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## Farm characteristics and calf management practices on dairy farms with and without diarrhea: A case-control study to investigate risk factors for calf diarrhea

D. Klein-Jöbstl,<sup>1</sup> M. Iwersen, and M. Drillich

Clinical Unit for Herd Health Management, University Clinic for Ruminants, Department for Farm Animals and Veterinary Public Health, University of Veterinary Medicine Vienna, 1210 Vienna, Austria

### ABSTRACT

Calf diarrhea is one of the most important problems in calf rearing on dairy farms worldwide. Besides pathogens, several noninfectious management factors, especially management around birth, colostrum management, calf housing, feeding, and hygiene are important in the pathogenesis of diarrhea. To date, few data are available concerning calf rearing management on small and medium-sized dairy farms that are typical for Austria and the alpine region. Consequently, the objectives of this case-control study were to evaluate routine calf management practices on Austrian dairy farms and to examine differences in management between farms with and without the presence of calf diarrhea to identify risk factors. Overall, 100 dairy farms were visited. Of these farms, 50 were chosen based on the history and presence of calf diarrhea (case farms). Another 50 farms with no presence of calf diarrhea were chosen to serve as a standard of comparison (control farms). On farms, management was evaluated by face-to-face interview, and health status and hygiene were surveyed. Several calf rearing management procedures were similar on all of the visited farms, especially in areas regulated by national and European law. These factors include colostrum management and feeding. Consequently, no influence of these factors on the appearance of calf diarrhea could be detected. In contrast, other areas such as hygiene measures differed between farms and showed a partial association with the presence of calf diarrhea on farm. Variables related to diarrhea on farm were farm size; that is, the number of cows on farm. Farms with diarrhea cases were larger (median 40 cows, interquartile range 24.5 to 64.0) compared with farms with no presence of diarrhea (median 28 cows, interquartile range 18.8 to 44.0). Other risk factors that influenced the presence of diarrhea were the presence of other farm animal species on the farm [odds ratio (OR) 26.89, 95% confidence interval (CI): 2.64 to 273.5], frequency of

cleaning of the calving area (OR 0.12, 95% CI: 0.02 to 0.79), the placement of individual calf housings (barn vs. outdoors; OR 0.02, 95% CI: 0.00 to 0.47), and the presence of respiratory tract disease (OR 52.49, 95% CI: 1.26 to 2,181.83). The possible influence of these factors on the appearance of calf diarrhea should be considered when farmers are advised.

**Key words:** diarrhea, dairy calf, management

### INTRODUCTION

Calf management, especially calving management, care of the newborn, colostrum management, calf housing and feeding, as well as hygiene, has an important effect on calf performance and health. The most important health concern is calf diarrhea, resulting in the greatest economic loss in this age group (Torsein et al., 2011). Diarrhea is a complex, multifactorial disease with numerous infectious and noninfectious factors. Factors influencing the pathogenesis of diarrhea are pathogen exposure, environmental conditions, management, nutritional state, and immune status.

Different studies have aimed to identify risk factors for the presence of calf diarrhea, sometimes with contradictory results. Bendali et al. (1999), for example, reported that cow cleanliness and cleaning of the barns after the calving season may prevent diarrhea. Similar results were obtained in a prospective cohort study by Frank and Kaneene (1993). Pithua et al. (2009) compared the prevalence of diarrhea and other diseases in calves in regard to cleaning the calving area. In that study, the risk for diarrhea or any other calf disease was not different between groups, indicating that management factors other than the calving pen had a greater influence on calf health. Regarding colostrum supply, few authors could determine statistically significant effects. The origin of colostrum and route of colostrum feeding (nipple or bucket versus suckling) have been associated with the occurrence of diarrhea (Svensson et al., 2003; Lundborg et al., 2005). Furthermore, the concentration of IgG was related to diarrhea (Berge et al., 2009).

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<sup>1</sup>Corresponding author: Daniela.Klein@vetmeduni.ac.at

Additional factors associated with diarrhea were breed (Lundborg et al., 2005; Svensson and Liberg, 2006; Svensson et al., 2006), the placement of indoor calf pens against an outer wall compared with pens separated from outer walls (Lundborg et al., 2005), keeping grouped calves on a slatted concrete floor versus other floors, housing in freestalls compared with tiestalls, purchasing calves (Gulliksen et al., 2009), and calf stocking density (Bendali et al., 1999).

