Prevalence and risk factors for shedding of thermophilic *Campylobacter* in calves with and without diarrhea in Austrian dairy herds

D. Klein,^{*1} M. Alispahic,[†] D. Sofka,[‡] M. Iwersen,^{*} M. Drillich,^{*} and F. Hilbert[‡]

^{*}Section for Herd Health Management, Clinic for Ruminants, Department for Farm Animals and Veterinary Public Health,

[†]Clinic for Avian, Reptile and Fish Medicine, Department for Farm Animals and Veterinary Public Health, and

[‡]Institute of Meat Hygiene, Meat Technology and Food Science, Department for Farm Animals and Veterinary Public Health, University of Veterinary Medicine Vienna, 1210 Vienna, Austria

ABSTRACT

The objectives of this study were to evaluate the presence of thermophilic *Campylobacter* in feces of calves with and without diarrhea on dairy farms and to survey farm characteristics and management practices to define risk factors for the presence of *Campylobacter*. Fifty dairy farms were chosen based on the presence of calf diarrhea, and 50 farms in which calves were free from diarrhea served as a standard of comparison. In total, fecal samples were taken from 382 calves. Farm data and management practices were surveyed using a questionnaire on farm. *Campylobacter* were isolated from fecal samples and colonies were identified by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry analysis. *Campylobacter* spp., mainly *Campylobacter jejuni* (93% of isolated species), were detected on 33% of the farms and in 14.9% of the calves. Detection of *Campylobacter* did not differ between farms or between calves with and without diarrhea, although we found a tendency for calves suffering from diarrhea to shed *Campylobacter* more often. Calves may act as a reservoir of *Campylobacter* and may therefore lead to infections of other animals and humans. To define control strategies to reduce *Campylobacter* in calves, we identified on-farm risk factors. The presence of poultry on the farm, the time of cow-calf separation following birth, the use of an individual bucket for each calf, the feeding of waste milk, and the duration of individual housing were variables significantly associated with the appearance or absence of *Campylobacter*.

Key words: *Campylobacter*, calf, dairy herd, risk factor

INTRODUCTION

Campylobacter has long been recognized as a pathogen and commensal organism of animals, and it is one of the most common causes of bacterial gastroenteritis in humans worldwide (Allos, 2001). *Campylobacter* species are widely distributed among animals. In contrast to most other animals, in which *Campylobacter* does not cause any symptoms, *Campylobacter* spp., especially *Campylobacter jejuni*, may cause diarrhea in calves (Al-Mashat and Taylor, 1983; Diker et al., 1990; Schulze, 1992). In addition to the potential risk of *Campylobacter* in contributing to enteritis in calves, calves might act as a reservoir for *Campylobacter* spp. and be a source of human infection, either by direct contact or through fecal contamination of food and water.

Little information is available on the prevalence of *Campylobacter* spp. in milk-fed dairy calves. Reported prevalence ranges from 11 to 36% (Achá et al., 2004; Grinberg et al., 2005), and inter-herd prevalence in young cattle up to the age of 1 yr varied between 47 and 97% (Giacoboni et al., 1993; Ellis-Iversen et al., 2009a). Such data are not available for Austrian cattle herds.

Few risk factors for shedding of *Campylobacter* spp. by cattle have been described. Ellis-Iversen et al. (2009b) identified the presence of dairy cows on farm, drinking from a private water supply, feeding of hay, presence of horses, and indoor housing of young cattle as risk factors for shedding *Campylobacter* spp. in 3- to 17-month-old cattle. In contrast, in adult cattle, outdoor housing was associated with the appearance of *Campylobacter* (Grove-White et al., 2010). In calves up to the age of 3 mo from cow-calf operations in Switzerland, animal's age, housing in open barns, herd size, and the feeding of more than 50% silage were identified as risk factors (Busato et al., 1999). In contrast, in young dairy calves up to the age of 15 d, only group housing was described as a risk factor for harboring *Campylobacter* (Waltner-Toews et al., 1986).

The aim of the present study was to evaluate the prevalence of thermophilic *Campylobacter* in feces of

Received July 27, 2012.

Accepted November 5, 2012.

