Effect of health status upon arrival at a single milk-fed veal facility on breakeven purchase price of calves

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ABSTRACT

Male calves are purchased from the dairy industry in North America to produce red meat. The price paid for male calves varies widely, and it is unclear which variables influence the price paid for each calf. The objective of this study was to assess how the health traits of calves at the time of arrival and demographic variables affect the breakeven purchase price of a male calf entering the veal industry. A financial model was constructed using the prevalence of health abnormalities, weight at arrival, source of the calf, number of days in the barn, base carcass price, days to mortality, feed costs, season at arrival, interest rate, housing location, carcass dressing percentage, and costs associated with housing, labor, utilities, trucking, and health to calculate the breakeven purchase price and an estimate of profit. Sensitivity analysis was conducted using health variables measured at arrival and demographic variables, including season at arrival and housing location, to identify the factors with the largest impact on the predicted average daily gain, early and late mortality risk, breakeven purchase price, and profit. At the baseline inputs, the average calculated profit was −\$5.36 per calf and it was most sensitive to the location of housing where calves were fed and the body weight of the arriving calf. The mortality risk in the first 21 d after arrival (early) was calculated to be 2.2%, whereas the risk of mortality after 21 d (late) was 3.7%. The risks of early and late mortality were most sensitive to the level of dehydration measured at arrival and the season at arrival for the purchased calves, respectively. The calculated average daily gain was 1.12 kg/d and it was most sensitive to housing location. The breakeven purchase price was calculated to be \$242.49 per calf, which was most sensitive to the housing location

where the calves were fed. The results of this analysis demonstrate that veal producers need to consider many variables before purchasing calves. In addition to overall market conditions, veal producers should factor health characteristics and the expected performance of the calves they purchase into what they are willing to pay for them.

Key words: veal calf, economics, breakeven purchase price

INTRODUCTION

Male calves continue to be produced in high numbers by the dairy industry. Because few of the calves have sufficient genetic merit to be used as sires, they are often sold before 2 wk of age to be raised for red meat (Renaud et al., 2017). The purchase price paid for male calves is extremely variable. In auction barns in Ontario, Canada, from 2000 to 2016, the price paid for calves weighing <56 kg ranged from \$50 to \$450 per head, with high volatility existing from year to year (Beef Farmers of Ontario, 2016; Figure 1). It could be assumed that, similar to beef stocker cattle purchase prices, the value of the calves at slaughter, feed prices, and health factors should be factored into the purchase price (Sartwelle et al., 1996; Dhuyvetter and Schroeder, 1999; Smith et al., 2000); however, it is unclear to what level these factors are considered before the purchase of veal calves.

As many calves enter the veal industry with obvious health abnormalities (Bähler et al., 2012; Pempek et al., 2017; Renaud et al., 2018a), information regarding these abnormalities and the health status of the calves may be useful in determining the value of the calf. This information could be used to determine the maximum purchase price of a calf, which in turn is an important determinant of profitability. The presence of these health challenges contributes to an increased risk of mortality in the production period and a reduced rate of growth (Renaud et al., 2018a,b), which affects profitability. However, the screening of individual calves is

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Figure 1. Price paid per male dairy calf <57 kg at Ontario auction facilities by year (data from Beef Farmers of Ontario, 2016)

time consuming and, to be adopted by the industry, an effect on veal production economics may be necessary to demonstrate the value of this information.

There is variation with respect to colostrum and feeding management for male calves on Canadian dairy farms (Renaud et al., 2017). With failure of passive transfer of immunity and individual BW at arrival being important predictors of morbidity and mortality in the veal industry (Brscic et al., 2012; Pardon et al., 2015; Winder et al., 2016), differences in care could be accounted for in the price paid to individual source dairy farms for their calves. The challenge with this strategy, however, is that the origin of many calves is unknown because of the lack of an open traceability system in Canada. Thus, the ability to implement differential pricing may depend on the veal farm's capability to source calves directly from dairy farms or to price calves based upon their individual health characteristics at the time of arrival at the veal farm.

The objective of this analysis was to model how the health traits of calves at the time of arrival and demographic variables, including season at arrival and housing location, affect the breakeven purchase price of a male calf entering the veal industry.