In Europe, some management and environmental factors concerning calf rearing are regulated by law (Council Directive 2008/119/EC; European Community, 2008). This European directive is specified in some areas by Austrian legislation (Tierhaltungsverordnung, 2004). Regulated areas are colostrum support within the first 6 h postpartum and some aspects of calf housing and feeding. In contrast, although the importance of hygienic measures is known (Weaver et al., 2000), they are not regulated.

Little data are available concerning calf management on small and medium-sized dairy farms as typical for Austria. Thus, the objective of the present study was to evaluate routine calf management practices on Austrian dairy farms and to define risk factors for the presence of calf diarrhea in a case-control study.

## MATERIALS AND METHODS

### *Experimental Design*

One hundred dairy farms in Austria were visited and evaluated once by the same person from September to March of 2009–2010. To recruit case farms, local veterinarians of 2 areas in Austria, Lower Austria and Styria, were asked to provide lists of dairy farms with a documented problem of calf diarrhea during the past year. A farm with diarrhea problems was defined as a farm with multiple treatments by the veterinarian for calf diarrhea. Out of these lists, farms were randomly chosen, and farmers were contacted in the week before the planned visit, asked if problems with calf diarrhea were still present on farm, and asked whether they were willing to participate in the study. Farms were only enrolled into the study when at least one calf suffered from diarrhea at the farm visit. Five farms refused to participate and another 7 of the contacted farms had no actual cases of diarrhea. To define cases of diarrhea, feces of preweaned calves was evaluated as described by Larson et al. (1977), where scores 3 (runny, spreads readily to about 6 mm depth) and 4 (watery, liquid consistency, splatters) were categorized as diarrheic.

Local veterinarians were asked to identify additional farms to serve as control farms, from the same geographical region and of similar structure but with no

history of calf diarrhea problems and no current diarrhea cases. To achieve good similarity in structure, the type of farm (conventional or organic), the type of cow barn (freestall or tiestall), and the number of dairy cows were used as further criteria. The farms that best fit these criteria were contacted and visited at the same time as the farms with diarrhea. If no suitable farm was available in the same geographical region or the farms did not want to participate in the study (17 farms), the next best fitting farm was chosen. Farms were excluded as control farms if one or more calves suffered from diarrhea at the time of the visit; this was the exclusion criterion for 7 farms. Presence of other diseases did not exclude a farm from the study.

A sample size of 50 case and 50 control farms provides 95% confidence of detecting an odds ratio of  $\geq 3.5$  (80% statistical power), assuming a minimum of 20% of control farms exposed to the factor of interest (Thrusfield et al., 2001).

A questionnaire was used to collect data during a face-to-face interview with the farm owner or manager. Areas of interest were farm characteristics, health status of the animals, calf housing and feeding, focusing on calves within the first weeks of life, management practices around calving and birth, as well as hygienic measures. Calf rearing areas were visited and hygiene was evaluated as described by Lundborg et al. (2005). To evaluate calf hygiene, the legs, thighs, and ventral abdomen of up to 5 randomly chosen preweaned calves were scored. The percentage of the body part that was contaminated with feces was documented (0 to 100%). Furthermore, the pen walls and bedding material of up to 5 individual and group calf housings for preweaned calves were scored. A value of 0 to 5% described a clean area, 6 to 30% a mildly dirty area, 31 to 70% a moderately dirty area, and  $>70\%$  a severely contaminated area.

Depending on farm size, up to 5 randomly chosen preweaned calves were examined by the same person according to the clinical examination of ruminants (Radostits et al., 2007). This examination included evaluation of behavior and general appearance, posture, body condition, body conformation, skin (including umbilicus), head (eyes, nostrils, mouth), thorax (respiratory rate, rhythm, depth, type, and noises), pulse, auscultation of the lung and heart, and abdomen. Respiratory tract disease was defined as severely increased respiratory sounds at lung auscultation or as moderately increased respiratory sounds together with additional signs, such as dyspnea, coughing, or nasal discharge. By definition, an umbilical infection was diagnosed when at least 2 of the 3 following signs were present: local swelling of the external umbilicus, increased local temperature, and pain.