¹Corresponding author: Daniela.Klein@vetmeduni.ac.at

preweaned calves in Austrian dairy herds and to assess farm characteristics and management factors as possible risk factors associated with shedding of *Campylobacter* spp. Calves suffering from acute diarrhea were compared with healthy neighbor calves and to animals from farms without calf diarrhea.

MATERIALS AND METHODS

During 2009 and 2010, 100 dairy farms were visited in 2 regions of Austria (Lower Austria and Styria). In herds with a maximum of 5 preweaned calves, 100% of the animals were tested. On farms with more than 5 preweaned animals, 5 were randomly chosen. Assuming an inter-herd prevalence of over 40% (Giacoboni et al., 1993; Ellis-Iversen et al., 2009a), 5 samples were required from each herd to detect 1 positive calf with 95% confidence (calculation by use of Win Episcope 2.0; www.clive.ed.ac.uk/winepiscope/). Fifty herds were chosen based on the history of calf diarrhea. In these farms, one or more calves were suffering from acute diarrhea at the time of the farm visit (hereafter “diseased” farms). Another 50 farms were included in the study where calves had been free from diarrhea for at least 6 wk (hereafter “healthy” farms). These farms were comparable in structure and geographic distribution to the diseased farms.

Farm management characteristics were evaluated by a face-to-face interview with the farmer during the farm visit by use of a questionnaire that included questions concerning farm structure, farm size, health status of the herd, calf housing, cleaning and disinfection of calf housing and calving areas, feeding of the calves, calving management, and common hygienic measures. The calf rearing area was inspected and hygiene was estimated by evaluation of calf housing (bedding and pen walls) and the calves themselves according to Lundborg et al. (2005).

The health status of each sampled calf was evaluated by clinical examination. Healthy calves had to be free from diarrhea, whereas sick calves showed signs of abnormal fecal consistency at the time of sampling. Feces were evaluated using the scoring system (scaled 1 to 4) published by Larson et al. (1977). Scores 3 and 4 were categorized as diarrhea. After clinical examination, a fecal sample was taken by gloved hand directly from the rectum and stored in a sterile plastic tube. Samples were transported cooled on ice to the laboratory and processed within a day.

Laboratory Procedures

For detection and isolation of thermophilic *Campylobacter* spp., fecal samples were analyzed according to the standards described by ISO-10272 (ISO, 2006).

In brief, fecal samples were enriched in Bolton broth (Oxoid, Basingstoke, UK) for 48 h at 42°C under microaerophilic conditions (10% CO₂, 5% O₂, and 85% N₂). A loopful of this enrichment was streaked onto modified charcoal cefoperazon deoxycholate agar (Oxoid) and a second loopful onto CampyFoodAgar (bioMérieux, Marcy l'Étoile, France). Both plates were incubated at 42°C for 48 h under microaerophilic conditions. Additionally, fecal material (without prior enrichment) was directly streaked on modified charcoal cefoperazon deoxycholate agar and CampyFoodAgar and incubated at 42°C for 48 h. Morphological typical colonies were differentiated by aerobic incubation, PCR (Linton et al., 1997), and 16S rRNA gene sequencing on selected strains.

Campylobacter isolates were further identified and differentiated by matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) mass spectrometry analysis and Biotyper reference database version 3 (Bruker Daltonik GmbH, Leipzig, Germany) as described by Alispahic et al. (2010). For MALDI-TOF, colonies were grown on Columbia blood agar containing 5% sheep blood (bioMérieux) at 42°C for 48 h under microaerobic conditions. Single colonies were removed and analyzed.

Statistical Analysis

Data were analyzed statistically using PASW version 17.0 (IBM Corp., New York, NY). Descriptive statistics were calculated to describe farm characteristics and management practices. A 2-step process was used to assess the influence of different variables on the appearance of *Campylobacter* spp. on farms (herd level) and in calves (individual level).

