J. Dairy Sci. 108:5170–5181
https://doi.org/10.3168/jds.2024-26118

Dairy farm management factors associated with clinical observations in young dairy calves sold at auction markets in Québec, Canada: A cross-sectional study

Sébastien Buczinski,[1]* Gilles Fecteau,[1] Anne-Sophie Perrault,[1] Salvatore Ferraro,[1,2] Julie Arsenault,[3] Younes Chorfi,[4] Marcio Costa,[4] Jocelyn Dubuc,[1] David Francoz,[1] Marjolaine Rousseau,[1] and Marianne Villettaz-Robichaud[1]

[1]Département des Sciences Cliniques, Faculté de Médecine Vétérinaire, Université de Montréal, St-Hyacinthe, QC, Canada J2S 2M2
[2]Department of Clinical Sciences, Swedish University of Agricultural Sciences, (SLU), SE-750 07 Uppsala, Sweden
[3]Département de Pathologie et Microbiologie, Faculté de Médecine Vétérinaire, Université de Montréal, St-Hyacinthe, QC, Canada J2S 2M2
[4]Département de Biomédecine, Faculté de Médecine Vétérinaire, Université de Montréal, St-Hyacinthe, QC, Canada J2S 2M2

ABSTRACT

In Québec, Canada, nonreplacement calves are generally sent at a young age to auction markets to be sold for veal or dairy beef production. Various clinical observations found during the calves' journey, either at an auction market or on arrival at a calf raiser farm, have been associated with increased risk of morbidity, such as dehydration or umbilical problems. The objective of this cross-sectional study was to quantify associations between calf raising management strategies at the dairy farm level and clinical observations at auction markets during sale. For this purpose, during 8 different sale days, the 2 largest auction markets in Québec were visited, and all calves sold on those days were systematically examined. The number of clinically relevant findings (CRF) present per calf (among presence of umbilical cord, wet umbilical area, umbilical pain, umbilical swelling, persistent cervical skin fold ≥2 s, sunken eyes, eye or nasal discharge, ear drop, limb anomaly, emaciation or dirty hide) was recorded. After the sale, farm owners were contacted to answer a specific questionnaire on calf management. The total number of CRF from all sold calves from the same farm (dependent variable) was modeled using Poisson multivariable regression, with questionnaire answers as potential covariates and the number of calves sold per farm during the observation period as an offset. The questionnaire was completed during a standardized phone call and focused on farm characteristics and characteristics of calves sold, including calving management, calf care at birth, nutrition, housing, and transportation. A total of 3,656 calves from 1,349 different sellers were examined. The questionnaire information was obtained from 409 different farms representing 847 calves. The median number of calves sold per farm was 2 (range: 1–19). The umbilical cord was visually present in 376 calves (44%). Among the most commonly observed CRF, eye discharge (n = 290, 34%), umbilical swelling (n = 144, 17%), and presence of dehydration signs (persistent cervical skin fold ≥2 s [n = 111, 13%] or sunken eyes [n = 83, 9.8%]) were the most commonly reported anomalies. According to the final multivariable Poisson regression model, the incidence rate ratio (IRR) of CRF for farms that sold calves at a mean age <8 d was higher than for farms that sold calves at a mean age of >10 d (IRR = 1.21, 95% CI: 1.04–1.41). The IRR was also higher for farms that did not give colostrum to calves within 1 h following birth compared with calves receiving colostrum within 1 to 2 h (IRR = 1.73, 95% CI: 1.24–2.49), 2 to 6 h (IRR = 1.48, 95% CI: 1.06–2.14) and more than 6 h (IRR = 1.59, 95% CI: 1.06–2.44) after birth. The IRR were higher for farms using milk replacer to feeding sold calves versus raw milk (IRR = 1.2, 95% CI: 1.06–1.37) and higher for farms where calves typically receive their last meal >3 h before transportation to the auction market versus calves receiving their last meal <1 h before transportation (IRR = 1.26, 95% CI: 1.04–1.53). This study provides interesting insight into farm practices that are associated with an improved clinical status of nonreplacement calves sold at auction markets for veal and beef meat.

Key words: veal calf, calf health, farm management

INTRODUCTION

Surplus dairy calves, also called nonreplacement calves, are generally male dairy calves but also include females not to be raised as replacement animals (Bolton and von Keyserlingk, 2021). In Eastern Canada, nonre-

Received December 6, 2024.
Accepted January 20, 2025.
*Corresponding author: s.buczinski@umontreal.ca

The list of standard abbreviations for JDS is available at adsa.org/jds-abbreviations-25. Nonstandard abbreviations are available in the Notes.

placement calves are classically sold before 2 to 3 wk of age directly to veal farms or after being commingled at auction markets (Winder et al., 2016; Wilson et al., 2020a; Buczinski et al., 2021). Previous Canadian studies have shown that indicators of calf illness, such as depressed attitude (Wilson et al., 2020a), unhealthy appearance, and presence of abnormal joints (Marquou et al., 2019), are associated with decreased sale prices. These clinically relevant findings (**CRF**) are nonspecific and rather suggestive of an unidentified primary disease. Such diseases are often associated with dehydration and a systemic inflammatory response (with or without a bacterial infection), which can be identified by experienced buyers. Depending on the studies and CRF, up to 20% of calves can have abnormal findings. In addition to the decreased market value, these underlying conditions may have deleterious effects during the feeding period on veal farms (Renaud et al., 2018c; Wilson et al., 2020b).

The observation of various CRF signs in young calves can be associated with individual-level (e.g., inadequate transfer of passive immunity) or farm-level (e.g., farms with an inadequate colostrum management protocol) risk factors. Previous studies have also shown that management of nonreplacement calves on dairy farms can be different from that of replacement heifers (Renaud et al., 2017). Consequently, some dairy farm management characteristics have been associated with increased risk of mortality on veal farms (Renaud et al., 2018b). Indeed, an adequate preparation of the calf before transport to the auction market is important as this transportation creates stress influencing various metabolic and clinical parameters, particularly in young calves (Roadknight et al., 2021). General guidelines for calf management and preparation for transport have been proposed as a promising way to improve health in dairy calves commingled to be fed for veal production (Devant and Marti, 2020; Renaud and Pardon, 2022).

Little is known on the effects of management practices at the farm on the clinical findings observed in nonreplacement calves at auction markets. Therefore, our objective was to evaluate associations between potential farm management factors and the presence of CRF that may potentially affect later performance in the fattening units. Our hypothesis was that some farm management characteristics would be associated with the health status of calves based on clinical observations.

MATERIALS AND METHODS

Data Collection

For this observational cross-sectional study, the 2 largest auction markets in Québec were each visited during 2 sale days in the summer of 2019 and 2 sale days in the winter of 2020. The selection of these examination days was based on convenience for the research team. The 2 auction markets were selected for convenience because ~75% of nonreplacement calves annually sold in Québec go through these 2 sites (Buczinski et al., 2021). This project was promoted by the Provincial Québec Beef Producer association (Producteurs de Bovins du Québec, Longueuil, QC, Canada) with the full participation the Québec auction market network (Réseau Encan Québec, St-Hyacinthe, QC, Canada), which provided authorization for performing the calf assessment. The project received ethical authorization from the Institutional Animal Care Committee (CEUA) of the Université de Montréal (Protocol #19-Rech-2015).