MATERIALS AND METHODS

Data for this model were from Renaud et al. (2018a,b). Those studies were conducted in cooperation with a milk-fed veal producer and in accordance with the University of Guelph Animal Care Committee

requirements (Animal Use Protocol: #3453). Health variables measured at arrival and demographic variables including season at arrival and housing location were associated with the risk of mortality and growth. Calves were scored using a standardized health scoring system (Renaud et al., 2018a) by 1 of 3 observers. Inter- and intra-observer reliability were measured for the observers, with the majority of parameters having a kappa score >0.50 (Renaud et al., 2018a). Definitions for the health characteristics and their means can be found in Table 1. Source was categorized as "drover": transporter responsible for going to multiple dairy farms to gather calves; "auction": calves purchased at an auction facility; or "local": calves brought to the facility by local dairy producers. Drover was further broken into 5 categories because each drover sourced the calves from different dairy farms and transported the calves varying distances. Season of arrival was categorized as winter (December to February), spring (March to May), summer (June to August), and fall (September to November). Housing location was categorized into 5 barns that were present in different geographical locations within the southwestern region of Ontario, Canada. In barns 1, 2, and 4, the calves were fed manually, whereas in barns 3 and 5, automatic calf feeders were used. Calves were housed individually in barns 1 and 4 and in groups of 60 calves in barns 3 and 5. Calves in barn 2 were housed in individual pens in early life, transitioning to groups of 8 calves 5 to 6 wk following arrival. Thus, housing reflected both geographical and facility type variation.

Two explanatory logistic regression models were estimated, one for early mortality (occurring ≤ 21 d following arrival) and one for late mortality (> 21 d after arrival). A mixed linear regression model was constructed to evaluate the association of health variables measured at arrival with ADG occurring in the production period while controlling for the slaughterhouse as a random effect. Average daily gain was calculated by subtracting weight at arrival from the estimated live weight at slaughter and this value was divided by the number of days on feed. Hot carcass weight (**HCW**) was used to estimate final live weight with the assumption that HCW was 58.5% of live weight at slaughter (Renaud et al., 2018b). All statistical analyses were completed using Stata 14 (StataCorp LP, College Station, TX).

The assumption of linearity of continuous explanatory variables was assessed in the logistic models by plotting the natural logarithm of the odds of the outcome against the variable, whereas in the linear regression model, the linearity of continuous variables was assessed by plotting ADG against the variable. If a variable failed to meet the linearity assumption, it was categorized. Univariable regression models were constructed to screen for variables that were unconditionally associated with the outcome, using a P -value of 0.2. Risk factors that

were associated with the outcome were subsequently offered to a multivariable model through a manual backward stepwise removal process. Variables were retained in the multivariable models if they were significant at $P < 0.05$. Confounding was assessed by evaluating the effect of removal of a variable on the coefficients of the remaining variables. A variable was deemed to be a confounder if it was not an intervening variable based on the causal diagram and the log odds of a significant variable in the model changed by at least 20% when the variable was removed from the model. Two-way interactions were evaluated between variables suspected to interact based on evidence from the literature and remained in the final models if significant (P -value < 0.05 ; Dohoo et al., 2010a). The model fit was assessed using the Hosmer-Lemeshow goodness-of-fit test and Pearson and deviance χ^2 tests for the early and late logistic regression models, respectively. Homoscedasticity and normality of the residuals and BLUP were used to evaluate model fit in the mixed linear regression model. Each model fit the data. Outliers were identified and evaluated. If outliers were found, they were explored to determine the characteristics of the observations that made them outliers and ensure data were not erroneous.

Table 1. Model inputs (means) to estimate ADG and early and late mortality risk¹

Variable	Category	Mean
Weight at arrival (kg)		46.9
Sunken flank (%)	No	80.4
	Yes	19.6
Navel score (%)	0: Normal	73.9
	1: Slightly enlarged with slight pain or moisture	19.7
	2: Enlarged with heat, pain or malodorous discharge	6.2
Cough score (%)	0: None	94.7
	1: Induce single cough	4.0
	2: Induce repeated or spontaneous coughs	1.3
Dehydration score (%)	0: $\leq 5\%$ dehydrated	54.4
	1: 6 to 8% dehydrated	34.3
	2: 8 to 10% dehydrated	9.9
	3: $> 10\%$ dehydrated	1.3
Source (%)	Local	18.0
	Drover 1	36.5
	Drover 2	21.2
	Drover 3	1.7
	Drover 4	7.6
	Drover 5	3.6
	Auction	11.5
Season (%)	Winter	21.1
	Spring	28.9
	Summer	39.6
	Fall	10.5
Barn (%)	1	25.9
	2	28.6
	3	28.6
	4	9.4
	5	7.6

¹Source: Renaud et al. (2018a) where 4,825 calves were screened upon arrival to a milk-fed veal facility

