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Dairy farm management factors associated with auction sale price of young dairy calves sold at auction markets in Québec, Canada—A cross-sectional study

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ABSTRACT

Each year ~150,000 surplus calves are sold at auction markets in Québec, Canada. Surplus calves (male or female not kept in the herd of origin) are sold at a young age, but these animals are at risk of receiving lower quality neonatal care than replacement heifers. Knowledge of factors associated with a higher selling price could help convince farmers to spend more resources in the care surplus calves. Our objective was to explore the associations between farm management practices and the median percentile of surplus calf selling price per farm at auction markets. The price (Canadian dollars/kg of BW) and the individual identification number of surplus calves sold in 2 auction markets in Québec during 4 sale days in the summer 2019 and in the winter 2020 were recorded. The recorded price of each surplus calf was transformed as percentile for each breed and day of sale. Farmers managing the surplus calves were contacted and interviewed on farm management practices. The data from farmer's interviews were analyzed as potential variables associated with the median percentile of calves' selling price per farm (farm-level dependent variable) in a multivariable linear regression model. A total of 509 farmers were contacted, of which 433 farmers agreed to participate, and 409 interviews were retained for statistical analysis. The farms enrolled in the study had sold a median of 2 calves (range 1–19 calves) during the sale days considered. The main breed of surplus calves sold were Holstein (82%) and Angus crossbred calves (9%). The results from the multivariable model showed that median percentile of calves' selling price was positively associated with farms with an average milk production per cow superior to 11,000 L/yr (β 0.13, 95% CI: 0.045, 0.221) and farms with 3 or more workers available to take care of surplus calves (β 0.08, 95% CI: 0.005, 0.167). Those results indicate that farms having an average milk production per cow superior to 11,000 L/yr increase the calves' selling price by 13 percentiles (i.e., from 50th to 63rd) and that farms having at least 3 caretakers increase their median percentile calves' selling price by 8 percentiles (i.e., from 50th to 58th). Median percentile of calves' selling price was negatively associated with farms that vaccinated cows for neonatal calf diarrhea (β −0.06, 95% CI: −0.127, −0.011), that do not disinfect the navel of newborn calves (β −0.07, 95% CI: −0.133, −0.012), that allow transporters to enter the farm's building (β −0.07, 95% CI: −0.130, −0.015) and that used wood shaving as bedding for surplus calves (β −0.08, 95% CI: −0.156, −0.021). Sensitivity analyses performed on farms that have sold 2 or more surplus calves did not show significant changes in the associations found. Despite the fact that the study was based on self-reported questionnaire answers and a small number of calves per farm, it provides insight on farm management practices associated with median percentile of surplus calf selling price at the auction markets. Taking these results in consideration, farmers could potentially improve the market value of their animals.

Key words: veal calves, sustainability, dairy calf welfare, male calves, bobby calves

INTRODUCTION

The term "surplus calves" generally refer to male and female dairy calves sold for veal or beef production during their first weeks of age (Wilson et al., 2020a; Creutzinger et al., 2021). In the past, this category of animals was considered a "waste product" of the dairy industry and has received little attention by the farmers

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The list of standard abbreviations for JDS is available at adsa.org/jds-abbreviations-24. Nonstandard abbreviations are available in the Notes.

(Bolton and von Keyserlingk, 2021; Creutzinger et al., 2021). In North America the veal production industry is mostly concentrated in the northeast of the United States and the eastern provinces of Canada (Ontario and Québec) (Creutzinger et al., 2021). The veal calf industry in Québec, Canada, produces ~80% of all the veal calves in Canada (representing ~150,000 head/yr) (MAPAQ, 2019).

Recently, surplus calves and the veal calf industry have been under scrutiny because of public concerns about animal welfare (high risk of mortality and morbidity after arrival at veal farms) and the risk of developing antimicrobial resistance related to the frequent use of antimicrobials in these categories of animals (Bolton and von Keyserlingk, 2021; Creutzinger et al., 2021). Furthermore, the low price of surplus calves was of concern at the time of the study (Marquou et al., 2019; Perrault, 2020; Wilson et al., 2020c; Buczinski et al., 2021). In fact, the average price of surplus calves (Holstein males of 41–54 kg) adjusted for the inflation rate declined from 5.9 Canadian dollars [**CAD**]/kg of BW in 2016 to 3.2 CAD/kg of BW in 2019 (PBQ, 2021a; Bank of Canada, 2022). From 2022, this trend has been reversed when price of surplus calves increased (PBQ, 2024).