Rapid Calf Assessment. All calves sold during the selected auction days were systematically examined using a validated approach by 7 different raters but with 4 raters examining 80% of the calves (Gwet's agreement coefficient type 1 [**AC1**] between trained raters ranged from 0.71 to 1 for all signs except ear position, with an AC1 of 0.31 [Buczinski et al., 2022; Ramos et al., 2023]). Briefly, the count of CRF included the assessment of 12 different dichotomous clinical observations that may be associated with efficiency of calf performance in the fattening unit (Table 1). Among them, umbilical swelling was defined as an umbilicus larger than 2 fingers (or 3 cm in diameter), whereas umbilical pain was considered to be present if abdominal contraction or a defense reaction occurred during umbilical palpation. A wet umbilical area could be associated with umbilical disorder or poor hygiene of the calf and therefore be negatively perceived by the buyers. The presence of an umbilical cord was included because it is associated with calf age and could therefore be indicative of calves being too young to be transported (Buczinski et al., 2022). Additionally, young transported calves are at higher risk of experiencing negative fattening performance (Goetz et al., 2023). Abnormal hide cleanliness was also noted as a sign that can be easily observed by the buyers. Other clinical signs were indicative of dehydration (persistent cervical skin fold ≥2 s, sunken eye), respiratory disease (ocular or nasal discharge), otitis or depression (ear drop), and lameness (limb anomaly), whereas emaciation was considered a general indicator of poor health. These clinical observations were easily assessed in auction market settings and relevant to previous studies performed in Canadian dairy calves sold for beef market (Marquou et al., 2019; Wilson et al., 2020a).

Each calf's identification and characteristics, which included live BW, sex, and price paid by buyers (in CAD/kg), as well as the owner identification information, were obtained from the provincial sale dataset of the Producteurs de Bovins du Québec (Longueuil, QC, Canada). This list was used by the research team to re-

Table 1. Physical characteristics of 847 calves from 409 dairy farms in 2 auction market sales and comparison with calves from nonparticipating farms examined during the study period

Physical characteristic of calves	Calves from interviewed dairy farms (n = 847)[1]	Other examined calves (n = 2,809)	P-value[2]
Umbilical cord	376 (44%)	1,140 (40.5%)	0.05
Wet umbilical area	49 (5.8%)	138 (4.9%)	0.85
Umbilical pain	47 (5.5%)	136 (4.8%)	0.46
Umbilical swelling	144 (17%)	477 (16.0%)	0.99
Persistent skin fold ≥2 s	111 (13%)	422 (15.0%)	0.17
Sunken eyes	83 (9.8%)	320 (11.4%)	0.19
Eye discharge	290 (34%)	971 (34.6%)	0.89
Nasal discharge	4 (0.5%)	17 (0.6%)	0.85
Ear drop	5 (0.6%)	39 (1.4%)	0.09
Limb anomaly	7 (0.8%)	18 (0.6%)	0.74
Unclean hide	188 (22%)	579 (20.6%)	0.35
Emaciation	32 (3.8%)	137 (4.9%)	0.21

[1]The numbers represent the number of calves presenting each characteristic (proportion %).

[2]P-values obtained from chi-squared tests comparing the 2 proportions.

trieve a phone number for all owners and contact them. The sellers were located at a median distance of 57 km (interquartile range = 32.4–106.2 km) from the auction markets, as reported by Ramos et al. (2023).

Questionnaire. A questionnaire was built based on 2 previously published questionnaires; one developed to assess farm-level risk factors for poor health and death of bobby calves during transport or lairage in slaughterhouse in New Zealand (Boulton et al., 2018, 2020), and another one used to assess specific management of male calves in Canadian dairy farms (Renaud et al., 2017). Our questionnaire was created with the objective of being simple to administer within a reasonable time (aiming for 25–30 min per interview). The questionnaire, presented in Table 2, specifically addressed 1 general and 6 specific domains: (1) general farm characteristics, (2) characteristics of calves sold to auction markets, (3) calving management, (4) neonatal care, (5) calf nutrition, (6) calf housing, and (7) transportation information from farm to auction market. Full explanations on the development and testing of this questionnaire were presented in a previous paper (Ferraro et al., 2025).

From the complete list, commercial livestock traders of calves listed as owner were excluded based on the sellers' identification name including "transport" in the sale list. The dairy producers were contacted by phone. Before these phone interviews, to increase the response rate, information regarding the study was published using social media and an electronic newsletter sent to all Québec dairy producers. The producers were not aware of the specific sale day when the research team performed data collection at the different auctions. Questionnaire answers were captured in a spreadsheet (Access, Microsoft, Redmond, WA). The outreach procedure included 3 different attempts by phone to speak to the person in charge of calf care. At this stage, if the responder declined, was not a dairy producer but rather a livestock carrier not previously identified, or if the producer could not be reached, this farm was considered as not participating in the study. The objective was to enroll at least 250 different dairy herds, representing 5% of Québec dairy farms (total n = 4,877 farms in 2021). We planned to contact at least 500 different dairy farms because we anticipated a response rate of approximately 50% based on our prior experience. However, no formal sample size calculation was performed for this specific part of the study.

Descriptive Analyses

All data analyses were performed using R statistical software (R Development Core Team, 2020). Descriptive statistics were computed. A small number of farms were contacted twice during the study period (i.e., multiple calves sold by the same farm). Only 1 interview and specific calf characteristics associated with the interview period were kept for further analysis using the "unique" function of base R language.

Poisson Regression Analyses

Because the aim of the study was to describe the general quality of calves sold at auction markets, the CRF observed (up to 12 per calf, as listed in Table 1) during clinical inspection were used to define the dependent variable. An initial comparison of characteristics of calves from owners that answered the questionnaire and other calves (i.e., calves with rapid assessment results during the study period but not coming from interviewed sellers) was performed using chi-squared tests to ensure the sampled subpopulation was not different from the other calves. No strong correlations were observed among CRF (Goodman Kruskal tau test).