Table 2. Example budget and identification of variable type

Variable ¹	Value	Variable type ²	Source
Production parameters			
Days in barn	147	Constant	Renaud et al., 2018a
ADG (kg/d)	1.12	Modeled	
Projected end weight (kg)	212	Calculated	
Dressing percent (%)	58.5	Constant	Renaud et al., 2018a
Projected dressed weight (kg)	124	Calculated	
Mortality ≤ 21 -d risk (%)	2.2	Modeled	
Mortality > 21 -d risk (%)	3.7	Modeled	
Income			
Carcass price (\$/kg)	8.91	Constant	Les Producteurs de bovins du Quebec (2018a)
Revenue [\$ /head (out)]	1,104.47	Calculated	
Expenses			
Purchase price of calf (\$/head)	248.00	Constant	Les Producteurs de bovins du Quebec (2018b)
Feed cost [\$ /head (out)]	653.56	Constant	Veal Farmers of Ontario (personal communication) ³
Housing, labor, utilities [\$ /head (in)]	120.00	Constant	Pascal Bouilly (personal communication) ⁴
Trucking to processor [\$ /head (out)]	20.00	Constant	Pascal Bouilly (personal communication)
Health costs [\$ /head (in)]	20.00	Constant	Pascal Bouilly (personal communication)
Mortality costs [feed for dead (out)]	10.91	Calculated	
Interest cost (out)	14.00	Calculated	
Total cost [\$ /head (out)]	847.12	Calculated	
Total cost including calf [\$ /head (out)]	1,110.15	Calculated	
Profit [\$ /head (out)]	−5.69	Calculated	
Profit [\$ /head (in)]	−5.36	Calculated	
Breakeven purchase price (\$/head)	242.49	Calculated	

¹Where (in) and (out) refer to a value on a “per head in” or “per head out” basis.

²Modeled and calculated were generated from regression models and algebraic calculations, respectively.

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Financial Model

A financial model was constructed in Excel (Microsoft Corp., Redmond, WA) where some input values were held constant and others were calculated or estimated (modeled). “Modeled” refers to values that were generated from a regression-based model, and “calculated” refers to values that were simply calculated from other variables. Table 2 presents the resulting budget for a baseline set of inputs and identifies whether values were constant, calculated, or modeled. The baseline inputs reflect mean values for calf health characteristics and demographics (Table 1).

The prevalence of health abnormalities, weight at arrival, source of calf, season at arrival, and housing location were evaluated. Each parameter was changed individually while holding the remainder of the variables constant to determine the influence of each of the variables of interest in the model. The values at which these variables were held constant can be found in Table 1 and are based on the levels of the parameters found in Renaud et al. (2018a). Dressing percentage, days to early and late mortality, purchase price of the calf, days in the barn, dressing percentage, base carcass price, interest rate, and costs associated with housing, labor, utilities, trucking, health, and feed were held constant. The feeding schedule of the facility was used

to calculate feed costs, with the amount of milk replacer varying depending on the number of days the calf was on feed. We assumed that if a calf was fed for 147 d before slaughter, it would consume 16 kg of starter milk replacer powder (\$2.58/kg), 35 kg of intermediate milk replacer (\$1.79/kg), and 296 kg of finisher milk replacer (\$1.74/kg). We also assumed that the calves would consume 35 kg of pellet (\$0.94/kg). This led to a total feed cost of \$653.56 per calf over the assumed 147-d production period (Renaud et al., 2018b). Due to the proprietary nature of the feed schedule of the study facility, details cannot be provided here. For calves that died, it was assumed they died 11 d following arrival and 84 d following arrival if they died in the ≤ 21 -d period or > 21 -d period, respectively (Renaud et al., 2018a). Days to mortality was not specifically explored because when varied at $\pm 10\%$ of the presented means, it had a small effect on profit [≤ 21 -d period $-\$5.31$ to $-\$5.31$ per calf; > 21 -d period $-\$3.78$ to $-\$6.86$ per calf] and breakeven purchase price [≤ 21 -d period $\$242.39$ to $\$242.54.31$ per calf; > 21 -d period $\$241.02$ to $\$244.03$ per calf]. An interest rate of 5.71% was used to calculate the interest cost (Federal Reserve Bank of Kansas City, 2018).

Predicted ADG was calculated using the coefficients from a linear mixed regression model presented in Table 3 using equation [1]. The predicted early mortality risk

Table 3. Results from a multivariable mixed linear regression model evaluating the effect of health status at arrival to a milk-fed veal facility on ADG

Variable	Description	Coefficient (kg/d)	SE	P-value
Intercept		−0.93	0.52	0.08
Barn	1	Referent		
	2	−0.01	0.01	0.73
	3	0.15	0.01	<0.01
	4	0.09	0.02	<0.01
	5	0.19	0.02	<0.01
Season	Winter	Referent		
	Spring	−0.02	0.01	0.09
	Summer	−0.07	0.01	<0.01
	Fall	−0.06	0.01	<0.01
Dehydration score	0	Referent		
	1	−0.02	0.01	0.02
	2	−0.01	0.01	0.50
	3	−0.08	0.03	0.01
Source	Local	Referent		
	Drover 1	0.02	0.01	0.08
	Drover 2	0.03	0.01	0.01
	Drover 3	0.01	0.03	0.84
	Drover 4	0.05	0.02	<0.01
	Drover 5	0.04	0.02	0.09
	Auction	0.03	0.01	0.03
Weight at arrival	kg	0.002	0.00	0.04
Days on feed	days	0.03	0.01	<0.01
Days on feed squared		−0.0001	0.00	<0.01

was calculated using the coefficients from a logistic regression model presented in Table 4 using equation [2], and late mortality risk was calculated using the logistic regression model reported in Table 5 using equation [3]. Profit was calculated as revenue (dressed weight $\times$ carcass price) less costs, as shown in equation [4], and breakeven price was calculated as the price that could be paid for the calf (i.e., purchase price) such that profit was exactly equal to zero, as shown in equation [5]. All equations are shown in the Appendix.