The selling price of surplus calves is fluctuating over the seasons, the day of the sale, as well as the auction market site (Winder et al., 2016; Marquou et al., 2019; Buczinski et al., 2021). It is also associated with the distance between the auction market and the farm of origin (Buczinski et al., 2021). Moreover, the price of surplus calves depends on calf characteristics such as breed, sex, and BW (Buczinski et al., 2021). The calf health status during sale is also associated with the price, even if the variance associated with these characteristics is generally lower than the external factors aforementioned (Marquou et al., 2019; Wilson et al., 2020c). The presence of omphalitis, wet navel, and dehydration are the most important clinical signs negatively associated with the price of surplus calves (Marquou et al., 2019; Wilson et al., 2020c). Some studies have reported that farm management is associated with calves' characteristics such as BW, health status, and mortality after transportation (Boulton et al., 2018; Boulton et al., 2020; Wilson et al., 2020b). Renaud et al. (2018) showed that management of colostrum and the type of bedding used for raising male calves at the farm of origin were associated with subsequent mortality at veal farms. However, calf care requires substantial time on dairy farms (Creutzinger et al., 2021) and unfortunately, the lack of immediate financial payoff for surplus dairy calves brings negative consequences for their health (Creutzinger et al., 2021). One of the important barriers for farmers to improve their care of surplus calves has been their low value (Wilson et al., 2021; Hendricks et al., 2022; Reed et al., 2022), with economic benefits being an effective way to motivate farmers to change their management (Ritter et al., 2017). The improvement of surplus calves' market value could be an incentive for producers to invest in their welfare and health early in life (Hendricks et al., 2022; Reed et al., 2022). Although the importance of farm management on health status and on subsequent performance of surplus calves has been reported (Renaud et al., 2018; Creutzinger et al., 2021; Renaud and Pardon, 2022), studies taking into consideration the direct association between farm management practices and the price paid for surplus calves during the sale process are missing.

To fill this gap of knowledge, the objective of the present study was to explore the potential associations between farm management practices and auction selling price of surplus calves. We hypothesized that specific farm management practices would be associated with the auction selling prices.

MATERIALS AND METHODS

The present exploratory observational study was part of a larger project on welfare and health of surplus calves during their marketing. The study was completed in accordance with the guidelines of the Institutional Animal Care Committee (CÉUA) of the Université de Montréal (CÉUA protocol: #19-Rech-2015). The manuscript was written following STROBE-VET guidelines (Strobe-vet statement, 2021).

Study Design

A cross-sectional study was carried out during summer 2019 (from June 26 to July 8) and winter 2020 (from February 10 to February 26). Over this period, 2 livestock auctions markets (Saint-Hyacinthe and Saint-Isidore) located in the province of Québec, Canada, were visited twice during each season, for a total of 4 visits in the summer (2019) and 4 in the winter (2020). These 2 livestock auctions represent 74% of the total surplus calves sold in Québec (Buczinski et al., 2021). During each visit of the auction markets, all surplus calves (n = 3,656) sold during those days were examined. The physical exam included sex, breed, presence, and visual assessment of the umbilical cord, hide cleanliness, body condition, lameness (i.e., abnormal bearing of one limb, swollen joint, or limb wound), hydration status, presence of ocular and nasal discharge, presence of umbilical pain, and ears position as previously described elsewhere (Buczinski et al., 2022; Ramos et al., 2023). Because the focus of the study was to determine farm practices associated with calf price, health data were considered as intermediate variables in such framework and were not accounted for in our modeling (Dohoo et al., 2009).

Data Collection from Auction Markets

Using provincial unique ear tag numbers for identification, BW (determined by auction market scale) and selling price (CAD/kg of BW) of each surplus calf sold were retrieved from the auction market database. These data also included the name and contact information for each of the selling farm. This information was used to contact the farmers to administer our questionnaire. All farms selling surplus calves during the study period in selected auction markets considered were eligible to be enrolled in this study.

Farm Questionnaire

Information regarding farm management practices about replacement calves and surplus calves were collected using a questionnaire built based on the results reported by Boulton et al. (2020). The latter was a study conducted on bobby calves in New Zealand; its questionnaire was translated in French and adapted for the dairy industry in Québec. It was pretested on 2 farms of the Bovine Ambulatory Clinic of the Faculté de Médecine Vétérinaire, Université de Montréal (Saint-Hyacinthe, QC, Canada). The content of the questionnaire is reported in Table 1.

Farmers from the farms of origin were contacted by phone by trained personnel (3 undergraduate veterinary students, 1 PhD student, and 1 animal health technician). The interviewers were blind regarding the price of the surplus calves sold by the farms. Three different attempts (at 1-d intervals) were made to contact each farm. The interviews were conducted between July 10, 2019, and May 20, 2020. The questionnaire took ~30 min to complete. The answers were recorded in a preformed sheet on Microsoft Access (Microsoft Corp., Redmond, WA).

Sample Size Estimation

This exploratory cross-sectional study was a part of a larger study on health of surplus calves at marketing. No a priori sample size was determined for this specific study objective. The initial aim was to enroll at least 250 dairy farmers (i.e., representing 5% of the Québec dairy farms) to describe the main characteristics of surplus calves' management in Québec.

Data Management and Analysis

Data collected were transferred to a Microsoft Excel (Microsoft Corp., Redmond, WA) spreadsheet. All data handling and statistical analyses were performed using R statistical software (version 4.0.4; R Core Team, 2020). If farmers were contacted twice (for 2 different calves), only one questionnaire per farm was randomly selected and retained for data analysis using the function "distinct()" in base R language.

Continuous data obtained from the questionnaire were transformed into categorical variables according to rounded quartile, rounded median, or accepted benchmark limits. The missing data were less than 10% and they were excluded from the analysis. Descriptive analyses were performed for each variable.

Model Building Strategy

The auction market selling price is generally volatile, and heavily depends on calf breed phenotypes, days of sales, and auction market sites (Buczinski et al., 2021). For each breed and day of sale (confounded with the site sampled), the price was therefore transformed in percentile rank, which was reported as a robust indicator of calf quality in its own breed category for a specific day (Buczinski et al., 2021). After price was transformed in percentile rank, surplus calves from the same dairy farm were aggregated. The median percentile rank of surplus calves sold from each farm was the dependent variable.