Table 2. Descriptive characteristics and univariable analyses of count regression from 409 Québec dairy farms

Characteristic	Frequency	N	IRR[1]	95% CI	*P*-value
Milking cows		409			
50–100	191		—	—	
<50	127		0.85	0.74, 0.99	0.037
>100	91		1.09	0.97, 1.23	0.2
Production per cow (over a 305-d period)		367			
9,500–11,000 kg	216		—	—	
<9,500 kg	91		0.96	0.83, 1.11	0.6
>11,000 kg	50		1.04	0.90, 1.21	0.6
Main breed of nonreplacement calves		388			
Holstein	336		—	—	
Angus crossed	38		0.94	0.77, 1.14	0.6
Dairy breed other than Holstein	11		0.58	0.34, 0.92	0.032
Crossbred with non-Angus beef breed	3		1.31	0.52, 2.66	0.5
Presence of Angus crossbred calves		409			
No	348		—	—	
Yes	61		1.16	1.01, 1.32	0.029
Persons involved in calf care		406			
2	190		—	—	
1	148		0.97	0.85, 1.09	0.6
≥3	68		1.02	0.88, 1.19	0.8
Specific agriculture courses		402			
Yes	283		—	—	
No	85		1	0.87, 1.15	>0.9
Unknown	34		1.06	0.88, 1.26	0.5
Presence of foreign worker on the farm		409			
No	381		—	—	
Yes	28		1.19	1.01, 1.39	0.037
Minimal years of experience with calves for caretakers	13 (IQR: 4–17)	408	0.99	0.99, 1.00	0.003
Maximal years of experience with calves for caretakers	30 (IQR: 20–40)	408	1	0.99, 1.00	0.14
Cows vaccinated against calf diarrhea		409			
Yes	131		—	—	
No	278		0.98	0.87, 1.09	0.7
Calves vaccinated against calf diarrhea		409			
Yes	16		—	—	
No	393		0.93	0.73, 1.20	0.5
Calving area		407			
Separated calving area	110		—	—	
Grouped	144		1.09	0.96, 1.24	0.2
Attached	153		1.02	0.88, 1.19	0.8
Calf separation from the dam		409			
Calf raised with the dam	44		—	—	
Separated immediately (<1 h)	42		1.15	0.89, 1.51	0.3
Separated 1–3 h after birth	157		1.28	1.03, 1.60	0.027
Separated 3–12 h after birth	98		1.27	1.01, 1.61	0.041
Separated >12 h after birth	68		1.08	0.84, 1.39	0.6
Calves raised with their dam		409			
No	365		—	—	
Yes	44		0.81	0.66, 1.00	0.054
Umbilical disinfection for calves		409			
Yes	295		—	—	
No	114		0.93	0.82, 1.05	0.3
Umbilical disinfection for nonreplacement calves		409			
Disinfection used	296		—	—	
Not disinfected	113		0.95	0.84, 1.08	0.4
Colostrum		409			
Colostrum given to surplus calves	394		—	—	
No colostrum given	15		1.59	1.07, 2.51	0.03
First feeding among replacement calves		392			
≥4 L	76		—	—	
No colostrum given	15		0.6	0.38, 0.90	0.019
<4 L	301		0.95	0.84, 1.08	0.4
First feeding different for nonreplacement calves		409			
Yes	28		—	—	
No	381		0.87	0.66, 1.13	0.3

Continued

Table 2 (Continued). Descriptive characteristics and univariable analyses of count regression from 409 Québec dairy farms

Characteristic	Frequency	N	IRR[1]	95% CI	*P*-value
First feeding among nonreplacement calves		386			
≥4 L	75		—	—	
<4 L	296		0.96	0.85, 1.09	0.5
Calves with their dam	10		0.67	0.39, 1.07	0.12
No colostrum given	5		0.47	0.19, 0.97	0.07
Colostrum feeding different for nonreplacement calves		409			
Same for all calves	378		—	—	—
Different for surplus calves	31		0.75	0.58, 0.95	0.021
First colostrum meal feeding time		408			
≤1 h after birth	16		—	—	
1–2 h after birth	168		1.63	1.18, 2.35	0.005
2–6 h after birth	185		1.39	1.00, 2.00	0.064
>6 h after birth	24		1.51	1.01, 2.31	0.049
Calf not separated from the dam for colostrum	10		1.04	0.56, 1.84	>0.9
No colostrum given	5		0.73	0.28, 1.61	0.5
Colostrum quality		409			
Test performed	63		—	—	
No test performed	346		0.84	0.74, 0.96	0.009
Different feeding program for nonreplacement calves		409			
All calves received the same feeding program	317		—	—	
Surplus calves received different feeding program	92		1.16	1.01, 1.33	0.036
Maximal volume of milk fed for nonreplacement calves		405			
≥8 L/d	58		—	—	
<6 L/d	57		0.94	0.76, 1.16	0.6
6–8 L/d	231		0.96	0.82, 1.14	0.6
Automatic milk feeder, free access	15		0.98	0.71, 1.33	>0.9
Calf fed by their dam	44		0.78	0.61, 1.00	0.054
Meal feeding frequency for nonreplacement calves		401			
2 meals per day	328		—	—	
1 meal per day	1		0.82	0.29, 1.76	0.7
3 meals per day	13		1.2	0.91, 1.55	0.2
Automatic milk feeder, free access	15		1.03	0.77, 1.35	0.8
Calf fed by their dam	44		0.82	0.66, 1.00	0.059
Milk type		408			
Milk replacer	103		—	—	
Raw milk	203		0.84	0.74, 0.96	0.007
Both	72		0.91	0.77, 1.07	0.3
Group versus individual housing		408			
Individual	275		—	—	
Grouped	93		0.98	0.85, 1.12	0.8
Attached	40		1.05	0.86, 1.27	0.7
Location of nonreplacement calf housing		407			
Inside (building)	380		—	—	
Outside (hutch)	27		0.94	0.73, 1.18	0.6
Housing conditions		408			
Individual	264		—	—	
Attached	24		0.88	0.66, 1.14	0.3
Grouped (>2)	58		0.95	0.81, 1.12	0.6
Paired	18		1.01	0.78, 1.28	>0.9
Calf raised with their dam	44		0.8	0.64, 0.99	0.041
Type of bedding		406			
Straw	200		—	—	
Wood shavings	91		1.14	1.00, 1.31	0.051
Straw and wood shavings	82		1.12	0.97, 1.30	0.12
Other	33		1.11	0.91, 1.34	0.3
Depth of bedding		352			
<10 cm	135		—	—	
≥10 cm	217		1.07	0.95, 1.20	0.3
Bedding		401			
New bedding added once a day	178		—	—	
Bedding added less than once a day	168		1.01	0.90, 1.14	0.8
Bedding added twice a day	52		1.02	0.85, 1.21	0.8

Continued

Table 2 (Continued). Descriptive characteristics and univariable analyses of count regression from 409 Québec dairy farms