Sensitivity Analysis

Sensitivity analyses were conducted to identify the inputs related to cattle health and demographics with the largest impact on calculated ADG, early mortality risk, late mortality risk, breakeven purchase price, and profit. The sensitivity analyses were done by holding all cattle health and demographic variables constant at their baseline values (i.e., means in Table 1) while varying one factor at a time to determine its effect on ADG and early and late mortality and the resulting impact on breakeven purchase price and profit. Arrival weight, the purchased source of the calves, season at arrival, dehydration score, and housing location were evaluated to determine their effects on ADG. The presence of a sunken flank, navel score, cough score, level of dehydration, season at arrival, housing location, arrival weight, and source of the calves were evaluated for their ef-

fects on early mortality risk, whereas season at arrival, source of the purchased calves, housing location, and navel score were evaluated for their effects on late mortality risk. For categorical variables in each sensitivity analysis, the effect of every categorical level was determined while holding the remainder of the variables at a constant rate (Table 1). Arrival weight was the single continuous variable used and was inputted at the 10th and 90th percentile of the nearly 5,000 calves presented in Renaud et al. (2018a) to account for the variation in arrival weight that could be expected. The values of arrival weight used for the sensitivity analysis were 39.3 kg (10th percentile) and 56.8 kg (90th percentile). Tornado plots were created to display a relative ranking of the magnitude of effects on the changes in the input variables on each output variable.

Variables that did not include calf health and demographic information were varied at $\pm 10\%$ of their presented means. Specifically, carcass price paid, feed cost, other costs (aggregate of housing, labor, utilities, trucking and health costs), and purchase price of the calf were evaluated to determine their effects on profit using equation [4], whereas carcass price paid, feed cost, and other costs were evaluated to determine their effects on breakeven purchase price using equation [5]. The predicted ADG, early mortality risk, and late mortality risk were also varied to determine the influence of each predicted outcome on profit and breakeven purchase price. Changing the variables by $\pm 10\%$ of their

Table 4. Output of logistic regression model evaluating early mortality (mortality occurring ≤ 21 d after arrival) at a milk-fed veal facility in Ontario, Canada

Variable	Description	Coefficient	P-value	95% CI
Intercept		-0.09	0.92	-2.03 to 1.84
Dehydration score	0			
	1	0.55	0.01	0.15 to 0.96
	2	0.74	0.01	0.19 to 1.30
	3 and 4	1.95	<0.01	1.03 to 2.87
Source	Local			
	Drover 1	-0.95	<0.01	-1.45 to -0.44
	Drover 2	-1.19	<0.01	-1.85 to -0.53
	Drover 3	-1.26	0.22	-3.29 to 0.77
	Drover 4	-1.47	<0.01	-2.37 to -0.57
	Drover 5	-0.86	0.16	-2.08 to 0.35
	Auction	-0.29	0.36	-0.90 to 0.33
Sunken flank	No			
	Yes	-0.45	0.42	-1.54 to 0.65
Sunken flank $\times$ source	Yes $\times$ Drover 1	1.37	0.03	0.14 to 2.59
	Yes $\times$ Drover 2	1.49	0.04	0.10 to 2.88
	Yes $\times$ Drover 3	1.82	0.24	-1.23 to 4.87
	Yes $\times$ Drover 4	0.57	0.88	-2.56 to 5.66
	Yes $\times$ Drover 5	1.85	0.06	-0.05 to 3.75
	Yes $\times$ Auction	0.30	0.72	-1.36 to 1.96
Navel score	0 and 1			
	2	0.22	0.31	-0.20 to 0.64
	3	0.89	<0.01	0.34 to 1.45
Barn	1			
	2	-0.20	0.39	-0.66 to 0.26
	3	0.04	0.86	-0.40 to 0.48
	4	-0.46	0.21	-1.18 to 0.26
	5	-1.08	0.05	-2.15 to -0.01
Season	Winter			
	Spring	0.01	0.98	-0.50 to 0.52
	Summer	0.70	0.01	0.16 to 1.24
	Fall	-0.26	0.54	-1.08 to 0.57
Cough score	0			
	1	0.49	0.16	-0.19 to 1.17
	2 and 3	1.22	0.01	0.24 to 2.19
Weight at arrival	kg	-0.03	<0.01	-0.05 to -0.02