**Table 1.** Overview of general farm characteristics on the 100 visited farms

Variable	Category	Number of farms <sup>1</sup>		P-value
		Case	Control	
Farm type	Conventional	40	44	0.41
	Organic	10	6	
Type of cow barn	Freestall	43	42	0.78
	Tied up	7	8	
Number of dairy cows	Median <sup>2</sup>	40	28	0.01
	IR <sup>3</sup> (25 to 75%)	24.5 to 64.0	18.8 to 44.0	
Animal caretaker	Farmer and family	42	48	0.09
	Employee(s)	8	2	
Main cattle breed on farm	Simmental	45	45	1.00
	Holstein-Friesian	4	2	0.68
	Brown Swiss	0	2	0.99
	Others	1	1	
Farm animals other than cattle on farm	No	32	18	0.16
	Yes	24	24	
	Variable	0	2	
Other species on farm (multiple answers possible)	Poultry	24	18	0.31
	Pigs	18	13	0.39
	Small ruminants (sheep and goats)	3	5	0.32

<sup>1</sup>Case farms are farms with the presence of diarrhea; control farms are farms without calf diarrhea.

<sup>2</sup>Variable was not categorized; continuous variable.

<sup>3</sup>IR = interquartile range.

## Data Analysis

Data were analyzed using PASW (version 20.0; IBM Corp., New York, NY). Descriptive statistics were calculated to describe farm characteristics and management practices. The association of farm characteristics and management factors with the occurrence of calf diarrhea was tested in a 2-step process. The association between the appearance of diarrhea on farm and the evaluated factors was analyzed by  $\chi^2$  test, Fisher's exact test if in one field the number was  $<5$ , or univariable regression tests for each binary or categorical variable. Student's *t*-tests were performed to compare normally distributed continuous variables and health status (diarrhea present vs. not present), and the Mann-Whitney U-test was used for not normally distributed continuous variables. Variables with a *P*-value  $\leq 0.2$  were included in a multiple logistic regression model using presence of diarrhea on farm as a binary outcome variable (present vs. not present). All variables were tested for correlation by Pearson or Spearman rank correlation coefficient before entering the model. If a correlation of  $>60\%$  was given, one of the covariates was discarded. A backward stepwise elimination of non-significant variables was performed to obtain a minimal model containing only significant variables ( $P < 0.05$ ). Herd size was forced into the model as a confounder. Model fit was evaluated with the Hosmer-Lemeshow test for 10 groups.

## RESULTS

Farm characteristics, with the exception of the number of cows, were similar between the visited farms as shown in Table 1. The median number of dairy cows was 34 [interquartile range (IR; 25 to 75%): 22 to 50], whereas on farms with diarrhea the median number was 40 and on farms without diarrhea the median number was 28 cows.

### Management Around Calving and Care of the Newborn

Data concerning management around calving and care of the newborn calf are presented in Table 2. A calving pen or box was present on 69 farms, with a significant difference between farms with (40) and without (29) diarrhea. Another significant difference between farms with and without diarrhea was detected in cleaning frequency of this area. Questions in terms of "care of the newborn" included the time of cow-calf separation after birth, first colostrum supply, and umbilical care. On most of the farms (76), calves were separated from their dam immediately after birth or recognition of birth by the farmer if the calf was born unattended. On 20 farms, calves were usually separated within 24 h after birth; on the remaining 4 farms, calves were separated later than 24 h after birth. On almost all farms (99), the owner or manager stated that each calf

**Table 2.** Summary of management around calving and care of the newborn calves on the 100 visited farms

Variable	Category	Number of farms <sup>1</sup>		P-value
		Case	Control	
Calving pen or box on farm	No	10	21	0.02
	Yes	40	29	
If a calving pen or box is present:				
Calving area used for diseased animals	No	6	7	0.15
	Yes	34	28	
Bedding material in calving area	Straw	38	29	0.65
	Rubber mattress	2	0	
Cleaning of calving area after each use	No	12	30	0.03
	Yes	8	5	
Cow-calf separation postpartum	Immediately	35	41	0.29
	Within 24 h postpartum	12	8	
	Later than 24 h postpartum	3	1	
First colostrum feeding	Within 6 h postpartum	50	49	1.00
	Later than 6 h postpartum	1	0	
Colostrum quantity within first 6 h postpartum	>3 L	42	45	0.55
	1 to 3 L	8	5	
Route of first colostrum feeding	Suckle dam	5	2	0.44
	Bucket	45	48	
	Esophageal feeder	0	0	
Checking colostrum quality	No	49	50	1.00
	Yes	1	0	
Frozen colostrum stock	No	16	13	0.73
	Yes	34	37	
Dam vaccination prepartum (against rotavirus, coronavirus, and different <i>Escherichia coli</i> )	No	39	44	0.19
	Yes	11	6	
Umbilical care	No	22	12	0.06
	Yes	26	36	
	Variable	2	2	