Univariable regression tests were performed to analyze associations between *Campylobacter* status (negative = 0, positive = 1) and each binary or categorical variable. *t*-Tests were performed to compare between continuous variables and the *Campylobacter* status. Variables with a *P*-value ≤ 0.2 were included in a multiple logistic regression model, using *Campylobacter* status as outcome variable and farm as random effect. All variables (parametric and nonparametric) were tested for correlation by Pearson or Spearman rank correlation, respectively, before entering the model. If a correlation (>60%) was found, one of the covariates was discarded, taking biological plausibility into account. A backward stepwise elimination of nonsignificant variables was performed to obtain a minimal model containing only significant variables (*P* < 0.05); independently of statistical significance, herd size was forced into the model as a proxy confounder. Model fit was evaluated with the Hosmer-Lemeshow test for 10 groups.

RESULTS

Shedding of *Campylobacter*

The median number of dairy cows per farm was 36, with a minimum of 5 and a maximum of 223 cows. The number of cattle per farm (categorical) and the distribution of *Campylobacter* related to herd size are shown in Table 1. In total, 382 calves from 100 dairy farms were enrolled in the study. In 62 herds, all preweaned calves were sampled, and on 91 herds, $\geq 50\%$ of all preweaned calves on farm were sampled. The median age of examined calves was 17 d, with a range of 1 to 69 d. Percentages of sampled animals per farm are shown in Table 1. The detection rate of *Campylobacter* spp. did not differ with herd size ($P = 0.75$) or the proportion of sampled animals ($P = 0.85$).

Campylobacter spp. were detected in 57 of 382 fecal samples (14.9%) and in 33% of the herds. On diseased farms, 79 diarrheic calves and 126 nondiarrheic calves were tested. The remaining 177 calves originated from healthy farms. Of the 79 diarrheic calves, 17 (21.5%), and of the 303 healthy calves, 40 (13.2%) shed *Campylobacter* spp. *Campylobacter* spp. could be diagnosed in 13% of the healthy and 20% of the diseased farms. The detection rate of *Campylobacter* did not differ significantly in healthy and diseased animals or between healthy and diseased farms ($P = 0.06$ and $P = 0.14$, respectively). Table 2 shows the distribution of *Campylobacter* spp. among herds and animals.

By use of PCR and MALDI-TOF/Biotyper analysis, 93% (53/57) of all *Campylobacter* isolates were identified as *C. jejuni*. The remaining 4 isolates were identified as *Campylobacter coli*.

Farm Characteristics and Risk Factors

All calves were fed with milk, milk replacer, or both. Thirty-six percent of all examined calves received only liquid feed, whereas 64% of the animals were offered additional hay or grain. Most of the calves (304 calves, 80%) were housed in individual calf hutches or igloos. The remaining 20% were housed in groups of 2 to 30 animals. Concerning the site of housing, 169 calves (44%) were housed within the cow stable, 99 (26%) in facilities for calves and young stock, and 30% (114 animals) outdoors.

The univariable analysis revealed that at the herd level, the presence of poultry was associated with the shedding of *Campylobacter* spp. [odds ratio (OR) 2.54, 95% CI: 1.08–5.97; $P = 0.03$; Table 3]. Furthermore, the time of cow-calf separation after birth had an influence. Herds in which calves were left with their dam for more than 1 h had a 2.62 higher risk for being *Campylobacter* positive than herds in which calves were separated from the cow immediately after birth (OR 2.62, 95% CI: 1.02–6.74; $P = 0.05$; Table 3). At the individual level, the presence of poultry also showed an association with the presence of *Campylobacter* in calves (OR 2.14, 95% CI: 1.21–3.79; $P = 0.01$; Table 4). Additionally, feeding of waste milk (OR 0.47, 95% CI: 0.24–0.92; $P = 0.03$) and the duration of individual housing (OR 0.98, 95% CI: 0.96–0.99; $P < 0.01$) were negatively associated with shedding of *Campylobacter* (Table 4).