Table 5. Output of logistic regression model evaluating late mortality (mortality occurring > 21 d after arrival) at a milk-fed veal facility in Ontario, Canada

Variable	Description	Coefficient	P-value	95% CI
Intercept		-2.74	<0.01	-2.27 to -3.21
Source	Local			
	Drover 1	0.11	0.61	-0.31 to 0.53
	Drover 2	-0.30	0.22	-0.79 to 0.18
	Drover 3	0.58	0.25	-0.41 to 1.56
	Drover 4	-0.60	0.19	-1.50 to 0.30
	Drover 5	-0.14	0.75	-0.98 to 0.71
	Auction	0.48	0.05	0.00 to 0.96
Barn	1			
	2	0.59	<0.01	0.23 to 0.95
	3	-0.42	0.06	-0.85 to 0.01
	4	-0.07	0.83	-0.67 to 0.54
	5	-0.09	0.80	-0.74 to 0.57
Season	Winter			
	Spring	-0.40	0.02	-0.75 to -0.05
	Summer	-0.86	<0.01	-1.24 to -0.49
	Fall	-1.53	<0.01	-2.24 to -0.81
Navel score	0 and 1			
	2	0.12	0.53	-0.24 to 0.47
	3	0.70	0.01	0.22 to 1.19

presented means was chosen because it could be equally applied and lead to plausible changes in the variable that could be expected.

RESULTS

Average daily gain was influenced by housing location, season at arrival, level of dehydration, source of calves, BW at arrival, and days on feed (Renaud et al., 2018b; Table 3). In the multivariable logistic regression model, the variables associated with the risk of early mortality (death occurring ≤ 21 d following arrival) were the level of dehydration, source of calves, housing location, season at arrival, presence of an induced or spontaneous cough, BW at arrival, and presence of an enlarged navel with heat, pain, or moisture (Table 4). The presence of a sunken flank interacted with source of the calves and was the sole interaction term found in the 3 models. Furthermore, the source of the calves, housing location, season at arrival, and presence of an enlarged navel with heat, pain, or moisture were associated with late mortality (death occurring >21 d following arrival) (Renaud et al., 2018a; Table 5).

The calculated values for each output are found in Table 2, where ADG, early mortality, and late mortality are model-estimated values with cattle health and demographic values at their means (Table 1). Table 6 highlights the changes that occurred with each output as the input variables were altered while holding the other variables constant. When all input variables were held constant at their means, the ADG was 1.12 kg/d. The largest influencer of ADG was housing location followed by dehydration score, season at arrival, source of calves, and arrival weight (Figure 2). The predicted early mortality risk was 2.2%, with level of dehydration at arrival having the greatest effect on mortality risk (Figure 3). The season at which the calves arrived at the facility had the greatest effect on late mortality risk, which was predicted to be 3.7% when all variables were held constant (Figure 4). The estimated profit that was calculated was $-\$5.36$ per calf. The largest influencer on profit was housing location followed by arrival weight, level of dehydration, source, navel score, season of arrival, cough score, and the presence of a sunken flank (Figure 5). With all variables at their means, the breakeven purchase price was calculated to be $\$242.49$

Table 6. Outputs from financial model (results shown are from altering a single parameter and holding all other variables constant)

Variables	Category	ADG (kg/d)	Early mortality (%)	Late mortality (%)	Profit [\$/head (in)]	Breakeven purchase price (\$/calf)
Baseline (all values at means)		1.12	2.2	3.7	-5.36	242.49
Sunken flank	No	1.12	1.9	3.7	-4.43	243.39
	Yes	1.12	3.2	3.7	-9.81	238.14
Navel score	0 and 1	1.12	1.9	3.4	-2.88	244.91
	2	1.12	2.4	3.8	-7.73	240.17
	3	1.12	4.6	6.7	-37.58	210.99
Cough score	0	1.12	2.1	3.7	-5.03	242.81
	1	1.12	3.3	3.7	-10.62	237.34
	2 and 3	1.12	6.7	3.7	-25.42	222.88
Dehydration score	0	1.13	1.6	3.7	3.63	251.28
	1	1.11	2.8	3.7	-16.50	231.60
	2	1.12	3.3	3.7	-10.68	237.28
	3 and 4	1.05	10.4	3.7	-90.65	159.12
Season	Winter	1.16	1.7	6.6	5.14	252.75
	Spring	1.14	1.7	4.5	5.07	252.68
	Summer	1.09	3.3	2.9	-27.06	221.27
	Fall	1.10	1.3	1.5	-3.08	244.72
Barn	A	1.06	2.5	3.5	-52.41	196.49
	B	1.05	2.1	6.2	-71.58	177.75
	E	1.21	2.6	2.4	63.22	309.52
	H	1.15	1.6	3.3	18.40	265.71
	W	1.25	0.9	3.3	97.11	342.65
Arrival weight	Lowest 10% (39.3 kg)	1.11	3.8	3.7	-58.94	190.12
	Highest 10% (56.8 kg)	1.14	1.0	3.7	61.22	307.57
Source	Local	1.10	3.9	3.7	-29.80	218.59
	Drover 1	1.12	2.0	4.1	-10.56	237.41
	Drover 2	1.13	1.6	2.8	9.07	256.59
	Drover 3	1.10	1.6	6.4	-33.94	214.55
	Drover 4	1.15	0.9	2.1	33.16	280.14
	Drover 5	1.13	2.4	3.3	3.31	250.96
	Auction	1.14	3.1	5.8	-15.00	233.06