Characteristic	Frequency	N	IRR[1]	95% CI	*P*-value
Bedding changed every day	3		0.66	0.30, 1.24	0.2
Bedding change between nonreplacement calves		402			
After the calf leaves the farm, before a new calf arrives	329		—	—	
Between once and twice a week	65		0.95	0.81, 1.10	0.5
More than twice a week	5		0.77	0.33, 1.49	0.5
Less than once a week	3		1.76	1.03, 2.77	0.025
Nonreplacement and replacement calves are in separated areas		409			
No	297		—	—	
Yes	112		0.94	0.84, 1.06	0.3
Time of separation for nonreplacement and replacement calves		406			
No separation	297		—	—	
At birth	95		0.95	0.84, 1.07	0.4
In the following days	14		0.83	0.63, 1.09	0.2
Sale decision		404			
Animal age	52		—	—	
Sex/twins	157		0.98	0.84, 1.16	0.8
Health/vigor	90		0.85	0.71, 1.03	0.092
Auction market transport available	4		0.81	0.47, 1.31	0.4
Genetic/beef cross	30		0.8	0.62, 1.03	0.091
Weight	71		0.88	0.73, 1.06	0.2
Mean age of nonreplacement calves sold		409			
>10 d	187		—	—	
8–10 d	154		1.08	0.95, 1.22	0.2
≤7 d	68		1.31	1.13, 1.50	<0.001
Minimal age of nonreplacement calves sold		409			
>7 d	148		—	—	
≤7 d	261		1.17	1.04, 1.32	0.012
Commercial carrier for nonreplacement calf transportation		409			
No	54		—	—	
Yes	355		1.02	0.89, 1.17	0.8
Carrier commenting on nonreplacement calves		338			
Never made any comment	189		—	—	
Gave some advice to the farmer	124		0.94	0.82, 1.07	0.3
Refused at least once to transport a calf	25		1.11	0.91, 1.35	0.3
Arrival time at the auction market known		409			
No	348		—	—	
Yes	61		1.02	0.87, 1.20	0.8
Last feeding before transportation		408			
<1 h before transportation	73		—	—	
1–3 h before transportation	269		1.18	1.01, 1.39	0.039
>3 h before transportation	66		1.34	1.11, 1.61	0.002
Producer monitoring calf loading		407			
Systematically	243		—	—	
Often (≥50% of the time)	96		0.91	0.79, 1.05	0.2
Uncommonly (<50% of the time)	12		0.88	0.62, 1.20	0.4
Never	56		0.94	0.81, 1.09	0.4
Entry of carrier forbidden in the farm		409			
Yes	185		—	—	
No	224		0.95	0.85, 1.06	0.4

[1]IQR = interquartile range; IRR = incidence rate ratio.

The model framework was a general linear model for count regression using a Poisson modeling approach. The dependent variable Y was the average count of CRF per calf of each farm:

$$P\left(Y = y\right) = \frac{e^{-\lambda} \times \lambda^{y}}{y!},$$

where y is the value of Y (y = 0, 1, …, 12), and λ is the parameter defining the Poisson distribution.

The relationship between questionnaire items and count prediction was derived from a generalized linear model for count regression with the following equation:

$$\ln\left(\lambda\right) = a_0 + \sum_{i=1}^{k} a_i \times X_i,$$

where $a_{(1,\ldots,k)}$ is the regression coefficient for $X_{(1,\ldots,k)}$ farm-level covariates, and a_0 is the intercept of the model. An offset was also used to account for the total number of calves sold by the farm during the study pe-

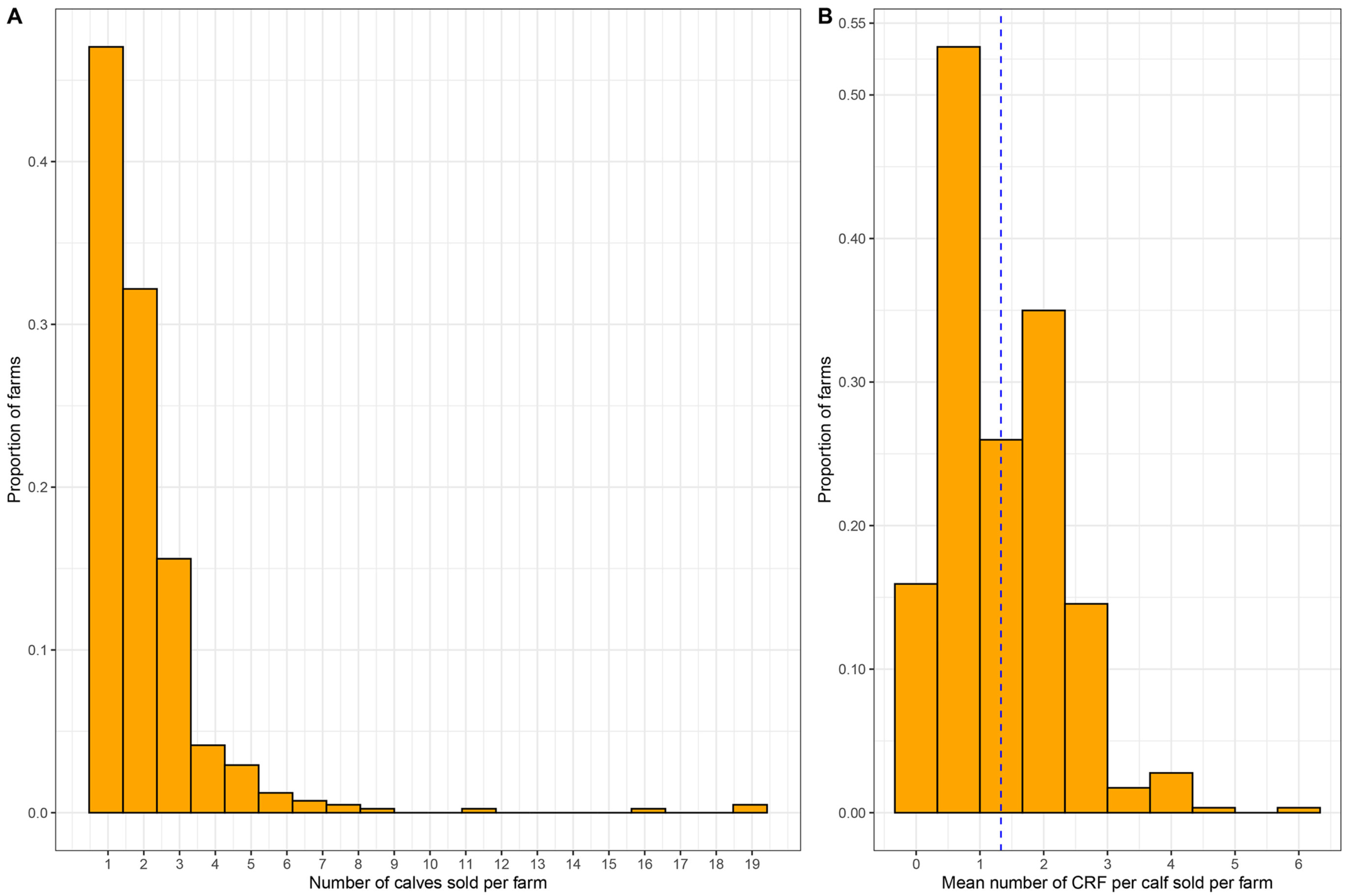

Figure 1. Number of calves sold per farm and mean clinically relevant findings (CRF) per calf from 409 Québec farms selling 847 surplus calves. Histogram describing the number of calves sold per farm (median = 2; A) and mean number of CRF per calf sold from each farm (B). The vertical blue dashed line indicates the median of the mean number of CRF per farm.

riod. The Poisson distribution assumes that the mean and variance of Y are equal to λ. Explanatory variables from the questionnaire were mostly analyzed in categorical format and were either defined a priori by clinically meaningful categories or based on the answer response profile, as previously described by Ferraro et al., (2025) and in Table 2. The modeling approach was performed in 2 different consecutive steps. First, univariable analyses were performed using univariable Poisson count regressions selecting variables with associated $P \leq 0.20$ (likelihood ratio test). Correlations between all selected categorical variables were assessed using the Goodman Kruskal tau statistic, indicating collinearity when >0.6 (Ferraro et al., 2025). When collinearity was detected, only 1 of the 2 correlated variables was kept for multivariable analysis. In a second step, a manual backward stepwise multivariable regression analysis was conducted with all variables remaining from the first step. Then starting from a full model, stepwise manual removal of the variable with the highest P-value was performed. These variables were kept in the model as confounders if they changed the coefficient of another variable by more than 20% (Dohoo et al., 2009). The procedure was repeated until all explanatory variables had $P \leq 0.05$ (except for the confounding variable).