At the herd level, the following variables with a P -value ≤ 0.2 at univariable analysis were used in a multiple logistic regression model: presence or absence of diarrhea, presence of poultry and farm animals others

Table 1. Number of cattle, preweaned calves, and sampled animals per farm and distribution of *Campylobacter* spp. on 100 dairy farms in Austria¹

Variable	Category	No.	<i>Campylobacter</i> spp.			
			Positive		Negative	
			No.	%	No.	%
Herd size/total no. of cattle on farm (categorical)	1–50	28	10	36	18	64
	51–100	48	14	29	34	71
	101–150	17	6	35	11	65
	>150	7	3	43	4	57
No. of preweaned calves on farm (categorical)	1–5	63	22	35	41	65
	6–10	28	7	25	21	75
	11–15	6	3	50	3	50
	>15	3	1	33	2	67
Proportion (%) of sampled calves (categorical)	100	62	22	35	40	65
	75–99	11	3	27	8	73
	50–74	18	4	22	14	78
	<50	9	4	44	5	56

¹No statistical significant differences were detected in the presence of *Campylobacter* spp. on farm in regard to herd size, number of preweaned calves, and proportion of sampled calves ($P > 0.05$).

Table 2. Occurrence of *Campylobacter* spp. in the feces of diarrheic and healthy calves on 100 dairy farms in Austria¹

Item	Number	<i>Campylobacter</i> spp.			
		Positive		Negative	
		No.	%	No.	%
Calves	382	57	14.9	325	85.1
Farms	100	33	33.0	67	67.0
Farms with diarrhea	50	20	40.0	30	60.0
Farms without diarrhea	50	13	26.0	37	74.0
Calves from farms with diarrhea	205	34	16.6	171	83.4
Calves from farms without diarrhea	177	23	13.0	154	87.0
Calves with diarrhea	79	17	21.5	62	78.5
Calves without diarrhea	303	40	13.2	263	86.8

¹No statistical significant differences were detected between any of the groups ($P > 0.05$).

than poultry or swine (e.g., goat, sheep), presence of horses, animal caretaker, site of group housing, birth in a calving pen or not, separation of calf and dam following birth, and use of a separate bucket for each calf (Table 3). Of these 9 variables initially included in the model, 3 remained significant ($P < 0.05$). The presence of poultry on the farm was associated with the occurrence of *Campylobacter* spp. in calves (OR 5.21,

95% CI: 1.82–14.92; $P < 0.01$). Furthermore, calves left with their dam in the maternity pen after birth were at a higher risk of shedding *Campylobacter* spp. compared with calves that were removed to individual housing immediately (OR 4.03, 95% CI: 1.37–11.82; $P = 0.01$). Feeding each calf from an individual bucket or not also had a significant effect on *Campylobacter* detection in calf feces. Feeding each calf from its own bucket pro-

Table 3. Results of the univariable analysis on herd level with *Campylobacter* presence (positive/negative) as independent variable¹

Variable	<i>Campylobacter</i>		Coefficient	SE	Odds ratio	95% CI	<i>P</i> -value
	Positive	Negative					
Farm free from calf diarrhea							
Yes	13	37			1		
No	20	30	0.641	0.433	1.90	0.81–4.43	0.14
Poultry present							
No	14	43			1		
Yes	19	23	0.931	4.544	2.54	1.08–5.97	0.03
Other farm animals (e.g., sheep, goats)							
No	28	62			1		
Yes	5	4	1.018	0.708	2.77	0.69–11.09	0.15
Horses present							
No	27	63			1		
Yes	6	4	1.253	0.685	3.50	0.91–13.41	0.07
Animal care							
Only family	32	58			1		
Employees	1	9	1.603	1.077	4.97	0.60–40.99	0.14
Grouped calf housing							
Indoor	20	50			1		
Outdoor	4	3	1.204	0.808	3.33	0.68–16.25	0.14
Calves are born in a calving pen							
No	13	18			1		
Yes	20	49	−0.571	0.450	0.56	0.23–1.37	0.20
Separation of calf and cow after birth							
Immediately	21	50			1		
After a few hours	10	10	0.963	0.482	2.62	1.02–6.74	0.05
Individual bucket for each calf							
No	29	46			1		
Yes	4	19	1.075	0.585	2.93	0.91–9.47	0.07

¹Only variables with a P -value ≤ 0.2 that were included in the multiple regression model are shown.