per calf. However, when evaluated across the different housing locations, holding all else constant, the breakeven price varied from \$177.75 to \$342.65 (range of almost \$165 per head; Figure 6).

Of the variables that did not include calf health and demographic information, the carcass price paid had the largest effect on both profit and breakeven purchase price. At a carcass price of \$8.02/kg (−10% from baseline carcass price of \$8.91/kg), the profit was predicted to be −\$118.86/calf and the breakeven purchase price was \$138.73/calf. A carcass price of \$9.80/kg (+10% from baseline) lead to a profit of \$102.04/calf and a breakeven purchase price of \$341.30. Feed costs also had a large impact on both profit and breakeven purchase price. A feed cost of \$588.20/calf (−10% from baseline feed cost of \$653.56/calf) lead to a profit and breakeven purchase price of \$56.85 and \$303.30/calf, respectively, whereas a feed cost of \$718.89 (+10% from baseline) per calf lead to a profit and breakeven purchase price of −\$68.66 and \$180.61/calf, respectively. Reducing other costs from a baseline of \$160.00 per calf by 10% resulted in a profit and breakeven purchase price of \$10.55 and \$258.04/calf, respectively. Likewise, increasing other costs 10% resulted in a profit and breakeven purchase price of −\$21.26 and \$226.94/calf, respectively. The purchase price paid for the calf had a smaller yet still important effect on profit. Purchasing a calf for \$223.2 (−10% from baseline purchase price of \$248.00) lead to a profit of \$17.20/calf, whereas paying \$272.80/calf (+10% from baseline) lead to a profit of −\$33.54.

Of the calculated outcomes, ADG had the largest effect on profit and breakeven purchase price paid per

calf. An ADG of 1.01 kg/d lead to a profit and breakeven purchase price of −\$86.95 and \$162.73/calf, respectively, whereas, at an ADG of 1.23 kg/d, the profit and breakeven purchase price were \$79.50 and \$320.92/calf, respectively. In contrast, early and late mortality had minimal effects on profit and breakeven purchase price. An early mortality risk of 1.93% lead to a profit of −\$4.42 per calf and a breakeven purchase price of \$243.40/calf, whereas an early mortality risk of 2.36% lead to a profit of −\$6.33 and a breakeven purchase price of \$241.54/calf. Late mortality risk had a larger effect than early mortality due to the increased feed cost. A late mortality risk of 3.31% lead to a profit and breakeven purchase price of −\$2.78 and \$245.01/calf, whereas a late mortality risk of 4.04% lead to a profit and breakeven purchase price of −\$7.89 and \$240.02/calf, respectively.

DISCUSSION

This study demonstrated that when purchasing calves for the veal industry, several controllable factors affect the breakeven purchase price of calves. Specifically, housing location, calf arrival weight, and the level of dehydration measured at arrival had the greatest effect on the purchase price. However, it is important to consider other factors over which producers likely have less control. The carcass price paid is the largest source of revenue and it is important for producers to consider future carcass price because it has shown considerable fluctuation, with HCW price ranging from \$8.27 to \$9.57/kg from 2016 to 2018 (Les Producteurs de bovins du Québec, 2018a,b). Feed costs were responsible for

Figure 2. Model-estimated ADG with changes in deterministic inputs. Black line indicates the variables at the baseline mean of 1.12 kg/d.

the highest cost in the production cycle; therefore, it is necessary to take these costs into consideration before the purchase of calves. A limitation of the study was that some of the data used to generate the variables were from a single veal operation. This could have led to results that might be different than if a representative portion of farms within the veal industry had been used in this study. However, we believe that this operation, with its differing housing styles, management practices, and sources of calves, is representative of the veal industry and the results generated would therefore be generalizable to the veal industry in Canada. Our inability to account for the effect that health status at arrival has on morbidity could have affected the results and should be considered another limitation of this study. Morbidity was not included because the morbidity data from the previous studies were missing large portions and were deemed insufficiently reliable to use within this study to calculate the associated health costs occurring throughout the production cycle. However, as disease is often associated with reduced growth (Windeyer et al., 2014), growth performance could serve as a proxy for morbidity. The results of this study showed that growth performance (ADG) had a large effect on the resulting economic metrics (profit and breakeven purchase price).