The final regression model fit was determined using the Kolmogorov-Smirnov test on the residual distribution and visualization of (1) the QQplot of expected versus observed residuals and (2) the plot of predicted values versus standardized residuals using the "diagnostic for hierarchical regression models" package, which also looks for model overdispersion (Hartig et al., 2016). The predicted counts of observed CRF versus observed counts per farm were also plotted as a visual way to assess model fit. Finally, the effects of retained covariates were visually investigated by marginal effect estimation using the "sjPlot" package (Lüdecke, 2013).

RESULTS

A total of 3,656 calves were rapidly assessed from a total of 1,349 sellers over the 8 selling days. After excluding sellers who were not farmers but livestock carrier companies, as well as farms that could not be reached after 3 attempts, 509 farms were initially contacted by phone. A total of 74 sellers (14.5%) were eliminated from data analysis either because they declined or were considered "nonparticipating." From an initial number of 435 phone questionnaires completed, 2 were further discarded because of incomplete information. At the end, a total of 433 completed questionnaires were obtained, representing a total of 409 different dairy farms. Twenty-four farms (5.8%) were interviewed twice because they sold calves during the 2 seasons of data recording. A total of 409 farms representing 847 calves were finally included and studied. The number of calves examined per farm varied from 1 to 19 calves, with a median of 2 calves (Figure 1A). In all, 225 farms sold at least 2 calves during the study period, and 97 farms sold 3 or more calves. The clinical observations from the study calves are presented in Table 1. The distribution of CRF observed per calf and farm is highlighted in Figure 1B.

The main characteristics of participating dairy farms have been reported in a recent publication (Ferraro et al., 2025). Briefly, the dairy farms interviewed were comparable with the demographic and production characteristics of dairy farms in the province of Québec. The univariable analyses results and distribution of main questionnaire answers are presented in Table 2.

The results of the multivariable Poisson count regression model are presented in Table 3 and Figure 2. The variables positively associated with an increased incidence of CRF were the mean age of calves sold, time of first colostrum feeding, use of milk replacer, and average time elapsed between last meal and transportation. Herd size was identified as a confounder of the first colostrum feeding variable and was therefore forced in the final model. The relationship between predicted and observed counts of CRF identified is illustrated in Figure 3.

Table 3. Multivariable Poisson regression model of herd characteristic factors associated with the number of physical signs found in 847 dairy calves from 409 dairy farms

Characteristic	IRR[1]	95% CI	*P*-value
Herd size (milking cows)			
50–100	Ref.	—	
<50	0.87	0.75, 1.01	0.078
>100	1.07	0.94, 1.21	0.3
Mean age			
>10 d	Ref.	—	
8–10 d	1.05	0.92, 1.19	0.5
<8 d	1.21	1.04, 1.41	0.013
First colostrum meal after birth			
≤1 h	Ref.	—	
1–2 h	1.73	1.24, 2.49	0.002
2–6 h	1.48	1.06, 2.14	0.028
>6 h	1.59	1.06, 2.44	0.029
Nursing with dam	1.17	0.62, 2.09	0.6
No colostrum fed	0.74	0.28, 1.64	0.5
Milk type			
Whole milk	Ref.	—	
Milk replacement	1.20	1.06, 1.37	0.005
Milk replacement and whole milk	1.12	0.96, 1.31	0.15
Last meal before transport			
<1 h	Ref.	—	
1–3 h	1.16	0.99, 1.36	0.072
>3 h	1.26	1.04, 1.53	0.019

[1]IRR = incidence rate ratio.

DISCUSSION

Nonreplacement calves from the dairy industry represent a challenge with multiple aspects to consider. As they represent a so-called by-product of the dairy industry, various concerns have been raised about how the industry values their welfare and health (Bolton and von Keyserlingk, 2021). The present study shows that several farm characteristics are associated with the clinical findings revealed by a brief physical examination of calves performed at the auction market. Farms administering colostrum to calves early after birth, serving whole milk as diet, selling calves with an average age >10 d, and giving the last milk feeding within an hour from departure to the auction sale market, were associated with a lower incidence rate of CRF during the auction sale.

Interestingly, of the 4 variables associated with CRF in the final multivariable model, 3 were related to calf nutrition. Early administration of colostrum, use whole milk as feeding diet, and giving the last meal before transport to auction market <1 h before leaving the farm were associated with fewer anomalies. Early colostrum administration, within 1 h after birth, had a protective effect with a decreased incidence rate of CRF compared with later administration of colostrum. Several clinical findings revealed during our rapid assessment were suggestive of an infectious disease (e.g., umbilical infection, diarrhea, and respiratory disease), which can be prevented by an optimal colostrum feeding program (Godden et al., 2019). The study design precludes determination of whether this association is causal. It is possible that the variable is a proxy for an unmeasured variable. However, the importance of the colostrum program remains an asset for preparation of the calf to be transported to an auction market (Devant and Marti, 2020).

Nonreplacement calves fed whole milk had a lower incidence rate of abnormal physical signs than calves fed milk replacer. Interestingly, feeding whole milk to calves is not common in Québec. In a previous study focusing on preweaning heifer calves from 39 dairy farms in Québec, Canada, only 7 farms (18%) used whole milk