A multivariable linear regression model was then used to model the associations between the median percentile of calves' selling price per farm and explanatory variables measured. A conceptual map was made to recognize the predictors that would be included in the multivariable model (Supplemental File S1, see Notes). The correlations between all categorical reported explanatory variables were assessed using Goodman Kruskal's τ (tau) statistics (Southwood, 1974; Buczinski et al., 2022). A value of Goodman Kruskal's $\tau > 0.6$ was used as a threshold to indicate collinearity between 2 variables (Buczinski et al., 2022).

Univariable analyses were first performed between the dependent variable and individual explanatory variables. Dichotomous variables were excluded from analysis if one of the categories represents less than 10% of the population (Turcotte et al., 2021). Predictors associated with the dependent variable during the univariable analysis using the threshold of $P < 0.20$ (likelihood ratio test) obtained from the function anova in R were included in the multivariable model. The linear model was built using linear model "lm ()" function in R (R Core Team, 2020).

The general multivariable model framework was as follows:

$$Y = \beta_0 + \beta_1 X_1 + \ldots + \beta_n X_n = [\boldsymbol{\beta}] \times [\mathbf{X}],$$

where Y, the dependent variable, is the median percentile of calves' selling price per farm; $[\boldsymbol{\beta}]$ is a vector of the regression coefficients (with β_0 the intercept and β_1 to β_n

Table 1. Description of the topics and questions of the questionnaire used to collect data about the farm's characteristics, calf management, and surplus calves' management; the topics are derived from the study of Boulton et al. (2020) and adapted to the French Canadian dairy industry

Theme of questionnaire	Characteristic	Question (focused on the most representative practice of the herd)	Type of question (possible choice)
Farm's characteristic	Type	What is the type of herd management?	Closed-ended (organic/conventional)
	Size	How many lactating cows are present in the herd?	Open-ended
		How many dry cows are present in the herd?	Open-ended
	Milk production	What is the average milk production of lactating cows (L/lactation)	Open-ended
	Production of surplus calves	What is the main breed of surplus calves sold?	Open-ended
		What is the relative proportion of surplus calves' breed?	Open-ended
	Number of calving in last month	How many calving occurred in the last month?	Open-ended
Human resource employed for calves' care	Number of workers available to take care of calves	How many people that are present at the farm are available to take care of calves?	Open-ended
	Education	What is the level of education of calves' caretaker(s)?	Closed-ended (primary, secondary, college, university, foreign workers)
	Experience	What are the minimal years of experience among calves' caretaker(s)?	Open-ended
	Status of personnel at the farm	What are the "statuses" of workers at the farm?	Closed (owner/employed/familiar owners)
Calving condition	Calving area	Where did the cattle calve?	Closed (collective box/tiestall/individual box)
	Cow-calf separation	At what time did the separation of calves from their dam (h) occur?	Open-ended
Neonatal care	Colostrum	Do newborn calves receive colostrum?	Closed-ended (yes/no)
		Are newborn calves kept with dams?	Closed-ended (yes/no)
		What volume of colostrum is offered to newborn calves at the first meal (L)?	Open-ended
		Do newborn surplus calves receive colostrum?	Closed-ended (yes/no)
		How much colostrum is offered to newborn calves (L)?	Open-ended
		How much time elapses between calving and first colostrum meal (h)?	Open-ended
		Is the time duration between calving and first colostrum meal the same for female and surplus calves?	Closed-ended (yes/no)
		Is colostrum quality tested?	Closed-ended (yes/no)
	Navel dipping	Is calf navel dipped in a disinfecting solution?	Closed-ended (yes/no)
		Is surplus calf navel dipped in a disinfecting solution?	Closed-ended (yes/no)
		What is the percentage of newborn calves that are navel dipped?	Open-ended
	Vaccination for neonatal calf diarrhea	Are cows vaccinated for neonatal calf diarrhea?	Closed-ended (yes/no)
	Vaccination of calves	Are calves vaccinated for neonatal calf diarrhea or bovine respiratory disease?	Closed-ended (yes/no)
Calf nutrition	Feeding practices	Is feeding program the same for replacement and surplus calves?	Closed-ended (yes/no)
		What is the milk allowance offered to surplus calves (L/d)?	Open-ended
		How many meals are offered to surplus calves in a day?	Open-ended
		What type of milk is offered to surplus calves?	Closed-ended (cow milk/milk replacers/cow milk and milk replacers)

Continued

Table 1 (Continued). Description of the topics and questions of the questionnaire used to collect data about the farm's characteristics, calf management, and surplus calves' management; the topics are derived from the study of Boulton et al. (2020) and adapted to the French Canadian dairy industry

