 94 °C, annealing for 1 min at 64 °C and elongation for 1 min at 72 °C. The final elongation was performed at 72 °C for 7 min. The samples were held at 4 °C until the PCR products were analyzed. The amplified DNA products were electrophoresed on 2% agarose gels at 90 V for 6 h using 1× TBE (0.89 M Tris borate, 0.02 M EDTA, pH 8.3) as the running buffer, then stained with ethidium bromide. Gels were visualized using a UV gel documentation system (Alpha Innotech; San Leandro, CA, USA; Fluorochem™ 8900). A set of molecular weight standards (Roche; Mannheim, Germany) ranging from 100 bp to 1500 bp was included on each gel.

Table 1
Arcobacter on broiler carcasses from poultry processing plant

Sampling day	Processing line site			Total
	Pre-scald	Pre-chill	Post-chill	
A	100% (25/25) ^a	NS ¹	8% (2/25) ^a	54% (27/50) ^a
B	96% (24/25) ^a	NS	12% (3/25) ^a	54% (27/50) ^a
C	100% (25/25) ^a	72% (18/25) ^a	8% (2/25) ^a	60% (45/75) ^a
D	100% (25/25) ^a	28% (7/25) ^b	4% (1/25) ^a	44% (33/75) ^a
E	88% (22/25) ^a	84% (21/25) ^a	16% (4/25) ^a	62.7% (47/75) ^a
Total	96.8% (121/125) ^x	61.3% (46/75) ^y	9.6% (12/125) ^z	55.1% (179/325)

¹Not sampled.

^{a,b}Values within columns with no common superscripts differ significantly ($P \leq 0.05$) by the chi-square test for independence.

^{x-z}Values within rows with no common superscripts differ significantly ($P \leq 0.05$) by the chi-square test for independence.

Table 2
Arcobacter spp. on broiler carcasses from poultry processing plant

Sample site	<i>Arcobacter</i> species		
	<i>A. butzleri</i>	<i>A. cryaerophilus</i> 1A	<i>A. cryaerophilus</i> 1B
Pre-scald: 67.2% (119) ¹	78.2% (93)	3.4% (4)	18.5% (22)
Pre-chill: 26% (46)	78.3% (36)	0	21.7% (10)
Post-chill: 6.8% (12)	91.7% (11)	0	8.3% (1)
Total: 100% (177)	79.1% (140)	2.3% (4)	18.6% (33)

¹Number of samples.

2.5. Identification of *Campylobacter*

Reference strains for *Campylobacter* included *C. coli* (ATCC 33559) and *C. jejuni* (ATCC 33560). Of the original 255 *Campylobacter* isolates from the broiler carcasses, 217 (85.1%) were recoverable from frozen storage and were re-grown for species identification. Identification of *C. coli* and *C. jejuni* was determined using the BAX[®] PCR assay (Dupont Qualicon; Wilmington, DE, USA) as previously described (Englen and Fedorka-Cray, 2002). Amplification products were analyzed by electrophoresis at 130 V for 70 min using 1× TBE (0.89 M Tris borate, 0.02 M EDTA, pH 8.3) running buffer on 2% agarose gels. Gels were stained with ethidium bromide and visualized using a UV gel documentation system (Alpha Innotech). A set of molecular weight standards (Roche) ranging from 100 bp to 1500 bp was included on each gel.

2.6. Statistical analysis

Differences in the prevalence of *Arcobacter* and *Campylobacter* between plant visits and sampling sites were determined using the chi-square test for independence. The chi-square values were calculated using [no. positive/no. tested] rather than from the percentages. A value of $P \leq 0.05$ was considered statistically significant.

3. Results

Arcobacter was isolated from 55.1% (179 of 325) of carcasses from the three collection sites in the poultry processing plant (Table 1). Significantly more pre-scald samples were

Table 3
Campylobacter on broiler carcasses from poultry processing plant

Sampling day	Processing line site			Total
	Pre-scald	Pre-chill	Post-chill	
A	100% (25/25) ^a	NS ¹	4% (1/25) ^a	52% (26/50) ^a
B	60% (15/25) ^a	NS	0% (0/25) ^a	30% (15/50) ^b
C	100% (25/25) ^a	100% (25/25) ^a	68% (17/25) ^b	89% (67/75) ^{c,d}
D	100% (25/25) ^a	100% (25/25) ^a	88% (22/25) ^{b,c}	96% (72/75) ^d
E	100% (25/25) ^a	100% (25/25) ^a	100% (25/25) ^c	100% (75/75) ^d
Total	92% (115/125) ^x	100% (75/75) ^y	52% (65/125) ^z	78.5% (255/325)

¹Not sampled.