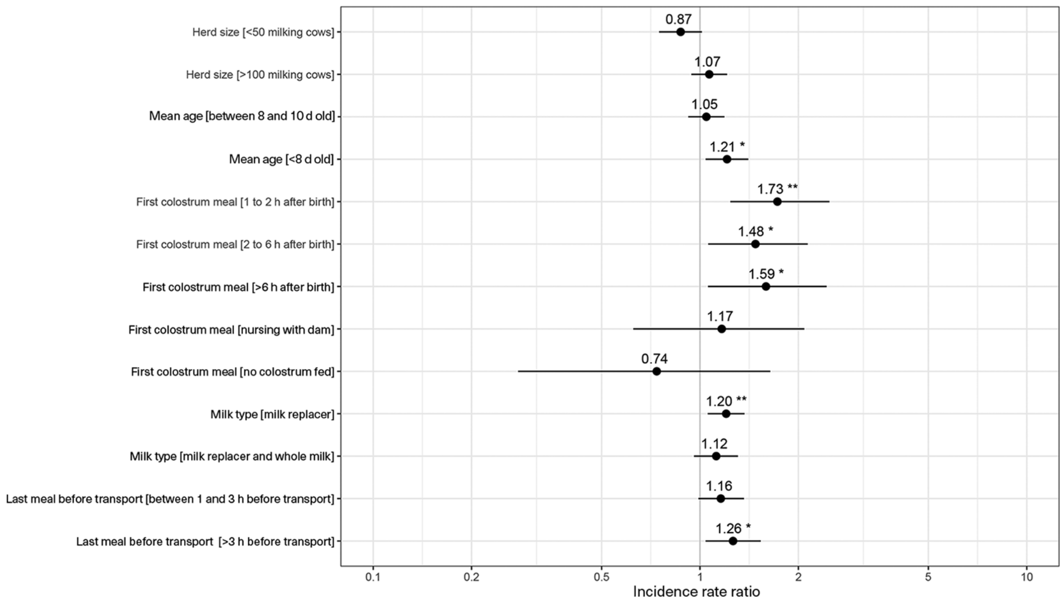

Figure 2. Regression coefficients of the multivariable count regression model showing the association between herd-specific characteristics and the number of anomalies among calves sold. The exponentially-transformed coefficients (incidence rate ratio estimates [dots] and associated 95% CI [associated line]) of the main model with all the 409 dairy farms involved. *$0.01 \leq P < 0.05$; **$P < 0.01$.

to feed replacement animals (Buczinski et al., 2018). In the present study, the majority of interviewed dairy farms were feeding nonreplacement calves whole milk (57%) or both whole milk and milk replacer (18%). The effects of feeding whole milk, compared with feeding milk replacer, on calf health is an important topic of dairy calf nutrition. Whole milk is considered a natural source of nutrients for calves and is associated with better weight gain than milk replacer (Firth et al., 2021). Whole milk generally has a higher energy content, lower lactose concentration, and consistently higher fat content than milk replacer (Amado et al., 2019). This can be especially important to cope with energy loss during transportation. However, unpasteurized, nonsealable milk is also associated with greater variability in nutrient and bacterial content than milk replacer (Hill et al., 2009; Moore et al., 2009) and an increased risk of antimicrobial resistance among calves' fecal bacteria (Aust et al., 2013; Firth et al., 2021); additionally, it may also be associated with antimicrobial residues (Maynou et al., 2017). We were unable to distinguish between specific preparation strategies of whole milk and types of whole milk that were given to the calves (e.g., transition milk vs. waste milk from sick or treated cows vs. sealable milk) on the different farms, so this finding should be considered with caution. This difference could also be due to the use of a low-quality milk replacer for nonreplacement calves.

A long delay between last feeding and transportation was associated with an increased incidence rate of CRF. Little data are available on current practices regarding the feeding of calves before they leave for the auction market, as recently reviewed (Devant and Marti, 2020). A last feeding given early in the day before departure would potentially increase the ability of the calf to better cope with transportation challenges. Marcato et al. (2020) reported that calves fed milk 2 h before a short transportation (6 h in duration) had higher glucose concentrations and lower nonesterified fatty acid levels (reflecting fat mobilization) than calves fed electrolyte solution. However, these differences were not observed for a longer transportation period (18 h in duration).

Farms selling older calves had lower incidence rates of CRF. The visual presence of an umbilical cord has been previously reported as a potential sign indicative of young age (Buczinski et al., 2022) and was the most common clinical finding observed. The umbilical cord healing process is age-dependent and has been described previously (Hides and Hannah, 2005; Roccaro et al., 2022). A dry cord is generally observed in calves older than 8 d. However, calves only 1 to 2 d of age may have a dry cord as well (Hides and Hannah, 2005). A scab present in the umbilical area may be observed after the umbilical cord has fallen (Roccaro et al., 2022). This umbilical feature is generally observed in calves older than 14 d but can also be observed in 9% of younger calves (Roccaro et al., 2022). In our study, the general practices concerning the average age to send calves to auction should be taken with caution because recent changes to Canadian federal regulations concerning calf transportation may affect the previous tendency. Since 2020, transportation of calves to auction market has been forbidden until they reach the age of 9 d. Farmers' interviews were performed before or during implementation of this new regulation. Current findings would likely change concerning this parameter due to the new regulation.

We chose to report the number of CRF based on a rapid assessment of calves with the aim of avoiding multiple models for every specific physical condition. This approach was selected to limit the analyses to one specific model, therefore reducing the chances of false discovery. Moreover, we wanted to work on an assessment representative of what can be observed during calf sale as an indicator of calf health or age, which are both associated with future performance in veal calves production (Winder et al., 2016; Renaud et al., 2018a,c).

This study reveals that different farm management practices are associated with clinical findings of calves. Improving the quality of calves sold should increase the sale price (Marquou et al., 2019; Wilson et al., 2020a) by potentially decreasing costs associated with health problems on veal farms. The profit generated by each calf depends on multiple factors, including health factors (dehydration, navel illnesses, and cough), as well as origin of the calf, as recently shown in an Ontarian study focusing on determination of the breakeven purchase price (Renaud et al., 2019). Improving surplus calf quality could potentially increase purchase price and could as a result be an incentive to improve their care and welfare on dairy farms.

This study also comes with specific limitations associated with the study design itself. Due to the number of questions tested, an increased type 1 error could not be ruled out, as well as specific risk of bias of social desirability. For example, some interviewed farmers could answer a particular question because they know what the good practice is but without implementing the practice on their own farms. Because the study was promoted through social media to improve the response rate, we also could not exclude that this promotion may have been associated with some risk of bias in the way the producers answered our questions. Moreover, due to the limited number of calves sold by every farm, the precision of the general health status of the farm heavily depended on the representativeness of the specific calves enrolled during the study period. A loss of precision could be associated with the limited number of calves available per farm. For clinical tests performed at the herd level, 10 to 12 samples are generally required as a rule of thumb to make a specific diagnosis (Oetzel, 2004). Obtaining these specific numbers of calves would have been challenging in Québec because the average herd size is 70 milking cows and approximately 80 calvings per year (with half of them producing male calves if no sexed or beef semen is used). In the absence of a seasonal calving period, we anticipated that a ~1-yr analysis period at auction market would have been necessary to recruit these numbers of surplus calves per farm. This was unfortunately not logistically feasible. Only focusing on larger herds could be perceived as an easy way to increase study precision but also be a limitation because management differences may exist between large, average, and small herds, as shown in our final analysis (i.e., the herd size was a confounder for the colostrum feeding variable). We performed a sensitivity analysis of our results focusing on farms that sold 2 or more calves (n = 225) and farms that sold 3 or more calves (n = 97). We did not observe any drastic changes in the incidence rate ratio (**IRR**) obtained because all estimates were included in the 95% CI of the main model IRR (Supplemental File S1, see Notes). Therefore, we consider that our main results are relatively robust. However, they should be confirmed in future studies recruiting more calves per farm.