Theme of questionnaire	Characteristic	Question (focused on the most representative practice of the herd)	Type of question (possible choice)
Housing	Housing type	Where surplus calves are housed?	Closed-ended (outdoor hutches/indoor housing)
		How surplus calves are housed?	Closed-ended (individually/paired/grouped)
		Are surplus calves housed differently than replacement calves?	Closed-ended (yes/no)
		How many calves are housed in a single housing unit?	Open-ended
	Bedding	What type of bedding is used for calves?	Closed-ended (straw/wood shaving/straw and wood shaving, others)
		What is the thickness of calves' bedding (cm)?	Open-ended
		How many times in a week new bedding is added?	Open-ended
		Is bedding changed between batches of surplus calves? If yes, how many times in a month?	Semi closed-ended
Transport	Preparation for transport	What are the criteria used by farmers to decide to sell surplus calves?	Closed-ended (age, replacement need, beef crossbreed, space available, genetic merit, BW, surplus calves, sex, provided transport at the farm of origin, surplus calves' vigor)
		Are surplus calves separated from replacement calves? If yes, when?	Semi closed-ended
		What is the average age of surplus calves sold (d)?	Open-ended
		What is the minimal age of surplus calves sold (d)?	Open-ended
		Does the farmer call transporters for the transport of surplus calves?	Closed-ended
		Does the transporter had given any advice or judgment on surplus calves?	Closed-ended (yes, he gives some advice, yes, he has refused to transport a calf, not, he never gives advice)
		Do you know when surplus calves arrive at the auction market?	Closed-ended (yes/no)
		When the surplus calves received the last meal before transport (h)?	Open-ended
	Biosecurity of transport	What is the proportion of transports when farm personnel are present during loading?	Open-ended
		Is the transporter allowed to enter the farm building?	Closed-ended (yes/no)

the coefficients of regression of the model explanatory variables X_1 to X_n); and [**X**] is the associated covariates' matrix.

A manual backward elimination strategy was used until only explanatory variables with *P*-value < 0.05 were retained. An explanatory variable was deemed to be a confounder if it was not an intervening variable and if the estimate of a significant explanatory variable in the model changed by at least 20% when the explanatory variables were removed from the model. If an explanatory variable was recognized as a confounder, it was forced into the final model. Moreover, the possible 2-way interactions were tested one by one in separated models based on the biological knowledge of the research topic (Dohoo et al., 2009; de Jong et al., 2021). The amount of variance explained by the explanatory variables was assessed using the R^2 of the final model (Dohoo et al., 2009). The fit of the final model was visually assessed for residuals-distribution normality and homoscedasticity using the Q-Q plot and residuals versus the predicted-values plot (Dohoo et al., 2009). Presence of outliers, unusual observations (leverage), and Cook's distance were assessed.

RESULTS

A total of 509 farmers were reached, and 433 (85%) agreed to participate to the study. The reason of nonparticipation was reported for 57 farmers. Of these, 34 (59.7%) did not have interest in participating to the project, 17 (29.8%) lacked time, 4 (7.0%) were not dairy farmers but transporters, and 2 (3.5%) were no longer in business. The median percentile of calves' selling price per farm did not differ between nonparticipating and participating farms (median = 0.544 vs. 0.504, $P = 0.35$, Wilcoxon test). Twenty-four farmers were selected twice (i.e., they sold calves during the 2 different sampling seasons) and one of the duplicates was removed for each. Finally, interviews derived from 409 questionnaires from different farmers were included in the analyses. The maximum delay between the calf's sale and the interview was 121 d (median: 38 d, interquartile range: 52 d).

As reported by Ramos et al. (2023), 3,610 surplus calves were retained in this project for the analysis with 2,937 male (81.4%) and 673 females (18.6%) calves. A total of 1,807 (50.1%) calves were sold in the auction market A and 1,803 (49.9%) in the auction market B. Of these calves 878 (24.3%) had a BW less than 45 kg, 881 (24.4%) between 45 and 48 kg, 913 (25.3%) between 49 to 53 kg, and 936 (25.9%) more than 54 kg.

Description of the farms indicates that 127 (31.0%) had less than 50 lactating cows, 191 (46.7%) had between 50 and 100 milking cows, and 91 (22.2%) had more than 100 milking cows which is compatible with data reported by Lactanet (2021). In the province of Québec, the average dairy farm has 81 dairy cows (Les Producteurs de Lait du Québec, 2024).

The farms enrolled in this study have sold 847 surplus calves, the median number of calves sold by farm enrolled during the study period was 2 (range 1–19). A total of 225 farms sold at least 2 calves during the study period, and 97 farms sold 3 or more calves.

The interviewed farmers have declared that the main breed of surplus calves sold during the sampling period was Holstein Friesian (82.2%) and crossbred Holstein-Angus (9.2%); the others were 0.7% crossbreed with non-Angus beef breeds, 2.7% dairy-colored breeds (Jersey, Ayrshire, Brown Swiss). For 5.2% of the farms the data were not available.

The results of the descriptive statistics of all variables of this study are presented in Supplemental File S2 (see Notes). Descriptive analyses and univariable analyses of variables used to build the main multivariable model are presented in Table 2.

The results of the final multivariable model predicting the median percentile of calves' selling price per farm are presented in Table 3 and Figure 1. The amount of variance (R^2) of the dependent variable explained by the multivariable model was 12.2%. No particular problem was observed concerning the model fit according to visual residual distribution. The evaluation of the outliers, unusual observations (leverage) and the observations having the greater Cook's (Supplemental File S3, see Notes) did not reveal specific patterns, and they were retained in the analyses. Average marginal effect of explanatory variable was visually assessed to illustrate the effect of a single explanatory variable on the dependent variable when controlling for other explanatory variables (Supplemental File S3).