<sup>1</sup>Case farms are farms with the presence of diarrhea; control farms are farms without calf diarrhea.

received colostrum within 6 h after birth; on 7 farms, calves were allowed to suckle their dam. Esophageal feeders were not routinely used on any of the farms, but this option was left for exceptional cases. Only on one of the farms colostrum quality was determined by use of a hydrometer.

Umbilical disinfection was performed on 34 of the farms, where iodine, antimicrobial-containing sprays, foreshot (the impure spirit produced in the first stages of distillation), or schnapps (distilled alcohol with a minimum of 15% alcohol by volume) was used.

Prepartum dam vaccination against rotavirus and coronavirus as well as different species of *Escherichia coli* was performed on 17 farms. This was a standard procedure on 6 farms without and 11 farms with the presence of diarrhea. None of these variables differed between case and control farms.

### Calf Housing

Calf housing characteristics are summarized in Table 3. On 99 farms, calves were housed individually after birth, usually for 1 to 12 wk, with a median of 6 wk. On 66 farms (38 case and 28 control farms), calves were already grouped preweaning, and on the remaining 34 farms, calves were grouped after weaning. Preweaning

calves were kept in groups of 2 to 30 animals (median 6), mainly with animals of different ages. Calves were housed individually within the cow barn on 40, in facilities for calves and young stock on 12, outdoors on 21, and indoors and outdoors depending on number of calves and season on 26 of 99 farms. Significant differences were found between farms with and without diarrhea when a combination of indoor and outdoor housing was used compared with outdoor housing of all calves. Outdoor housing of all calves was more common on control farms compared with farms with diarrhea (case farms). All preweaned calves were housed on straw. Individual housings were cleaned daily only on 6 farms. On all other farms, the farmer indicated that fresh straw was added if necessary, and pens were cleaned after the calf left the box.

### Calf Feeding

Standard calf feeding procedures on the visited farms are summarized in Table 4. Calves were fed with whole milk on 84 farms. Waste milk (milk from cows treated with antibiotics and from cows with mastitis) was offered to calves on 82 farms, but to male calves only on 48 farms. On most of the farms (96), milk or milk replacer was fed restricted to 10 to 12% of the calf

**Table 3.** Data on calf housing on the 100 visited farms

Variable	Category	Number of farms <sup>1</sup>		<i>P</i> -value
		Case	Control	
Individual calf housing postpartum	No	1	0	
	Yes	49	50	1.00
Days of individual calf housing postpartum	Median <sup>2</sup>	42	42	0.18
	IR <sup>3</sup> (25 to 75%)	21 to 56	14 to 56	
Type of individual calf housing	Synthetic igloo	6	10	
	Wooden box	28	33	0.07
	Combination	16	7	0.08
Bedding material	Straw	50	50	
	Others	0	0	
Placement of individual calf housing	Outside	10	11	
	Within a barn	21	31	0.14
	Combination	18	8	0.02
Cleaning of individual calf housings	Daily	1	5	
	After calf left the housing	49	45	0.20
Cleaning individual calf housing (multiple answers allowed)	No cleaning	1	3	
	Dry	15	7	0.53
	Use of water	32	28	0.78
	Disinfection	10	14	0.62
Group housing of calves preweaning	No	12	22	
	Yes	38	28	0.06
Place of preweaning group housing <sup>4</sup>	Outside	4	1	
	Barn for young stock and calves	15	10	0.44
	Within the cows barn	18	16	0.78
	Combination	1	1	0.94
Group composition preweaning <sup>4</sup>	Calves of the same age group	7	1	
	Calves of different ages	31	27	0.13
Group size preweaning (no. of calves) <sup>4</sup>	Median <sup>2</sup>	6.0	5.5	0.22
	IR <sup>3</sup> (25 to 75%)	4.0 to 9.5	4.0 to 8.3	

<sup>1</sup>Case farms are farms with the presence of diarrhea; control farms are farms without calf diarrhea.