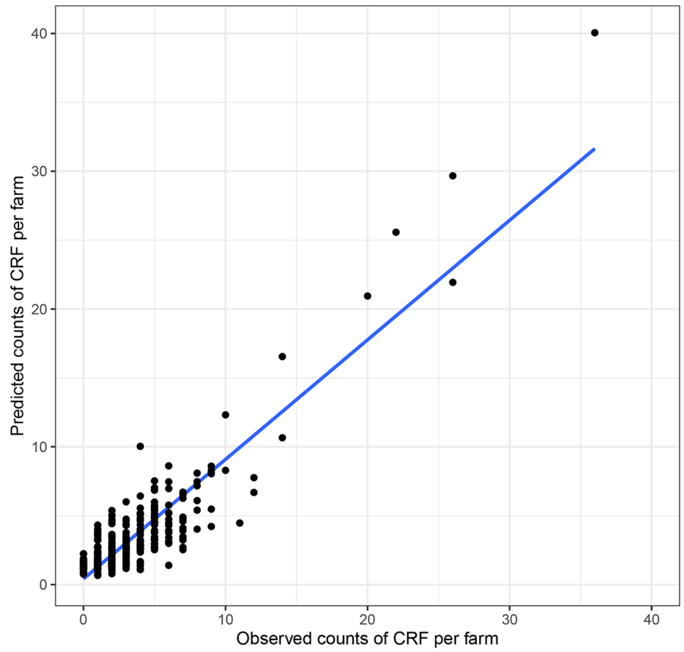

Figure 3. Predicted and observed clinically relevant findings (CRF) from the final multivariable Poisson regression model of 409 Québec dairy farms. The dots represent the predicted counts of CRF from the final multivariable model as a function of the observed counts for each farm. The blue line is the default regression line obtained from the dot distribution.

CONCLUSIONS

This study shows that different management factors at the dairy farm of origin are associated with the incidence of specific physical findings at auction markets. Practical recommendations for farmers to prepare adequately young calves for their transportation and selling at auction markets should be further investigated; however, based on our study findings, early administration of good quality colostrum, a good milk feeding program, a last meal administered shortly before transportation to the auction market, and selling calves 10 d or older could be valuable ways to improve the quality of calves entering veal farms.

NOTES

This project was part of a larger project supported by the Programme de Développement Sectoriel du Québec-Canada (Ministère de l'Agriculture des Pêcheries et de l'Alimentation du Québec, Partenariat Canadian Pour Une Agriculture Durable, Québec City, QC, Canada), the Producteurs de Bovins du Québec (Longueuil, QC, Canada) and MITACS Accelerate Program (Ottawa, ON, Canada). The authors thank Bérénice Mathet, Morgane Bastide, Annaelle Pichon, Nicolas Barbeau-Grégoire, Julie Berman, Marie-Pascale Morin, and Jean-Philippe Pelletier for their technical help during different steps of the project. The authors also thank the Réseau Encans Québec for allowing the research team to access the auction market facility. Supplemental material for this article is available at https://doi.org/10.6084/m9.figshare.28436321.v1. The project received ethical authorization from the Institutional Animal Care Committee (CEUA) of the Université de Montréal (Protocol #19-Rech-2015). The authors have not stated any conflicts of interest.

Nonstandard abbreviations used: AC1 = Gwet's agreement coefficient type 1; CRF = clinically relevant finding; IRR = incidence rate ratio.

REFERENCES

Amado, L., H. Berends, L. N. Leal, J. Wilms, H. van Laar, W. J. J. Gerrits, and J. Martín-Tereso. 2019. Effect of energy source in calf milk replacer on performance, digestibility, and gut permeability in rearing calves. J. Dairy Sci. 102:3994–4001. https://doi.org/10.3168/jds.2018-15847.

Aust, V., K. Knappstein, H. J. Kunz, H. Kaspar, J. Wallmann, and M. Kaske. 2013. Feeding untreated and pasteurized waste milk and bulk milk to calves: Effects on calf performance, health status and antibiotic resistance of faecal bacteria. J. Anim. Physiol. Anim. Nutr. (Berl.) 97:1091–1103. https://doi.org/10.1111/jpn.12019.

Bolton, S. E., and M. A. G. von Keyserlingk. 2021. The dispensable surplus dairy calf: Is this issue a "wicked problem" and where do we go from here? Front. Vet. Sci. 8: 660934. https://doi.org/10.3389/fvets.2021.660934.

Boulton, A., N. Kells, N. Beausoleil, N. Cogger, C. Johnson, A. Palmer, and C. O'Connor. 2018. Bobby calf welfare across the supply chain—Final report for year 1. Accessed Jan. 7, 2025. https://www.mpi.govt.nz/dmsdocument/30005-Bobby-Calf-Welfare-Across-the-Supply-Chain-Final-Report-Year-One-.

Boulton, A. C., N. J. Kells, N. Cogger, C. B. Johnson, C. O'Connor, J. Webster, A. Palmer, and N. J. Beausoleil. 2020. Risk factors for bobby calf mortality across the New Zealand dairy supply chain. Prev. Vet. Med. 174:104836. https://doi.org/10.1016/j.prevetmed.2019.104836.

Buczinski, S., M. E. Borris, and J. Dubuc. 2018. Herd-level prevalence of the ultrasonographic lung lesions associated with bovine respiratory disease and related environmental risk factors. J. Dairy Sci. 101:2423–2432. https://doi.org/10.3168/jds.2017-13459.

Buczinski, S., G. Fecteau, L. Blouin, and M. Villettaz-Robichaud. 2021. Factors affecting dairy calf price in auction markets of Québec, Canada: 2008–2019. J. Dairy Sci. 104:4635–4649. https://doi.org/10.3168/jds.2020-19523.

Buczinski, S., G. Fecteau, M. Cichocki, S. Ferraro, J. Arsenault, Y. Chorfi, M. Costa, J. Dubuc, D. Francoz, M. Rousseau, and M. Villettaz-Robichaud. 2022. Development of a multivariable prediction model to identify dairy calves too young to be transported to auction markets in Canada using simple physical examination and body weight. J. Dairy Sci. 105:6144–6154. https://doi.org/10.3168/jds.2022-21806.

Devant, M., and S. J. A. Marti. 2020. Strategies for feeding unweaned dairy beef cattle to improve their health. Animals (Basel) 10:1908. https://doi.org/10.3390/ani10101908.

Dohoo, I. R., W. Martin, and H. E. Stryhn. 2009. Veterinary epidemiologic research. VER Inc., Charlottetown, PE, Canada.

Ferraro, S., M. Villettaz-Robichaud, A. S. Perrault, J. Arsenault, Y. Chorfi, M. Costa, J. Dubuc, D. Francoz, M. Rousseau, G. Fecteau, and S. Buczinski. 2025. Dairy farm management factors associated with auction sale price of young dairy calves sold at auction markets in Québec, Canada: A cross-sectional study. J. Dairy Sci. 108:914–927. https://doi.org/10.3168/jds.2024-24890.

Firth, C. L., K. Kremer, T. Werner, and A. J. P. Käsbohrer. 2021. The effects of feeding waste milk containing antimicrobial residues on dairy calf health. Pathogens 10:112. https://doi.org/10.3390/pathogens10020112.

Godden, S. M., J. E. Lombard, and A. R. Woolums. 2019. Colostrum management for dairy calves. Vet. Clin. North Am. Food Anim. Pract. 35:535–556. https://doi.org/10.1016/j.cvfa.2019.07.005.