Overall, the simulation predicted a negative profit of $-\$5.36$ per finished calf. This value is a function of both the time period when prices were set and as-

sumptions about specific input costs; thus, the absolute value of the average profit is not particularly relevant. However, what is relevant is how profit changed as various inputs were changed. It is also important to consider that many of the companies involved in milk-fed veal production are vertically integrated and produce their own milk replacer and market their own veal. This could lead to lower feed costs and higher carcass prices than those used in this model.

Despite following the same feeding schedule and providing the same milk replacer, housing location had the greatest effect on breakeven purchase price. The variation in growth performance and mortality could have resulted from the differing ventilation and housing systems used in the barns. Inadequate ventilation can lead to high levels of noxious gases, humidity, dust, and bacterial content being present in the air, contributing to the development of respiratory disease (Woolums et al., 2009). Another potential consideration is the differing experience of the labor and treatment protocols used between the different barns. Early recognition and appropriate treatment of disease is extremely important to prevent long-term consequences associated with it. If some barns provided late or even ineffective treatment, this could have contributed to the differences between the barns.

Body weight measured at arrival was an important factor influencing many of the estimated parameters. Calves with greater BW arriving at a veal facility are

Figure 3. Model-estimated early mortality with changes in deterministic inputs. Black line indicates the variables at the baseline mean of 2.15% early mortality risk.

Figure 4. Model-estimated late mortality with changes in deterministic inputs. Black line indicates the variables at the baseline mean of 3.67% late mortality risk.

associated with a reduced risk of mortality (Winder et al., 2016; Renaud et al., 2018a) and morbidity (Brscic et al., 2012) but also a higher growth rate (Renaud et al., 2018b), which together lead to increased revenue per purchased calf. To capture this advantage, veal producers should consider paying more for heavier calves or discounting lighter weight calves.

Of health status measures, the level of dehydration and presence of an enlarged navel with heat, pain, and malodorous discharge had the greatest effect on break-even purchase price. The level of dehydration had a significant effect on the risk of early mortality but also on the growth of the calves at the facility, leading to a range of breakeven purchase price of \$92.16, whereas an

Figure 5. Calculated profit generated per calf with changes in deterministic inputs. Black line indicates the variables at the baseline mean of -\$5.36 profit generated per calf.

Figure 6. Calculated breakeven purchase price with changes in deterministic inputs. Black line indicates the variables at the baseline mean of \$242.49 breakeven purchase price per calf.

abnormal navel score had a smaller effect on the risk of early and late mortality (Renaud et al., 2018a,b), leading to a range of breakeven purchase price of \$33.92. As both of these variables are easily measured at arrival, an intervention could be applied to prevent the negative implications associated with these characteristics. However, if it is possible to evaluate calves before purchase, calves with these abnormal health characteristics should be discounted.

The management of male calves on the source dairy farm is imperative to the future success of the calf on veal farms. However, on some Canadian dairy farms, colostrum and nutritional management of male calves is far from ideal (Renaud et al., 2017), leading to a greater risk of mortality and reduced ADG (Renaud et al., 2018a,b). Although we were unable to differentiate specific dairy farms, the results of the study suggest that differential pricing should be used to reward producers with excellent management of male calves and discount others that are not providing adequate care.

CONCLUSIONS

Using a financial model evaluating calf health and demographic information, we found that housing location had the largest effect on the breakeven purchase price per head; BW at arrival and source of the purchased calves were important factors for breakeven purchase price. We also determined that health status measured at arrival, specifically the level of dehydration and presence of an enlarged navel with heat, pain, or malodor-

ous discharge, affected the breakeven purchase price for male dairy calves.

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Appendix

Equation 1: Calculating ADG

$$\begin{aligned} \text{ADG} = & -0.93 + (-0.01)a + 0.15b + 0.09c + 0.19d + (-0.02)e \\ & + (-0.07)f + (-0.06)g + (-0.02)h + (-0.01)j + (-0.08)k + 0.02l \\ & + 0.03m + 0.01n + 0.05p + 0.04q + 0.03r + 0.002s + 0.03t + (-0.0001)t^2, \end{aligned}$$

where a, b, c, d = proportion of calves entering barn 2, 3, 4 or 5, respectively; e, f, g = proportion of calves entering the barn in the spring, summer, or fall, respectively; h, j, k = proportion of calves that were 6 to 8%, 8 to 10%, or >10% dehydrated, respectively; l, m, n, p, q, r = proportion of calves from drover 1, drover 2, drover 3, drover 4, drover 5, or auction, respectively; s = weight at arrival; and t = days on feed.