<sup>2</sup>Variable was not categorized; continuous variable.

<sup>3</sup>IR = interquartile range.

<sup>4</sup>As the focus of the study was on preweaned calves, only data of farms with preweaning group housing (n = 66) are shown.

BW, usually in 2 meals per day. Weaning on farm was mainly dependent on the animals' age. The median age at weaning on farms with diarrhea was 10.0 wk (IR 8.0 to 12.0) and on farms without diarrhea was 9.0 wk (IR 8.0 to 12.0). On none of the farms was the amount of solid feed eaten by the calf before weaning or BW examined and documented.

Hay was offered to the calves from the second week of life on 79 farms (41 case and 38 control farms). Silage was generally not fed to preweaned animals. On 68 farms, calves had free access to concentrates starting within the first 3 wk of life. On 25 farms, calves did not receive any concentrates before the third week of life; on 7 farms, only some calves received concentrates, depending on sex (when male calves were sold for veal production) and other factors. None of the variables concerning calf feeding differed between case and control farms.

### Hygiene Scores

On 94 farms, calves were categorized as clean or mildly dirty. On 5 farms, calves were moderately dirty,

and on only 1 farm were calves severely soiled. A similar distribution was found concerning calf housing. On 88 of the farms, calf housing areas were not soiled or were mildly soiled. Housing was categorized as moderately dirty on 10 farms and as severely soiled on 2 farms.

### Diseases

Overall, 382 calves were examined on 100 farms, 205 of which were on case farms. Of these 205 calves, 79 animals (39%) suffered from acute diarrhea at the time of the farm visit. The average age of diarrheic calves was  $16 \pm 11$  d. On 19 (10 case and 9 control) farms, umbilical infections (swelling, increased local temperature, and pain) were diagnosed. Acute respiratory tract disease was detected on 8 (7 case and 1 control) farms.

### Farm and Management Characteristics Associated with Diarrhea

Sixteen variables with a *P*-value  $\leq 0.2$  by univariable regression test were used in the multiple test. These variables were number of cows, presence of other farm

**Table 4.** Data on standard calf feeding on the 100 visited farms

Variable	Category	Number of farms <sup>1</sup>		P-value
		Case	Control	
Milk feeding	Whole milk	44	40	
	Milk replacer	1	5	0.89
	Both	5	5	0.20
Feeding waste milk to calves	No	8	9	
	Only to male calves	24	24	0.84
	To all calves (males and females)	17	17	1.00
Quantity of milk fed	No answer	1	0	
	Ad libitum	2	2	
	Restricted (10 to 12% of calf BW)	48	48	
Type of feeding	Bucket with artificial teat	49	46	
	Bucket without artificial teat	0	2	0.54
	Automated milk feeder	1	2	0.99
Cleaning of bucket after each feeding	No	2	1	
	Yes	48	49	0.62
Cleaning of bucket	With cleaning agents	9	15	
	Only water	37	35	0.35
Buckets shared by calves	No	11	12	
	Yes	39	38	
Weaning age (wk)	Median <sup>2</sup>	10.0	9.0	0.63
	IR <sup>3</sup> (25 to 75%)	8.0 to 12.0	8.0 to 12.0	
Access to hay from wk 2 of life	No	9	9	
	Yes	41	38	0.75
	Variable	0	3	0.69
Access to concentrates from first 3 wk of life	No	12	13	
	Yes	33	35	0.28
	Variable	5	2	0.26
Access to water preweaning	No	7	4	
	Free access	19	22	0.42
	Restricted access	24	24	0.73

<sup>1</sup>Case farms are farms with the presence of diarrhea; control farms are farms without calf diarrhea.

<sup>2</sup>Variable was not categorized; continuous variable.