^{a–d}Values within columns with no common superscripts differ significantly ($P \leq 0.05$) by the chi-square test for independence.

^{x–z}Values within rows with no common superscripts differ significantly ($P \leq 0.05$) by the chi-square test for independence.

Table 4
Campylobacter spp. on broiler carcasses from poultry processing plant

Sample site	<i>Campylobacter</i> species	
	<i>C. coli</i>	<i>C. jejuni</i>
Pre-scald: 48.9% (106) ¹	24.5% (26)	75.5% (80)
Pre-chill: 26.7% (58)	0	100% (58)
Post-chill: 24.4% (53)	1.9% (1)	98.1% (52)
Total: 100% (217)	12.4% (27)	87.6% (190)

¹Number of samples.

contaminated with *Arcobacter* (96.8%) compared to those from the pre-chill and post-chill sites. The positive rate of *Arcobacter* from pre-chill samples from sampling day “D” was much less than those in other sampling days, but the overall contamination rates observed for the five sampling days were not significantly different ($P \leq 0.05$). One hundred seventy-seven of the 179 *Arcobacter* isolates were recoverable from frozen storage and were identified to the species level by multiplex PCR (Table 2). *A. butzleri* was most commonly found (79.1%), followed by *A. cryaerophilus* 1B (18.6%); no *A. cryaerophilus* 1A was isolated from pre-chill and post-chill carcasses.

Campylobacter was isolated from 78.5% (255 of 325) of the carcasses from the three collection sites. Pre-scald and pre-chill carcasses had the highest contamination rate of *Campylobacter*, 92% and 100% positive, respectively (Table 3). Recovery of *Campylobacter* from post-chill carcasses was more than five-fold greater than for *Arcobacter* from the same site. The number of samples positive for *Campylobacter* varied significantly by sampling day and site. While all post-chill samples were positive for *Campylobacter* on sampling day “E”, only one post-chill sample on day “A” and none on day “B” was *Campylobacter* positive. Of the 255 total *Campylobacter* strains isolated from the broiler carcasses, 217 (85.1%) were recoverable from frozen storage and these were identified to the species level by PCR. Between *Campylobacter* species, *C. jejuni* (87.6%) was far more common than *C. coli* (12.4%; Table 4). However, on sampling day “A”, all positive samples were identified as *C. coli*, while for all other sampling days, *C. jejuni* was detected most commonly. Most *C. coli* (26/27) were recovered from pre-scald samples, while *C. jejuni* was distributed commonly among all three collection sites.

4. Discussion

The overall prevalence of *Arcobacter* and *Campylobacter* species on broiler carcasses at the commercial poultry plant surveyed was 55.1% (179 of 325) and 78.5% (255 of 325), respectively. *A. butzleri* was identified as the predominant species (79.1%), while *A. cryaerophilus* 1B was detected on 18.6% of all carcasses examined ($n=325$). Similarly, *C. jejuni* was identified far more frequently than *C. coli* (87.6% and 12.4%, respectively) from all carcasses.

In a study of Belgian poultry slaughterhouses, Houf et al. (2002) found 96.2% and 95% ($n=480$) of the tested samples positive for the presence of arcobacters on broiler neck skin samples collected after evisceration and chilling, respectively, although a different isolation method, sample type and technique

was used. These authors also found *Arcobacter* more frequently than *Campylobacter* on neck skins of broilers before and after chilling, and that the slaughter procedure used had no apparent effect. A Japanese survey of *Arcobacter* spp. in livestock reported 3.6% and 10.0% of cattle and swine fecal samples, respectively, were positive as well as 14.5% of chicken cloacal swabs (Kabeya et al., 2003b). They also reported that *A. butzleri* was the most prevalent species in cattle and swine. However, among *Arcobacter* strains from chickens, *A. cryaerophilus* 1B was more commonly isolated than *A. butzleri* (55.9% and 47.1%, respectively). High levels of *A. cryaerophilus* have also been reported in aborted porcine fetuses (Schroeder-Tucker et al., 1996; de Oliveira et al., 1997). In a study from the United Kingdom in which *A. butzleri*, *A. cryaerophilus* and *A. skirrowii* were isolated from retail chickens and abattoir chicken carcasses, the authors noted that *A. skirrowii* strains were sensitive to the deoxycholate contained in the agar plates used (Atabay et al., 1998). The comparison between our isolation method and their method is not possible due in part to different sampling numbers. *A. skirrowii* was not isolated from any samples in the present study. This may be due to its slow growth under aerobic conditions (Kabeya et al., 2003b). The growth of *A. butzleri* on CVA agar plates under aerobic atmosphere was faster than those of the other three species. The greater rate at which *A. butzleri* grows compared to the other *Arcobacter* spp. may account in part as to why it is encountered more frequently.