The results from the multivariable model showed that median percentile of calves' selling price was positively associated with farms with an average milk production per cow superior to 11,000 L/yr (β [coefficient of the regression model] = 0.13, 95% CI: 0.045, 0.221) and farms with 3 or more workers available to take care of surplus calves (β = 0.08, 95% CI: 0.005, 0.167). Median percentile of calves' selling price was negatively associated with farms that vaccinated cows for neonatal calf diarrhea (β = −0.06, 95% CI: −0.127, −0.011), that do not disinfect the navel of newborn calves (β = −0.07, 95% CI: −0.133, −0.012), that allow transporters to enter the farm's building (β = −0.07, 95% CI: −0.130, −0.015) and that used wood shaving as bedding for surplus calves (β = −0.08, 95% CI: −0.156, −0.021).

DISCUSSION

This study shows that specific characteristics and management practices of dairy farms are associated with

Table 2. Descriptive statistics and *P*-values from univariable linear regression modeling the median percentile of surplus calf selling price per farm in the 409 dairy farms enrolled in our study[1]

Variable	Categories of variable	Farm (n)	Farm (%)	Median percentile of calves' selling price per farm	IQR[2] of the median percentile of calves' selling price per farm	*P*-value	Reason for the categorization
Farm's characteristics							
Herd size[3] (lactating cows)	50–100	191	46.7	0.53	0.26–0.73	0.85	Categorized based on Lactanet (2021)
	<50	127	31.0	0.50	0.32–0.67		
	>100	91	22.2	0.46	0.33–0.67		
Milk production (L/cow per yr)	9,500–11,000	216	59.0	0.53	0.32–071	0.02	Rounded of the average of the milk production for cow per year (9,300) as reported by Gouvernement du Québec (2019) and the average of milk production per cow per year of the farm enrolled in the DHI
	<9,500	91	24.8	0.43	0.18–0.62		
	>11,000	60	16.0	0.61	0.38–0.76		
Crossbreeding with beef breed	Yes	300	73.0	0.54	0.28–0.70	0.03	
	No	109	27.0	0.45	0.36–0.68		
Human resource employed for calves' care							
Number of workers available to take care of calves	2	190	46.8	0.50	0.30–0.67	0.01	Categorized based on data distribution and close to quartile
	1	148	36.4	0.50	0.25–0.70		
	≥3	68	16.8	0.61	0.44–0.76		
Agricultural education of caregivers	Yes	283	76.9	0.51	0.32–0.70	0.02	
	No	85	23.1	0.47	0.19–0.61		
Minimal years of experience	3–12	114	28.0	0.50	0.32–0.71	0.02	Categorized based on data distribution and close to quartile
	12–25	106	26.0	0.51	0.30–0.67		
	>25	110	27.0	0.47	0.35–0.77		
	<3	78	19.0	0.58	0.25–0.62		
Calving conditions or neonatal calf care							
Quantity of colostrum offered to surplus calves for the first meal (L)	<4	296	76.7	0.50	0.25–0.67	0.10	Categorized based on the recommendations of the Canadian code of practice (National Farm Animal Care Council, 2023)
	4	75	19.4	0.60	0.38–0.72		
	Calf is left with the dam	10	2.6	0.37	0.20–0.60		
	No colostrum	5	1.3	0.30	0.20–0.47		
Disinfection of navel in newborn surplus calves	Yes	296	72.3	0.52	0.33–0.73	0.01	
	No	113	27.7	0.48	0.25–0.65		
Dam vaccination for neonatal calf diarrhea	No	278	68.0	0.56	0.33–0.73	0.01	
	Yes	131	32.0	0.45	0.25–0.62		
Calf nutrition							
Quantity of milk offered daily to surplus calves (L/d)	6–8	231	57.0	0.54	0.33–0.72	0.10	Categorized based on the recommendations of the Canadian code of practice (National Farm Animal Care Council, 2023)
	<6	57	14.0	0.36	0.21–0.58		
	>8	58	14.3	0.50	0.32–0.70		
	AMF/calf is left with the dam	59	14.6	0.49	0.31–0.72		

Continued

Table 2 (Continued). Descriptive statistics and *P*-values from univariable linear regression modeling the median percentile of surplus calf selling price per farm in the 409 dairy farms enrolled in our study[1]

Variable	Categories of variable	Farm (n)	Farm (%)	Median percentile of calves' selling price per farm	IQR[2] of the median percentile of calves' selling price per farm	*P*-value	Reason for the categorization
Calf housing							
Type of housing	Individual	264	64.7	0.53	0.32–0.72	0.005	
	Group	58	14.2	0.42	0.20–0.63		
	The calf is left with the dam	44	10.8	0.59	0.34–0.72		
	Tied	24	5.9	0.34	0.24–0.50		
	Paired	18	4.4	0.60	0.39–0.72		
Material used for bedding	Straw	200	49.2	0.54	0.32–0.79	0.03	
	Wood shaving	91	22.4	0.43	0.18–0.63		
	Wood shaving and straw	82	20.2	0.50	0.31–0.67		
	Others	33	8.1	0.63	0.43–0.79		
Average age to sell calves (d)	>10	187	45.7	0.49	0.25–0.68	0.07	Categorized based on data distribution and close to quartile
	8–10	154	37.6	0.51	0.33–0.67		
	<8	68	16.6	0.60	0.31–0.76		
Farmer monitors loading of surplus calves	Systematically	243	59.7	0.50	0.29–0.69	0.02	
	Often	96	23.6	0.57	0.34–0.75		
	Never	56	13.7	0.47	0.26–0.62		
	Rarely	12	3.0	0.60	0.48–0.75		
Ban transporter from entering the buildings	Yes	184	45.0	0.58	0.33–0.74	0.008	
	No	171	42.0	0.50	0.24–0.67		
	Farm does not use external transport	53	13.0	0.50	0.30–0.61		

[1]The variables presented in this table had a *P*-value < 0.20 at univariable analysis and were used to build the multivariable model. Note: For each univariable analysis, farms with data not available for the explanatory variable were excluded.