Table 4. Results of univariable analysis on individual level with *Campylobacter* presence (positive/negative) as independent variable¹

Variable	<i>Campylobacter</i>		Coefficient	SE	Odds ratio	95% CI	<i>P</i> -value
	Positive	Negative					
Season of sampling							
Winter	24	174			1		
Summer	33	151	−0.460	0.290	0.63	0.90–2.80	0.11
Farm							
Conventional	44	280			1		
Organic	13	45	0.609	0.354	1.84	0.92–3.69	0.09
Poultry present							
No	24	198			1		
Yes	33	127	0.763	0.291	2.14	1.21–3.79	0.01
Cats with access to the stable							
No	9	79			1		
Yes	48	246	0.539	0.386	1.71	0.08–3.65	0.16
Horses present							
No	48	294			1		
Yes	9	31	0.576	0.409	1.78	0.80–3.97	0.16
Animal care							
Only family	55	283			1		
Employees	2	42	−1.406	0.739	0.24	0.06–1.04	0.06
Individual calf housing							
Indoor	8	78			1		
Outdoor	49	245	0.688	0.400	1.95	0.88–4.29	0.10
Feeding waste milk to calves							
No	17	51			1		
Yes	40	273	−0.744	0.340	0.47	0.24–0.92	0.03
Water supply							
Private	38	251			1		
Public	16	68	0.441	0.328	1.55	0.82–2.95	0.18
Separate bucket for each calf							
Yes	9	80			1		
No	48	243	0.563	0.385	1.76	0.82–3.74	0.14
Calf diarrhea							
Absent	40	263			1		
Present	17	62	0.589	0.322	1.80	0.96–3.39	0.06
Duration of individual housing (d)	29	41	−0.250	0.007	0.98	0.96–0.99	0.00

¹Only variables with a *P*-value ≤0.2 that were included in the multiple regression model are presented.

tected it from being *Campylobacter* positive (OR 0.20, 95% CI: 0.05–0.77; *P* = 0.02; Table 5).

At the individual level, 12 variables with a *P*-value ≤0.2 were included in the multiple model: season, type of farm (conventional or organic), presence of poultry, cats with access to the stable, presence of horses, animal caretaker, place of individual calf housing (indoor vs. outdoor), feeding of waste milk to calves, private or public water supply, use of a separate bucket for each calf, calf diarrhea, and duration of individual housing of calves (Table 5). In the final model, the presence of poultry (OR 2.34, 95% CI: 1.17–4.68; *P* = 0.02), the feeding of calves with waste milk (OR 0.37, 95% CI: 0.17–0.84; *P* = 0.02), and the length of individual housing (OR 0.98, 95% CI: 0.97–0.99; *P* = 0.02) were significant (Table 6). The presence of poultry was identified as a risk factor, whereas calves fed waste milk had a lower risk for shedding of *Campylobacter* and the longer calves were housed individually, the lower their chance of being *Campylobacter* positive.

DISCUSSION

In this study, the proportion of *Campylobacter* shedding calves was 14.9%, within the range of previously reported prevalence, although higher values (up to 38%) have been described (Busato et al., 1999; Grinberg et al., 2005). A possible explanation for these findings could originate in management after birth. For example, time that calves spent with their dam turned out to be a risk factor for the shedding of *Campylobacter*. In contrast to our study, calves in these earlier studies (Busato et al., 1999; Grinberg et al., 2005) were mainly left with their dam. Furthermore, calves in these prior studies were group-housed, a variable positively associated with *Campylobacter* shedding (Waltner-Toews et al., 1986). Another explanation could be an underestimation of the true prevalence in our study because a maximum of 5 animals were tested on each farm. However, on more than half of the farms studied, these calves represented 100% of the preweaned calves, and on almost all the

Table 5. Multiple analysis of risk factors for the appearance of *Campylobacter jejuni* and *Campylobacter coli* in calves on a herd level¹

Variable	Coefficient	SE	Odds ratio	95% CI	P-value
Herd size ²	0.2	0.262	1.2	0.71–1.98	0.52
Poultry present					
No			1		
Yes	1.6	0.537	5.21	1.82–14.92	<0.01
Separation of calf and cow after birth					
Immediately			1		
After a few hours	1.4	0.550	4.03	1.37–11.82	0.01
Individual bucket for each calf					
No			1		
Yes	–1.59	0.678	0.20	0.05–0.77	0.02

¹Hosmer-Lemeshow $P = 0.62$.²Proxy confounder.

farms (91%), more than half of the calves were enrolled in the study.