<sup>3</sup>IR = interquartile range.

animals on farm (no/yes), animal caretaker [only family/employee(s)], presence of a calving pen (no/yes), usage of the calving pen for diseased animals (no/yes), cleaning of the calving pen after each use (no/yes), umbilical care postpartum (no/yes), cow-calf separation postpartum (immediately/within 24 h), prepartum dam vaccination (no/yes), type of individual calf housing (synthetic igloo/wooden box/combo), placement of individual calf housing (outdoors/within barn/combo), days of individual calf housing, cleaning of individual calf housing (dry/water), group housing of calves (same age group/different ages), group size, feeding of milk or milk replacer (milk/milk replacer), and respiratory tract disease (absent/present on farm). Type and placement of individual calf housing showed a high correlation (Spearman correlation  $r = 0.73$ ). Consequently, only the variable “placement of individual calf housing” was chosen for the model. After backward stepwise elimination of nonsignificant variables, a minimal model containing only significant variables was obtained. This minimal model consisted of 5 variables: herd size, presence of farm animals other than cattle on farm, cleaning of the calving pen, placement of in-

dividual calf housing, and the presence of respiratory tract disease in calves on farm (Table 5). A greater herd size, expressed by the number of dairy cows, increased the odds of calf diarrhea on farm [odds ratio (OR) 1.05, 95% CI: 1.00 to 1.10;  $P = 0.03$ ]. Furthermore, the presence of other farm animals was a risk factor (OR 26.89, 95% CI: 2.64 to 273.5;  $P = 0.01$ ). On farms where the calving area was cleaned after each calving, calves had decreased odds for calf diarrhea compared with farms where calves were born in calving areas only cleaned seldom or several times per year (OR 0.12, 95% CI: 0.02 to 0.79;  $P = 0.03$ ). Placement of individual calf housing in a barn (either in a barn only for calves and young stock or in the cows' barn) versus outdoors decreased the risk of diarrhea (OR 0.02, 95% CI: 0.00 to 0.47;  $P = 0.01$ ). Additionally, the presence of respiratory tract disease was associated with diarrhea on farm (OR 52.49, 95% CI: 1.26 to 2,181.83;  $P = 0.04$ ).

## DISCUSSION

This study surveyed and described management practices in calf rearing on dairy farms in Austria to

**Table 5.** Multiple analyses of risk factors for the appearance of calf diarrhea on the 100 visited dairy farms<sup>1</sup>

Variable	Category	Coeff. <sup>2</sup>	SE	Odds ratio	95% CI	P-value
Number of cows		0.05	0.02	1.05	1.00–1.10	0.03
Presence of other farm animals	No			1		
	Yes	3.29	1.18	26.89	2.64–273.5	0.01
Cleaning of calving pen after each calving	No			1		
	Yes	–2.01	0.94	0.12	0.02–0.79	0.03
Placement of individual calf housing	Outside			1		
	Inside	–3.76	1.54	0.02	0.00–0.47	0.01
	Combination	–2.90	1.42	0.06	0.00–0.90	0.04
Respiratory tract disease in calves	No			1		
	Yes	3.96	1.90	52.49	1.26–2,181.83	0.04

<sup>1</sup>Hosmer-Lemeshow:  $P = 0.98$ .

<sup>2</sup>Coeff. = regression coefficient.

identify risk factors for diarrhea on these farms. The sample size of 100 farms was within the range of similar studies (Healy et al., 2004; Dippel et al., 2009; Sauter-Louis et al., 2012). With this sample size, an OR of  $\geq 3.5$  for a risk factor prevalent at 20% would be significant (statistical power of 80%). A greater sample size might have increased the validity but sample size in this study was limited by time and funding resources.

### Farm Characteristics

Regarding farm characteristics, the type of the cow facilities, breed, and caretaker were similar between farms. The average number of cows per farm (34 cows in our study) was larger than the overall average in the 2 visited regions, with 18 and 21 cows per farm, respectively, as reported by the Austrian Association of Cattle Breeders (ZAR, 2010). This might be influenced by selection of the farms being based exclusively on the presence of diarrhea. It is likely that very small farms might have been recognized as diarrhea problem farms less often because only a few calves were present during the selection period. This might have biased the outcome and has to be taken into account when interpreting the results. In this study, the presence of diarrhea was significantly associated with herd size. One possible explanation for the association between farm size and diarrhea could be that although farms in Austria have become larger in recent years, additional personnel were not employed on the surveyed farms. Even on farms with up to 115 cows, no employees were present, which could lead to a decrease in the time that the farmer can spend on calf care. Similar results concerning the association between the appearance of diarrhea and the herd size were obtained by Vaarst and Sørensen (2009) in Denmark. Furthermore, Frank and Kaneene (1993) identified an increased incidence of calf diarrhea for larger herds, explained by greater housing density that could lead to larger disease outbreaks. Kehoe et al. (2007) reported better colostrum

management in smaller farms, which could also reduce the prevalence of disease in young calves.