[2]IQR = interquartile range.

[3]Herd size was included as a confounder.

Table 3. Parameter estimates with 95% CI from a final multivariable linear regression modeling the median percentile of surplus calves selling price per farm (adjusted for breed and day of sale) in 409 Québec dairy farms

Variable	Category	β[1]	95% CI	*P*-value
Intercept		0.51	0.432, 0.606	<0.001
Milk production (L/cow per year)	<9,500	Referent		
	9,500–11,000	0.05	−0.006, 0.124	0.07
	>11,000	0.13	0.045, 0.221	<0.01
Number of workers available to take care of calves	1	Referent		
	2	0.01	−0.043, 0.073	0.67
	≥3	0.08	0.005, 0.167	0.03
Herd size[2] (lactating cows)	50–100	Referent		
	<50	0.02	−0.041, 0.086	0.48
	>100	−0.01	−0.08, 0.054	0.67
Disinfection of navel in newborn surplus calves	Yes	Referent		
	No	−0.07	−0.133, −0.012	0.02
Dam vaccination for neonatal calf diarrhea	No	Referent		
	Yes	−0.06	−0.127, −0.011	0.02
Material used for bedding	Straw	Referent		
	Wood shaving	−0.08	−0.156, −0.021	<0.01
	Wood shaving and straw	−0.01	−0.090, 0.052	0.60
	Others	0.07	−0.028, 0.173	0.15
Ban transporters from entering the buildings	Yes	Referent		
	No	−0.07	−0.130, −0.015	0.01
	The farm does not use external transport.	−0.06	−0.148, 0.027	0.17

[1]Regression coefficient.

[2]Herd size was included in the model as a confounder.

the selling price of surplus calves at auction market. The high response rate (85%) along with the large sample size and inclusion of farms from all regions of the province support the validity of our results for all dairy cow farms in Québec. The implementation of management practices such as the disinfection of the navel or the use of straw for bedding, could help to improve the value of this category of animal at marketing.

In this study, yearly average milk production per cow >11,000 L was positively associated with the median percentile of surplus calf selling price compared with the yearly milk production for cow <9,000 L. A high average milk production per cow in the herd is one of the parameters that could indicate the presence of the good management of the herd. In fact, the average milk production per cow in a herd depends on several factors such as the general management of the farm (reproductive performance, nutrition, comfort of the animal, genetic makeup), the presence and occurrence of diseases in the herd, but also on the genetic of the animals present in the herd (Brand et al., 1996; Risco and Melendez Retamal, 2011; Green et al., 2012). Recently, 2 Canadian studies have reported that high average milk production per dairy cow in a herd (whether in tiestall or freestall operations) is associated with adequate cow comfort and welfare in dairy farms (Villettaz-Robichaud et al., 2019a,b). One possible explanation is that farms having a high average milk production per cow also have higher standards of animal management and care. In the surplus calves this association is not as clear as in cows. The questionnaire used in this study could not reveal causal relationship and possible unmeasured confounders cannot be ruled out.

In our study, farms having 3 or more workers available for calf care sold surplus calves at a greater price. Several studies have reported an association between characteristics of calves' caretakers and the subsequent mortality and morbidity of calves (Klein-Jöbstl et al., 2014; Al Mawly et al., 2015). Some of these studies have shown that gender, education, and years of experience of calves' caretakers are associated with calf health and welfare at herd level (Al Mawly et al., 2015; Renaud et al., 2017). In our study, caretakers' education and years of experience were not associated with surplus calves' price in the final multivariable model. Unfortunately, we did not include in our questionnaire the gender of farm workers. One Austrian study showed that the number of people working at the farm is inversely associated with the presence of neonatal calf diarrhea on the farm (Klein-Jöbstl et al., 2014). Authors suggest that in farms where the number of workers was insufficient, workers had less time to care for calves (Klein-Jöbstl et al., 2014). Similarly, our results indicate that when more people are available to take care of calves, more time can be spent for the surplus calves and this could be beneficial for this category of animals. According to previous results of a focus group conducted in Ontario, Canada, dairy farmers consider calf care as excessively demanding in time and prefer prioritizing lactating cows (Wilson et al., 2021). This was especially true for surplus calves because they are considered a farm "byproduct" (Wilson et al., 2021). Another hypothesis that could explain our results is that

