Fitness for transport of cull dairy cows at livestock markets

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ABSTRACT

Cows are regularly removed from dairy herds and sold at livestock markets. Many cows are removed because of health problems, and their fitness for transport may vary because of seasonal variation, delayed or poor on-farm culling decisions, injuries during transport, and other factors. However, many dairy producers lack feedback about the condition of their cows during the marketing process and how cow condition influences sale price. This study evaluated the condition of cull dairy cows sold at livestock markets, tested how changing demand for milk influenced fitness for transport, and quantified how cow condition affected the price paid. For 12 mo, 2 livestock markets in British Columbia, Canada, were visited during 137 auction events when cull dairy cows were sold; 3 trained assessors observed 6,263 cull dairy cows while they were marketed in a sale ring. Observers recorded the cows' body condition score (BCS), locomotion score (LS), udder condition, quality defects (e.g., injuries, illness), and price. Logistic regression was used to test how month-to-month changes in demand for milk affected cows' fitness for transport, and a linear mixed model assessed how the animals' condition influenced the price. About 10% of the cows were thin (BCS ≤ 2), 7% were severely lame (locomotion score ≥ 4), 13% had engorged or inflamed udders, and 6% had other quality defects including abscesses, injuries, and signs of sickness (e.g., pneumonia). Cows culled during months with increased milk demand had much higher odds of poor fitness for transport (odds ratio 8.6, 95% confidence interval: 4.02–18.22). The price was most reduced if cows were thin (BCS ≤ 2) or visibly sick ($-\$0.63 \pm 0.01/\text{kg}$ and $-\$0.56 \pm 0.02/\text{kg}$, respectively). Prices were reduced to a lesser degree by locomotion score ≥ 4 ($-\$0.35 \pm 0.02/\text{kg}$) and by udder condition (udder inflammation; $-\$0.30 \pm 0.02/\text{kg}$). Overall fitness for transport reduced the price by \$0.51

$\pm 0.01/\text{kg}$. In summary, about 30% of the cows sold at livestock markets had poor fitness for transport, which was partially influenced by increased milk demand and resulted in reduced market prices.

Key words: cull cows, livestock markets, transportation

INTRODUCTION

To maintain continuous and profitable milk production, dairy producers from Canada and the United States remove around 25 to 34% of milking cows from their herds annually (Pinedo et al., 2010; CDIC, 2019). Decisions to remove cows are driven by a combination of individual cow factors, herd factors, and the farmer's management style (Beaudeau et al., 1996, 2000; Hadley et al., 2006). Multiple cow factors, including various health conditions, may lead to culling, and many cows are removed because of health conditions such as mastitis and lameness that can affect their fitness for transport.

Economic factors also influence culling decisions. Because milk is the main product of the dairy industry, the demand for milk can influence herd management and culling decisions. In a free market system (as in the United States), both domestic supply and consumer demand influence milk price, which in turn influences herd management and culling decisions (Rogers et al., 1988; Hadley et al., 2006). In contrast, the supply management system used in Canada provides a stable milk price (Muirhead, 2014), but increased consumer demand leads to an increase in the production quota (set for each farm), which can influence herd management and culling decisions.

Cows removed from dairy herds are commonly transported to and sold through livestock markets. The condition of cows at livestock markets varies widely, with some cows showing severe lameness, emaciation, mastitis, visible signs of sickness and other quality defects (Ahola et al., 2011; Moorman et al., 2018). These conditions affect the price paid for cows (Moorman et al., 2018), and some dairy cows in very poor condition remain unsold (Ahola et al., 2011). While at livestock

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markets, cows are commonly exposed to novel environments, mixed with unfamiliar animals, segregated in a sales ring, exposed to people, and may experience significant delays to slaughter (Knowles, 1999; Ferguson and Warner, 2008). These circumstances can be stressful, and the multiple social interactions can cause exhaustion and injuries (Ferguson et al., 2001), resulting in lower meat quality (Knowles, 1999; Warren et al., 2010). Because of such issues, the use of livestock markets is declining in the European Union (Knowles, 1999), but it remains common in the United States (Glaze and Chahine, 2009).