Goetz, H. M., K. C. Creutzinger, D. F. Kelton, J. H. C. Costa, C. B. Winder, and D. L. Renaud. 2023. A randomized controlled trial investigating the effect of transport duration and age at transport on surplus dairy calves: Part I. Impact on health and growth. J. Dairy Sci. 106:2784–2799. https://doi.org/10.3168/jds.2022-22366.

Hartig, F., L. Lohse, and M. Souza Leite. 2016. Package 'DHARMa'. Accessed Feb. 18, 2025. https://doi.org/10.32614/CRAN.package.DHARMa.

Hides, S. J., and M. C. Hannah. 2005. Drying times of umbilical cords of dairy calves. Aust. Vet. J. 83:371–373. https://doi.org/10.1111/j.1751-0813.2005.tb15637.x.

Hill, T., H. Bateman II, J. Aldrich, and R. L. Schlotterbeck. 2009. Effect of consistency of nutrient intake from milk and milk replacer on dairy calf performance. Prof. Anim. Sci. 25:85–92. https://doi.org/10.15232/S1080-7446(15)30679-3.

Lüdecke, D. 2013. sjPlot: Data visualization for statistics in social science. Accessed Feb. 18, 2025. https://doi.org/10.32614/CRAN.package.sjPlot.

Marcato, F., H. van den Brand, B. Kemp, B. Engel, M. Wolthuis-Fillerup, and K. van Reenen. 2020. Effects of pretransport diet, transport duration, and type of vehicle on physiological status of young veal calves. J. Dairy Sci. 103:3505–3520. https://doi.org/10.3168/jds.2019-17445.

Marquou, S., L. Blouin, H. Djakite, R. Laplante, and S. Buczinski. 2019. Health parameters and their association with price in young calves sold at auction for veal operations in Québec, Canada. J. Dairy Sci. 102:6454–6465. https://doi.org/10.3168/jds.2018-16051.

Maynou, G., A. Bach, and M. Terré. 2017. Feeding of waste milk to Holstein calves affects antimicrobial resistance of *Escherichia coli* and *Pasteurella multocida* isolated from fecal and nasal swabs. J. Dairy Sci. 100:2682–2694. https://doi.org/10.3168/jds.2016-11891.

Moore, D., J. Taylor, M. Hartman, and W. Sischo. 2009. Quality assessments of waste milk at a calf ranch. J. Dairy Sci. 92:3503–3509. https://doi.org/10.3168/jds.2008-1623.

Oetzel, G. R. 2004. Monitoring and testing dairy herds for metabolic disease. Vet. Clin. North Am. Food Anim. Pract. 20:651–674. https://doi.org/10.1016/j.cvfa.2004.06.006.

R Development Core Team. 2020. R: A language and environment for statistical computing. R foundation for statistical computing. Vienna, Austria. Accessed Feb. 18, 2025. https://www.r-project.org/.

Ramos, J. S., M. Villettaz-Robichaud, J. Arsenault, Y. Chorfi, M. Costa, J. Dubuc, S. Ferraro, D. Francoz, M. Rousseau, G. Fecteau, and S. Buczinski. 2023. Health indicators in surplus calves at the time of arrival at auction markets: Associations with distance from farms of origin in Québec, Canada. J. Dairy Sci. 106:7089–7103. https://doi.org/10.3168/jds.2022-22827.

Renaud, D. L., T. Duffield, S. LeBlanc, D. Haley, and D. Kelton. 2017. Management practices for male calves on Canadian dairy farms. J. Dairy Sci. 100:6862–6871. https://doi.org/10.3168/jds.2017-12750.

Renaud, D. L., T. Duffield, S. LeBlanc, D. Haley, and D. Kelton. 2018a. Clinical and metabolic indicators associated with early mortality at a milk-fed veal facility: A prospective case-control study. J. Dairy Sci. 101:2669–2678. https://doi.org/10.3168/jds.2017-14042.

Renaud, D. L., D. Kelton, S. LeBlanc, D. Haley, and T. Duffield. 2018b. Calf management risk factors on dairy farms associated with male calf mortality on veal farms. J. Dairy Sci. 101:1785–1794. https://doi.org/10.3168/jds.2017-13578.

Renaud, D. L., and B. Pardon. 2022. Preparing male dairy calves for the veal and dairy beef industry. Vet. Clin. North Am. Food Anim. Pract. 38:77–92. https://doi.org/10.1016/j.cvfa.2021.11.006.

Renaud, D. L., K. C. Dhuyvetter, S. J. LeBlanc, D. F. Kelton, T. F. Duffield, and M. W. Overton. 2019. Effect of health status upon arrival at a single milk-fed veal facility on breakeven purchase price of calves. J. Dairy Sci. 102:8441–8453. https://doi.org/10.3168/jds.2018-15587.

Renaud, D. L., M. W. Overton, D. F. Kelton, S. J. LeBlanc, K. C. Dhuyvetter, and T. F. Duffield. 2018c. Effect of health status evaluated at arrival on growth in milk-fed veal calves: A prospective single cohort study. J. Dairy Sci. 101:10383–10390. https://doi.org/10.3168/jds.2018-14960.

Roadknight, N., P. Mansell, E. Jongman, N. Courtman, D. McGill, G. Hepworth, and A. Fisher. 2021. Blood parameters of young calves at abattoirs are related to distance transported and farm of origin. J. Dairy Sci. 104:9164–9172. https://doi.org/10.3168/jds.2020-19729.

Roccaro, M., M. Bolcato, N. T. Masebo, A. Gentile, and A. Peli. 2022. Navel healing and calf fitness for transport. Animals (Basel) 12:358. https://doi.org/10.3390/ani12030358.

Wilson, D. J., J. Stojkov, D. L. Renaud, and D. Fraser. 2020a. Condition of male dairy calves at auction markets. J. Dairy Sci. 103:8530–8534. https://doi.org/10.3168/jds.2019-17860.

Wilson, D. J., J. Stojkov, D. L. Renaud, and D. Fraser. 2020b. Risk factors for poor health outcomes for male dairy calves undergoing transportation in western Canada. Can. Vet. J. 61:1265–1272.

Winder, C. B., D. F. Kelton, and T. F. Duffield. 2016. Mortality risk factors for calves entering a multi-location white veal farm in Ontario, Canada. J. Dairy Sci. 99:10174–10181. https://doi.org/10.3168/jds.2016-11345.

ORCIDS

Sébastien Buczinski, https://orcid.org/0000-0002-8460-4885
Anne-Sophie Perrault, https://orcid.org/0009-0007-2584-2254
Julie Arsenault, https://orcid.org/0000-0001-8382-7326
Younes Chorfi, https://orcid.org/0000-0001-7893-9649
Marcio Costa, https://orcid.org/0000-0001-5067-7501
Jocelyn Dubuc, https://orcid.org/0000-0003-1013-8372
David Francoz, https://orcid.org/0000-0002-1634-0507
Marjolaine Rousseau, https://orcid.org/0000-0002-2702-434X
Marianne Villettaz-Robichaud https://orcid.org/0000-0001-9685-1827