Another variable significantly associated with diarrhea was the presence of farm animals other than cattle on farm. Other farm animals can host pathogens causing calf diarrhea (e.g., cryptosporidia; McGuirk, 2008) and therefore be a risk factor on farms.

### Management Around Calving and Care of the Newborn

The literature concerning the importance and influence of the calving area on calf health is contradictory (Frank and Kaneene, 1993; Bendali et al., 1999; Pithua et al., 2009). A calving pen was present more often on case farms in the current study than on control farms ( $P = 0.02$ ). Cleaning of such an area after each calving significantly reduced the odds of calf diarrhea on farm, as shown by the multiple analyses. A consequent cleaning was performed on only 19% of the farms with a calving area. The increased appearance of diarrhea on farms with a calving pen could therefore be explained by a lack of hygiene and the use of this area for diseased animals. This might lead to a high degree of contamination with pathogens and consequently to high infection pressure on the newborn calf. We can conclude that regular hygienic measures in the calving area should be implemented to reduce the risk of calf morbidity, as shown in other studies (Frank and Kaneene, 1993; Bendali et al., 1999).

Another factor that might influence the risk for diarrhea is the time the calf spends within the calving area with its mother, especially when hygiene is poor. This factor was not a risk factor on the visited farms.

The importance of an adequate colostrum supply, and therefore the passive transfer of immunoglobulins, for calf health is well known. Time of first colostrum feeding, as well as colostrum quantity and quality, plays an important role (Weaver et al., 2000; Barrington et al., 2002; Svensson and Liberg, 2006). According to the



statements of the farmers on the visited farms, calves received colostrum within 6 h after birth (as required by legislation; European Community, 2008) on 99% of the farms. On 7 of these farms, calves were allowed to suckle their dam, representing a risk factor associated with failure of passive transfer (Trotz-Williams et al., 2008). None of the factors associated with colostrum supply had a significant effect on the appearance of diarrhea in our study. This is in accordance with other studies (Bendali et al., 1999; Gulliksen et al., 2009) and can be explained by the high similarity between farms and by the fact that the time of feeding first colostrum is regulated by law. Another interesting finding in this context was that colostrum quality was not controlled on any of the farms except for one.

Another factor examined was the use of a prepartum dam vaccination against rotavirus and coronavirus as well as against different *E. coli*, which was performed on only 17 farms. This prophylactic measure was performed on farms with and without diarrhea and had no influence on the presence of diarrhea on the surveyed farms. Possible reasons could be that not all cows and heifers on the farm have been vaccinated and the presence of other pathogens such as cryptosporidia.

### **Calf Housing**

On almost all of the visited farms, calves were housed individually within the first weeks of life, as described by Marcé et al. (2010). Individual calf housing is commonly advised because it may lead to a decreased pathogen load (Barrington et al., 2002); in epidemiologic studies, group size rather than grouping itself was associated with an increased risk for morbidity and mortality (Svensson et al., 2003; Maunsell and Donovan, 2008). Nevertheless, in individual calf housing, it is possible to feed calves individually according to their special needs and it is easier to control animals and recognize certain abnormalities. Housing of calves outside the barn is thought to reduce the risk of disease (Marcé et al., 2010), as indoor housing has disadvantages such as an increased pathogen load and risk for disease transmission. This, however, was not the case on farms in the present study, in which greater odds for diarrhea were found for calves housed in igloos outside the barn compared with individual housing in a barn. This is in accordance with a study performed in the United Kingdom by Johnson et al. (2013). Possible explanations could be the cold environment and exposure of the calves to considerably greater climate changes (Vasseur et al., 2010). This could be true for the 2 areas of Austria visited in the current study because minimum temperatures were  $-14$  to  $-19^{\circ}\text{C}$  during December and January 2009 and 2010. Maxi-

mum temperature differences were registered during April with a difference in mean daily temperatures up to  $19^{\circ}\text{C}$  (ZAMG, 2009–2010). An advantage of indoor housing mentioned often by farmers is easier and better monitoring of the calves.

In the present study, none of the variables concerning grouping (i.e., age at grouping, number of animals per group, and grouping of animals of the same age or not) was significantly associated with the appearance of diarrhea on farm. This might be because of the relatively small group size, with a median of 6 animals (interquartile range 4 to 8) on the visited farms. Furthermore, grouping relatively late in the calves' life (median 6 wk, interquartile range 4 to 8 wk) could have positively influenced morbidity, because the risk for diarrhea is highest in the first 3 wk of life (Bendali et al., 1999; Svensson and Liberg, 2006).