Equation 2: Calculating Risk of Early Mortality

$$\text{Risk of early mortality} = \frac{\text{Exp} \left[\begin{aligned} & -0.09 + (-0.05)h + (-0.02)j + (-0.18)k + 0.04l + 0.07m \\ & + 0.01n + 0.11p + 0.07q + 0.08r + (-0.45)w + 1.36wl \\ & + 1.49wm + 1.82wn + 1.85wp + 0.29wr + 0.21y + 0.89z \\ & + (-0.20)a + 0.03b + (-0.45)c + (-1.08)d + 0.005e \\ & + 0.70f + (-0.25)g + 0.49u + 1.21v + (-0.03s) \end{aligned} \right]}{1 + \text{Exp} \left[\begin{aligned} & -0.09 + (-0.05)h + (-0.02)j + (-0.18)k + 0.04l + 0.07m \\ & + 0.01n + 0.11p + 0.07q + 0.08r + (-0.45)w + 1.36wl \\ & + 1.49wm + 1.82wn + 1.85wp + 0.29wr + 0.21y + 0.89z \\ & + (-0.20)a + 0.03b + (-0.45)c + (-1.08)d + 0.005e \\ & + 0.70f + (-0.25)g + 0.49u + 1.21v + (-0.03s) \end{aligned} \right]},$$

where a, b, c, d = proportion of calves entering barn 2, 3, 4 or 5, respectively; e, f, g = proportion of calves entering the barn in the spring, summer or fall, respectively; h, j, k = proportion of calves that were 6% to 8%, 8% to 10% or >10% dehydrated, respectively; l, m, n, p, q, r = proportion of calves from drover 1, drover 2,

drover 3, drover 4, drover 5, or auction, respectively; s = weight at arrival; t = days on feed; u, v = proportion of calves entering the barn with induced single cough or induced repeated and spontaneous coughs, respectively; w = proportion of calves arriving with a sunken flank; and y, z = proportion of calves with a slightly enlarged navel slight pain or moisture or enlarged navel with heat, pain or malodorous discharge.

Equation 3: Calculating Risk of Late Mortality

$$\text{Risk of late mortality} = \frac{\text{Exp} \left[\begin{array}{l} -2.74 + 0.11l + (-0.30)m + 0.57n + (-0.60)p + (-0.14)q + 0.47r + 0.59a \\ + (-0.42)b + (-0.07)c + (-0.09)d + (-0.40)e + (-0.86)f + (-1.53)g + 0.11y + 0.70z \end{array} \right]}{1 + \text{Exp} \left[\begin{array}{l} -2.74 + 0.11l + (-0.30)m + 0.57n + (-0.60)p + (-0.14)q + 0.47r + 0.59a \\ + (-0.42)b + (-0.07)c + (-0.09)d + (-0.40)e + (-0.86)f + (-1.53)g + 0.11y + 0.70z \end{array} \right]},$$

where a, b, c, d = proportion of calves entering barn 2, 3, 4 or 5, respectively; e, f, g = proportion of calves entering the barn in the spring, summer or fall, respectively; l, m, n, p, q, r = proportion of calves from drover 1, drover 2, drover 3, drover 4, drover 5, or auction, respectively; and y, z = proportion of calves with a slightly enlarged navel slight pain or moisture or enlarged navel with heat, pain or malodorous discharge.

Equation 4: Calculating Profit per Calf

$$\text{Profit per calf} = \left((pdw \times bcp) - \frac{fc + \frac{(hluc+hc)}{1-ptm} + tc + mc + ic + pc}{1-ptm} \right) \times (1-ptm),$$

where pdw = projected dress weight; bcp = base carcass price; fc = feed costs; $hluc$ = housing, labor, and utility costs; ptm = predicted total mortality risk; hc = health costs; tc = trucking costs; ic = interest cost; pc = purchase price of calf; and mc = mortality cost.

Equation 5: Calculating the Predicted Breakeven Purchase Price (\$/Head)

$$\text{Purchase price} = \left\{ [s + (ADG \times t)] \times dp \times bcp \right\} - fc - \left(\frac{hluc+hc}{2} - tc - (fc \times dem) - (fc \times dlm) \right) \\ - \left[\frac{fc + \frac{hc}{2} + \left[\frac{dem \times pem \times fc \times \frac{t-dlm}{2}}{1-ptm} \right] \times ir \times \frac{t}{365}}{1 + ir \times \frac{t}{365}} \right] \times (1-ptm),$$

where s = weight at arrival; t = days on feed; dp = dressing percentage; bcp = base carcass price; fc = feed costs; ptm = predicted total mortality risk; pem = predicted early mortality risk; ADG = predicted average daily gain; hc = health costs; tc = trucking costs; ir = interest rate; $hluc$ = housing, labor, and utility costs; dlm = days to late mortality; and dem = days to early mortality.