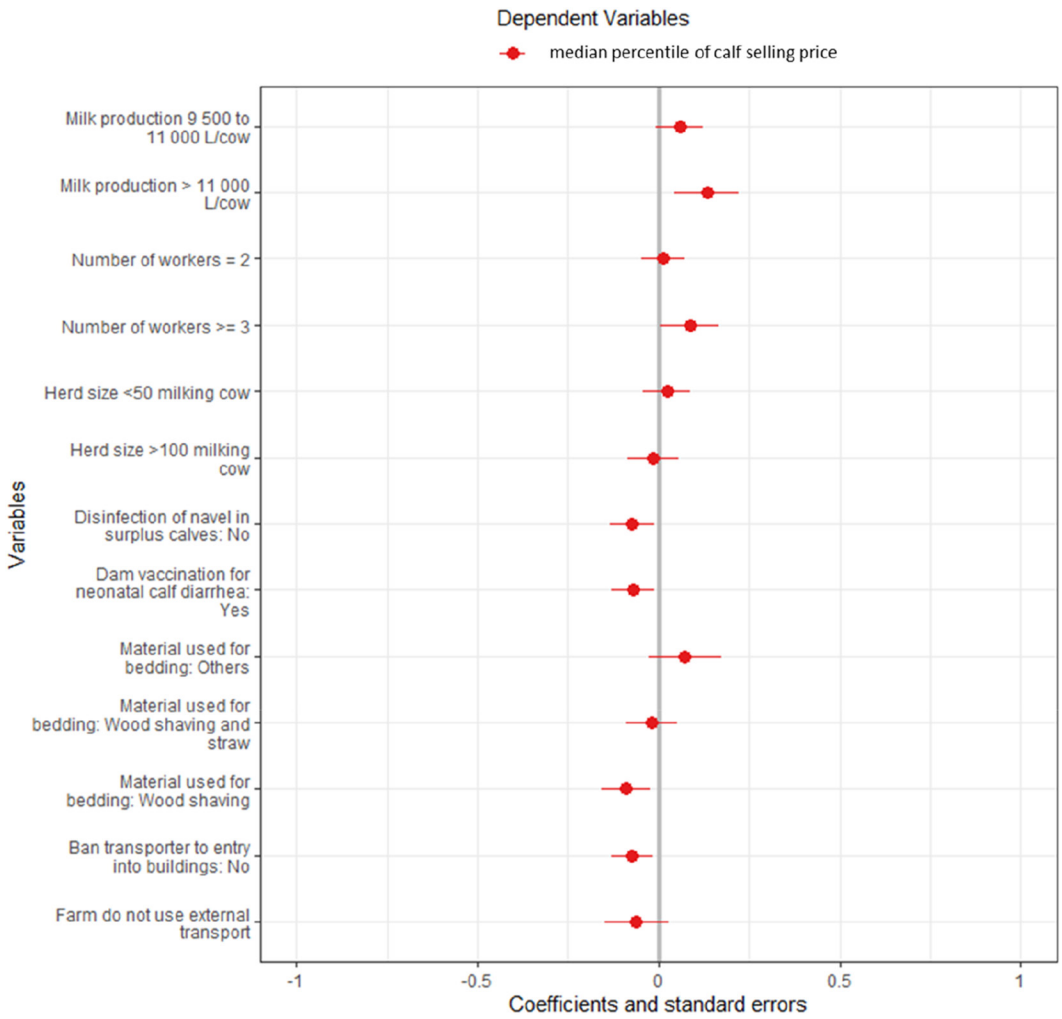

Figure 1. Regression coefficients from the multivariable linear regression modeling the associations between the farm management practices of surplus calves and median percentile of surplus calf selling price at auction from 409 dairy farms enrolled in this study. The coefficient point estimates (dots) and SE (lines) are reported on the abscissa axis. The significant ($P < 0.05$) variables after manual backward selection are reported on the ordinate axis.

a larger number of people could be associated with a broader spectrum of opinions and experiences between workers. A higher body of knowledge among workers could help avoid the so-called farm or herd blindness (Mee, 2020). One of the causes of "farm or herd blindness" is the lack of change in opinions and knowledge among farmers (Mee, 2020). This hypothesis is supported by a recent US study reporting that the major source of information and training for people involved in calves' care are coworkers (Moore et al., 2021). It is important, also, to consider that the presence of several workers in the farm helps to have a good motivation at the workplace (Kolstrup, 2012). All these elements could help workers to have a higher level of care of the animals and particularly of surplus calves.

In the main model, the selling price of surplus calves was negatively associated with the dam's vaccination for neonatal calf's diarrhea; a similar association was found for not disinfecting navel in newborn calves. These 2 practices were probably confounded with other characteristics or practices that were not captured in our questionnaire. The association between the dam's vaccination for neonatal calf's diarrhea and the median percentile of calves' selling price per farm could be explained by the presence of the neonatal calf's diarrhea in these farms. In some farms, the dams were probably vaccinated because of the presence of the neonatal calf's diarrhea (Bendali et al., 1999; Al Mawly et al., 2015). The presence of this disease in the farm could be responsible for the lower quality of the surplus calves sold by these farms. Instead, the association between the navel's disinfection and the price of the surplus calves at the marketing is less clear. Actually, the disinfection of the navel is largely recommended in literature but the evidence that this practice

reduce the risk of navel infections is scarce (Mee, 2008; Lorenz et al., 2011). Recently an Ontarian randomized clinical trial did not show any protective effect of 7% iodine tincture-based umbilical dipping solution versus no treatment to prevent umbilical infection (Van Camp et al., 2022). Instead, one prospective field study performed in French cow-calf operations showed that the disinfection of the navel is a protective factor to develop omphalitis at farm level (Perrot et al., 2024). In this article, Perrot et al. (2024) reported the calf and farm levels also have other risk factors associated with development of omphalitis, and therefore navel disinfection may not benefit every farm. The effectiveness of this practice could be confounded with other characteristics or practices that were not captured in this study. The disinfection of the navel is still among the practices recommended widely in Québec (PBQ, 2021b; Lactanet, 2024).