Although the importance of hygienic measures in association with calf diarrhea is well known (Barrington et al., 2002; Maunsell and Donovan, 2008), hygiene is an often neglected measure, as could be seen in our results. Standard operating procedures for cleaning and disinfection of calf housing were not present on any of the visited farms.

### **Calf Feeding**

As nutrition in calves affects calf immunity, and therefore morbidity and mortality (Nonnecke et al., 2003), data concerning this management area were evaluated.

On almost all farms (96%), calves were fed restricted amounts of milk. The reason for a restricted milk feeding program is that calves are forced to ingest concentrates earlier and at greater amounts, stimulating rumen development (Drackley, 2008). This procedure, however, does not take into account that these effects are of minor importance within the first 3 wk of life and that calves cannot meet their energy requirements by an additional intake of concentrates during this time of life (Jasper and Weary, 2002; Sweeney et al., 2010). In contrast, several studies (reviewed by Khan et al., 2011; Silper et al., 2014) showed that milk fed at amounts greater than 10 to 12% of calf BW had a positive influence on the calf performance, whereas deficiencies in nutrition may lead to depressed immunity in calves and increase morbidity (Nonnecke et al., 2003).

On most of the visited farms (84%), whole milk was fed. Waste milk was offered to the calves on 82% of the farms. Whole milk may have advantages over milk replacer in terms of greater energy content and a better balance of nutrients (Davis and Drackley, 1998; Godden et al., 2005). This might therefore improve calf immunity and lead to a decreased disease rate (Godden

et al., 2005). Additional advantages of feeding whole milk are that it is easier and less error-prone than feeding milk replacer (e.g., errors related to products with inadequate protein or incorrect mixing ratios) and that both milk produced over the available quota and waste milk can be used (Vasseur et al., 2010). Nevertheless, using whole milk and especially waste milk poses some risks, such as the transmission of pathogens and the transfer of drug residues to calves (Selim and Cullor, 1997). In the present study, no effect of milk feeding management on the appearance of diarrhea was found. This might be due to the high similarity in feeding management between farms.

### Hygiene Score

In the present study, no association was observed between calf or calf housing hygiene scores and the presence of diarrhea, in accordance with the findings of Lundborg et al. (2005). One possible explanation is that the scores were similar on most of the farms. This in turn could be explained by the fact that fresh straw was added frequently, even when calf housing was not cleaned regularly.

### Diseases

In the present study, the presence of respiratory tract disease was significantly associated with diarrhea. These results have to be interpreted with care as farms were visited only once and, therefore, results represent a snapshot. Furthermore, the number of farms with calves suffering from respiratory tract disease was low. Consequently, the confidence for this variable was low. Nevertheless, associations between respiratory tract disease and diarrhea in calves have been observed by other authors (Johnson et al., 2013; Woolums et al., 2013). The association can be explained by a lack of hygiene and impairment of the calf immunity, which predisposes calves to different multifactorial diseases. Furthermore, one disease may negatively affect calf performance and consequently predispose to other diseases. Pathogens such as coronaviruses often present on farms and have a predilection for the intestinal and respiratory tract (Boileau and Kapil, 2010).

When interpreting factors that are significantly associated with the outcome variable in a statistical model, it has to be considered that associations may not necessarily reflect actual causal or protective relationships. Furthermore, factors not analyzed in this study could have influenced the incidence of diarrhea.

### CONCLUSIONS

Many calf rearing management factors were similar between the visited farms, especially in areas regulated

by law. These factors include colostrum management, housing, and feeding procedures. Consequently, no significant influences of these factors on the appearance of calf diarrhea were detected in this study. In contrast, other areas, such as hygiene measures, differed between farms and showed, in part, a significant association with the presence of calf diarrhea on the farm. Variables significantly related to diarrhea on farm were farm size, presence of other farm animals on the farm, cleaning of the calving area after each calving, placement of individual calf housing, and the presence of respiratory tract disease. Consequently, the possible influence of these factors on the appearance of calf diarrhea should be taken into account. Improving these areas may lead to a decrease in diarrhea and might consequently reduce calf morbidity and mortality and be of economic importance.

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