Shedding of *Campylobacter* spp. did not differ between healthy and diarrheic calves or between farms with presence or absence of diarrhea; however, on an individual level, we observed a tendency that diarrheic calves shed *Campylobacter* more frequently than healthy calves (21.5 vs. 13.2%; $P = 0.06$). Nevertheless, it has to be taken into account that the number of diarrheic calves was low compared with healthy calves. Similar results were obtained by Adesiyun et al. (1992) concerning diarrheic calves. In contrast, De Rycke et al. (1986) and Achá et al. (2004) could not find any difference in shedding of *Campylobacter* between diarrheic and nondiarrheic calves. Our results support the hypothesis that *Campylobacter* might be one contributor to enteritis in calves but does not seem to be a major pathogen. This hypothesis should be confirmed by infection studies. The youngest calf that shed *Campylobacter* in the present study was only 3 d of age. Early infection could be due to contamination of the calving area because the time spent in this area was a risk factor.

Cattle may be a source for human infection either by direct contact (Eberhart-Phillips et al., 1997; Smith et al., 2004) or by environmental contamination. Until now, the importance of cattle in the epidemiology of *Campylobacter* has not been well understood. Critical control points to reduce shedding of *Campylobacter* in cattle herds are largely unknown. To establish intervention strategies on farm, knowledge of risk factors associated with the appearance of *Campylobacter* is essential.

In the current study, the presence of poultry was significantly associated with the shedding of *Campylobacter* in calves. Poultry are known to be the most important reservoir of *Campylobacter* and, as in poultry, *C. jejuni* was the predominant species in calves. Not only are cattle at risk of being infected by poultry, but cattle have been described as a risk factor for infection of broiler flocks (Hansson et al., 2010). We found no association between *Campylobacter* in calves and the presence of other animals such as sheep, goats, pigs, equines, and pets on farm.

Another variable associated with the appearance of *Campylobacter* was the time between separation of calf

Table 6. Multiple analysis of risk factors for the appearance of *Campylobacter jejuni* and *Campylobacter coli* in calves on an individual level with farm as cluster effect¹

Variable	Coefficient	SE	Odds ratio	95% CI	P-value
Herd size ²	0.621	0.680	1.86	0.49–7.06	0.39
Poultry present					
No			1		
Yes	0.852	0.353	2.34	1.17–4.68	0.02
Feeding waste milk to calves					
No			1		
Yes	–0.987	0.414	0.37	0.17–0.84	0.02
Time of individual housing (d)	–0.018	0.008	0.98	0.97–0.99	0.02

¹Hosmer-Lemeshow $P = 0.26$.²Proxy confounder.

and cow after birth. The odds of becoming *Campylobacter* positive was 4.03 times higher on farms in which calves were not immediately separated from their dams compared with farms where calves were immediately separated. A possible explanation could be that in stress situations (e.g., calving), cows shed *Campylobacter* more often and in greater amounts (Stanley et al., 1998), leading to a large environmental load that might infect newborn calves. Another risk factor could be the transmission of bacteria by suckling. The route of infection might be by fecal contamination rather than via milk itself (Hakkinen and Hanninen, 2009). Thus, the advice to transfer calves as quickly as possible from the calving area or herd to clean, individual housing could be important in reducing *Campylobacter* infection of calves.

Calves from farms on which animals were fed with an individual bucket were at a lower risk of being *Campylobacter* positive, supporting the hypothesis that *Campylobacter* could be spread by contamination of the bucket teat. Artificial teats are not usually cleaned between calves when the buckets are used for multiple animals. On the individual calf level, the feeding of waste milk was associated with the shedding of *Campylobacter*. Namely, calves fed waste milk showed a lower prevalence of *Campylobacter* than calves not fed waste milk. A possible explanation could be antibiotic residues present in the milk and the competition between *Campylobacter* and other bacteria that are usually higher in numbers in waste milk. This finding should be elucidated in further studies. Furthermore, milk composition and pH may change due to disease of the mammary gland or because of drug treatment and therefore negatively affect the survival of *Campylobacter* (Moore et al., 2000; Chaveerach et al., 2003; Doyle and Erickson, 2006).