In the present study, as broiler carcasses were processed from pre-scalding to post-chilling, the positive percentage of *Arcobacter* was decreased sharply. Other reports (Atabay and Corry, 1997; Corry and Atabay, 2001; Houf et al., 2002) support the idea that mechanical processing decreases the presence of *Arcobacter*. Poultry may not be a natural source and *Arcobacter* (Atabay and Corry, 1997), and contamination on the surface of broiler carcasses may occur in poultry processing plants. To our knowledge, no information has been reported on the prevalence of *Arcobacter* from carcasses from different processing sites in U.S. poultry plants.

Compared to *Arcobacter*, the contamination level of *Campylobacter* between the pre-chilled (100%) and pre-scalded carcasses (92%) was not considerably different. The reason could be the rupture of internal organs such as the ceca and colon resulting in high numbers of *Campylobacter* being leaked onto the carcasses (Berrang et al., 2000). It should be noted that the skin of poultry meat is usually not removed and high levels of *Campylobacter* may be present on and in the skin. Scalding at 50–53 °C generally can reduce the numbers of *Campylobacter* significantly, but defeathering may cause recontamination with *Campylobacter* and cross-contamination between carcasses. Logue et al. (2003) noted positive *Campylobacter* species (*C. jejuni* and *C. coli*) from surface swabbing of carcasses sampled at two plants (Plant A: 40.8% pre-chill vs. 37.6% post-chill; Plant B: 41.8% pre-chill vs. 19.8% post-chill). Our study found *Campylobacter* from 100% of pre-chilled carcasses and 52% in post-chilled carcasses. The different contamination rates may be due to the plants sampled, different conditions of the plant, processing procedure, and differences in the analytical methods used to process the samples.

According to decimal reduction value (*D*-values) of *Arcobacter* (D'Sa and Harrison, 2005) and *Campylobacter* reported by other researchers (Blankenship and Craven, 1982), *Arcobacter* and *Campylobacter* are usually more heat sensitive than other vegetative bacteria and are inactivated easily by cooking. Human infection typically results from eating of undercooked poultry or via cross-contamination from inadequate handling of poultry products. Factors that affect the incidence of *Arcobacter* and *Campylobacter* on poultry from processing plants are dependent on the season, poultry plant examined, geographical location, and type of production (Logue et al., 2003). A review by Corry and Atabay (2001) summarized that *C. coli* was found on 6% to 50% of broiler carcasses. Our study showed an overall rate of 12.4% for *C. coli*. *C. jejuni* has been reported to be the most frequent species recovered from poultry (Jorgensen et al., 2002; Kramer et al., 2000) and foods of animal origin (Zanetti et al., 1996) in accordance with our result (88%). Seasonal variations in occurrences of *Campylobacter* in poultry products have been described in several reports (Blaser et al., 1983; Genigeorgis et al., 1986; Peterson et al., 2001; Willis and Murray, 1997). No studies concerning the seasonal incidence of *Arcobacter* in poultry processing plants have been reported. However, *Arcobacter* isolated from cattle, swine and chicken farms did not show significant seasonal differences (Kabeya et al., 2003b). Although Atabay and Corry (1997) reported that *Arcobacter* species may not colonize the poultry intestinal tract, further studies are needed to determine the levels of *Arcobacter* recovered from external and internal sites of broilers, and whether seasonal variations occur with *Arcobacter* as it does with *Campylobacter*.

Arcobacter has gained attention in recent years as an emerging foodborne pathogen (for reviews see Lehner et al., 2005; Snelling et al., 2006), likely due in part to its close phylogenetic relationship to *Campylobacter*. The development of suitable control measures to minimize *Arcobacter* in the production, processing and retail environments merits attention and requires further investigation.

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