The other predictor negatively associated with the price of surplus calves was giving transporters access to farm buildings. Biosecurity is considered a challenge for the marketing of the surplus calves. Wilson et al. (2020) have reported discussion of a group of Canadian experts on potential health and welfare problems associated with the marketing of male dairy calves. From the results of this discussion, the participants noted that calf buyers and their vehicles entering dairy farms to collect calves could pose a biosecurity risk, acting as a fomite for transmission of pathogens between calf facilities (Wilson et al., 2020). In another Canadian study it is reported that among biosecurity practices, farmers consider avoiding introduction of animals from an external source to be very effective (Denis-Robichaud et al., 2019). Calf buyers and their vehicle entering in dairy farm, often with calves from other farms already loaded may be a risk to the introduction of pathogens and the same can be said for the transporters (Wilson et al., 2020). We consider the association found in this study as a general proxy of the respect of biosecurity measures. We could speculate that the farmers allowing the transporter entry in their farms building are less aware of biosecurity principles. This finding could also indirectly reflect a generally lower level of calf management.

In general, bedding material is important because it keeps calves in a clean, comfortable, and dry environment (Renaud et al., 2018). Our study showed a negative association between the use of wood shaving as bedding and the median percentile selling price of surplus calves. In another study, Renaud et al. (2018) reported that the use of wood shaving in dairy farms is associated with higher mortality of surplus calves in veal farms during the fattening period. Straw protects calves from cold and drafty conditions because it gives calves the possibility of deep nesting, and less energy is spent on thermoregulation during winter (Lago et al., 2006; Renaud et al., 2018). In addition, the possibility of deep nesting decreases the risk of respiratory disease in calves (Donlon et al., 2023). However, we need to consider that our study, as in the results of the study of Renaud et al. (2018), was conducted in winter, but also in summer when temperature was high. Unfortunately, due to the study design, it was not possible to remove season effect from farm effects because each farm was interviewed only in one season. As reported by Panivivat et al. (2004), straw has better capacity to dry the environment as well as less replication of bacteria than wood shaving and other materials used for bedding. These effects may occur independently of the season. Calves housed on long straw had the fewest scour days and lower coliform counts in the bedding compared with calves on other bedding types (Panivivat et al., 2004; Renaud et al., 2018). In our hypothesis the reduction of the prevalence of the diarrhea and respiratory disease made by the use of the straw as bedding allow the farm that use this type of bedding to sell surplus calves calf healthier and having better price at the marketing.

The data collected by the questionnaire used in this study could explain a limited percentage of variance (R^2 = 12.2%) according to our regression linear model. This was expected as the determination of the price of the surplus calves is complex and also depends on several other factors as sex and day of marketing (Marquou et al., 2019; Buczinski et al., 2021).

In the final multivariable model, we did not control for the proportion of females sold and for the weight of sold calves, which have also been associated with calf price, for 2 main reasons. For sex, this parameter was reported to explain a very small part of price variability with <5% of the scaled deviance of models versus 15% to 50% for breed and 40% to 70% for weight (Buczinski et al., 2021). Concerning the effect of calf weight in the results of the study, we did not include it a priori in our modeling because we thought it could be an intermediary variable of farm management characteristics. To test the potential effect of the herd median weight of calves as a potential confounder, we included it in the selection process and the multivariable model coefficients did not change our findings significantly, which showed that this variable was not a confounder in the current study (Supplemental File S4, see Notes). The only important change was that, as expected, the median weight was associated with sale price (Marquou et al., 2019; Wilson et al., 2020b; Buczinski et al., 2021). The effect of the median weight of surplus calves sold on the dependent variable was limited (β 0.003, 95% CI: 0.001–0.005) versus what has been traditionally found in calf-level studies (Marquou et al., 2019; Wilson et al., 2020b; Buczinski et al., 2021).

As reported in literature, phone interviews are prone to information bias, and in particular the social desirability bias. This means that respondent may tend to answer

the questions about what is socially desirable (Bowling, 2005; Choi and Pak, 2005). The effect of different types of bias associated with questionnaire studies is well known and difficult to exclude a posteriori nor to know the exact effect it may have in a particular study (Althubaiti, 2016).

Predictors of the main multivariable model were tested using 2 subsets of farms enrolled (model 2, farms that sold >1 calf, n = 225 and model 3, farms that sold >2 calves, n = 97). The results of this assessment (Supplemental File S5, see Notes) show that the directions of the statistical associations between farms' characteristics, calves' management practices, and the median percentile of calves' selling price per farm did not depend on the number of calves sold during the study period.

CONCLUSIONS

Results of this observational study indicate that farm management practices are associated with the price of surplus calves at marketing. The presence of more workers available to take care of surplus calves and the use of the straw as bedding could help the dairy farms to increase the value of the surplus calves at marketing. Because of the study design the other associations found in this study need a deeper exploration to better understand the effect of some farms' characteristics or practices and the price of surplus calves. For this further study using face-to-face interviews coupled with farm visits could help to better understand the drivers of these associations.

NOTES

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Nonstandard abbreviations used: CAD = Canadian dollars; IQR = interquartile range.

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