CONCLUSIONS

Although it had been assumed that *Campylobacter* spp. could lead to diarrhea in calves, the data from the current study suggest that *Campylobacter* spp. do not play a major role in diarrhea of calves. However, *Campylobacter* spp. were found in 33% of the examined farms, suggesting that calves may act as a reservoir for *Campylobacter*, especially *C. jejuni*, which may lead to infection of other animals and humans. Further research is required to elucidate these interactions. To establish on-farm intervention strategies to reduce the shedding of *Campylobacter*, risk factors associated with the presence of *Campylobacter* have to be determined. The following variables were associated with *Campylobacter* shedding in calves: presence of poultry on the farm, length of time in the calving area, use of a

shared feeding bucket, and the time of individual housing; these factors should be decreased or eliminated to reduce *Campylobacter* shedding in calves.

ACKNOWLEDGMENTS

This study was financed by the University of Veterinary Medicine Vienna (Austria) by a start-up project (Profillinie 2).

REFERENCES

- Achá, S. J., I. Kuhn, P. Jonsson, G. Mbazima, M. Katouli, and R. Mollby. 2004. Studies on calf diarrhoea in Mozambique: Prevalence of bacterial pathogens. *Acta Vet. Scand.* 45:27–36.
- Adesiyun, A. A., J. S. Kaminjolo, R. Loregnard, and W. Kitson-Piggott. 1992. *Campylobacter* infections in calves, piglets, lambs and kids in Trinidad. *Br. Vet. J.* 148:547–556.
- Al-Mashat, R. R., and D. J. Taylor. 1983. Production of enteritis in calves by the oral inoculation of pure cultures of *Campylobacter fetus* subspecies *intestinalis*. *Vet. Rec.* 112:54–58.
- Alispahic, M., K. Hummel, D. Jandreski-Cvetkovic, K. Nobauer, E. Razzazi-Fazeli, M. Hess, and C. Hess. 2010. Species-specific identification and differentiation of *Arcobacter*, *Helicobacter* and *Campylobacter* by full-spectral matrix-associated laser desorption/ionization time of flight mass spectrometry analysis. *J. Med. Microbiol.* 59:295–301.
- Allos, B. M. 2001. *Campylobacter jejuni* infections: Update on emerging issues and trends. *Clin. Infect. Dis.* 32:1201–1206.
- Busato, A., D. Hofer, T. Lentze, C. Gaillard, and A. Burnens. 1999. Prevalence and infection risks of zoonotic enteropathogenic bacteria in Swiss cow-calf farms. *Vet. Microbiol.* 69:251–263.
- Chaveerach, P., A. A. ter Huurne, L. J. Lipman, and F. van Knapen. 2003. Survival and resuscitation of ten strains of *Campylobacter jejuni* and *Campylobacter coli* under acid conditions. *Appl. Environ. Microbiol.* 69:711–714.
- De Rycke, J., S. Bernard, J. Laporte, M. Naciri, M. R. Popoff, and A. Rodolakis. 1986. Prevalence of various enteropathogens in the feces of diarrheic and healthy calves. *Ann. Rech. Vet.* 17:159–168.
- Diker, K. S., S. Diker, and M. B. Ozlem. 1990. Bovine diarrhea associated with *Campylobacter hyointestinalis*. *Zentralbl. Veterinarmed. B.* 37:158–160.
- Doyle, M. P., and M. C. Erickson. 2006. Reducing the carriage of food-borne pathogens in livestock and poultry. *Poult. Sci.* 85:960–973.
- Eberhart-Phillips, J., N. Walker, N. Garrett, D. Bell, D. Sinclair, W. Rainger, and M. Bates. 1997. *Campylobacteriosis* in New Zealand: Results of a case-control study. *J. Epidemiol. Community Health* 51:686–691.
- Ellis-Iversen, J., A. J. Cook, R. P. Smith, G. C. Pritchard, and M. Nielsen. 2009a. Temporal patterns and risk factors for *Escherichia coli* O157 and *Campylobacter* spp. in young cattle. *J. Food Prot.* 72:490–496.
- Ellis-Iversen, J., G. C. Pritchard, M. Wooldridge, and M. Nielsen. 2009b. Risk factors for *Campylobacter jejuni* and *Campylobacter coli* in young cattle on English and Welsh farms. *Prev. Vet. Med.* 88:42–48.
- Giacoboni, G. I., K. Itoh, K. Hirayama, E. Takahashi, and T. Mitsuoka. 1993. Comparison of fecal *Campylobacter* in calves and cattle of different ages and areas in Japan. *J. Vet. Med. Sci.* 55:555–559.
- Grinberg, A., W. E. Pomroy, J. F. Weston, A. Ayanegui-Alcerrecas, and D. Knight. 2005. The occurrence of *Cryptosporidium parvum*, *Campylobacter* and *Salmonella* in newborn dairy calves in the Manawatu region of New Zealand. *N. Z. Vet. J.* 53:315–320.
- Grove-White, D. H., A. J. Leatherbarrow, P. J. Cripps, P. J. Diggle, and N. P. French. 2010. Temporal and farm-management-associated variation in the faecal-pat prevalence of *Campylobacter jejuni* in ruminants. *Epidemiol. Infect.* 138:549–558.

- Hakkinen, M., and M. L. Hanninen. 2009. Shedding of *Campylobacter* spp. in Finnish cattle on dairy farms. *J. Appl. Microbiol.* 107:898–905.
- Hansson, I., E. O. Engvall, I. Vagsholm, and A. Nyman. 2010. Risk factors associated with the presence of *Campylobacter*-positive broiler flocks in Sweden. *Prev. Vet. Med.* 96:114–121.
- ISO. 2006. ISO/TS 10272: Microbiology of food and animal feeding stuffs—Horizontal method for detection and enumeration of *Campylobacter* spp. Part 2: Colony-count technique. International Organization for Standardization (ISO), Geneva, Switzerland.
- Larson, L. L., F. G. Owen, R. D. Albright, R. D. Appleman, R. C. Lamb, and L. D. Miller. 1977. Guidelines toward more uniformity in measuring and reporting calf experimental data. *J. Dairy Sci.* 60:989–991.
- Linton, D., A. J. Lawson, R. J. Owen, and J. Stanley. 1997. PCR detection, identification to species level, and fingerprinting of *Campylobacter jejuni* and *Campylobacter coli* direct from diarrheic samples. *J. Clin. Microbiol.* 35:2568–2572.
- Lundborg, G. K., E. C. Svensson, and P. A. Oltenacu. 2005. Herd-level risk factors for infectious diseases in Swedish dairy calves aged 0–90 days. *Prev. Vet. Med.* 68:123–143.
- Moore, S. J., M. J. VandeHaar, B. K. Sharma, T. E. Pilbeam, D. K. Beede, H. F. Bucholtz, J. S. Liesman, R. L. Horst, and J. P. Goff. 2000. Effects of altering dietary cation-anion difference on calcium and energy metabolism in peripartum cows. *J. Dairy Sci.* 83:2095–2104.
- Schulze, F. 1992. *Campylobacter* as the cause of diarrhea in calves. *Dtsch. Tierarztl. Wochenschr.* 99:458–461.
- Smith, K. E., S. A. Stenzel, J. B. Bender, E. Wagstrom, D. Soderlund, F. T. Leano, C. M. Taylor, P. A. Belle-Isle, and R. Danila. 2004. Outbreaks of enteric infections caused by multiple pathogens associated with calves at a farm day camp. *Pediatr. Infect. Dis. J.* 23:1098–1104.
- Stanley, K. N., J. S. Wallace, J. E. Currie, P. J. Diggle, and K. Jones. 1998. The seasonal variation of thermophilic *Campylobacters* in beef cattle, dairy cattle and calves. *J. Appl. Microbiol.* 85:472–480.
- Waltner-Toews, D., S. W. Martin, and A. H. Meek. 1986. An epidemiological study of selected calf pathogens on Holstein dairy farms in Southwestern Ontario. *Can. J. Vet. Res.* 50:307–313.