The objectives of this study were to better understand the animal health and welfare status of cows moving through the marketing system, and the factors that influence these outcomes. Specifically, this study (1) evaluated the condition of cull dairy cows sold at livestock markets in British Columbia, (2) tested how changing demand for milk influenced the cows' fitness for transport, and (3) quantified how the condition of the animals influenced the price paid.

MATERIALS AND METHODS

During 1 year (May 2017 to April 2018), 2 livestock auction markets in the Fraser Valley (British Columbia, Canada) were visited every week, on the 1 or 2 d/wk when cull dairy cows were sold. The markets were selected based on their willingness to participate in the study and because most cull cows originating in the region were sold at these markets. Livestock market owners provided verbal agreement to the collection of data before the study started. This study was completed under protocol number A16-0336, approved by the University of British Columbia Animal Care Committee.

Description of the Livestock Markets

Livestock markets are designed to house and market hundreds of animals per day. The animal holding area, which varies in size depending on market capacity, is arranged to house large numbers of animals in multiple holding pens separated by wooden or metal rails. These pens are not equipped with feed and water troughs and the flooring is usually soil, dirt, or sawdust. From here, cattle are brought to the sales area, which includes a platform for the auctioneer, a sales ring for the cattle (and for 1 or 2 employees), and an audience seating area.

Cattle arriving from farms in the lower Fraser Valley region of British Columbia were usually transported in

gooseneck trailers (trailers that have a curved projecting arm that attaches to the inside of a truck bed), whereas cattle originating from more distant regions (e.g., Vancouver Island or the British Columbia interior) were trucked in tri-axle trailers. On arrival, cattle were off-loaded via ramp from tri-axle trailers, or directly from gooseneck trailers. Once off-loaded, cattle were placed in the holding pens and mixed with other cattle (dairy and beef) from multiple farms. The stocking density was relatively high, as subjectively observed by the researcher, and it was uncommon to see cows resting in a lying position.

Most cattle arrived in the morning and spent several hours in these holding pens. Other cattle arrived the day before the auction and spent the night in the holding pens. These animals were usually marketed as "overnight stay" or "empty" animals, suggesting they were not fed during the night and had low gut content. In addition, cows staying at the livestock markets were not milked, and mixing with other cattle (dairy and beef) from multiple farms was a regular practice.

On the day of the sales, animals were moved from the holding pens by market employees who used metal rails to guide the animals to the sales ring. When a cow entered the sales ring, the entrance door was closed and the animal was thus confined to the ring, which had sawdust flooring and enough space for the animal to walk several strides. Cattle in the sales ring were accompanied by 1 or 2 employees who maintained close proximity to the animals and used plastic or wooden sticks to move the animals around the sales ring so buyers in the audience could observe the animal and bid. While in the sales ring, cows were close to the audience and subjected to a noisy environment caused in part by the auctioneer, who used a loudspeaker while marketing the cattle (range 63–93 dB; measured using a phone app; Decibel X, Sound Spectrum Analyzer & FFT, SkyPaw Co. Ltd., Hanoi, Vietnam). Once a cow was sold, the exit door was opened and the cow usually ran from the sales ring while the market employees used metal rails to guide the animal to the buyer's holding pen where it was mixed with unfamiliar animals. Cattle were then loaded via ramps to tri-axle trailers and transported either (1) to assembly yards where they were kept until full loads were assembled and the designated slaughter plant was ready to process the load, or (2) to another livestock market to be remarketed. After the sale, cattle intended for export to the United States were also locked individually in a chute so a Canadian Food Inspection Agency (CFIA)-accredited veterinarian could read their unique identification tag and prepare an export certificate.

Data Collection

One primary observer (a veterinarian) and 2 auxiliary observers (1 veterinarian and 1 provincial dairy inspector) were trained and involved in the data collection. The primary observer was present at most sales (>90%) and the other 2 observers were present periodically, either individually or accompanying the primary observer. After initial training, intra- and inter-observer reliability was assessed through live observations, photographs, and videos. Inter-observer reliability of the primary observer and the provincial dairy inspector was tested every 3 mo. Intra-observer reliability was tested every 3 mo for the primary observer and on 2 occasions for the provincial dairy inspector (midway and end of the study). The other auxiliary observer joined the study later and the inter-observer reliability was tested twice (midway and end of the study) while intra-observer reliability was tested at the end of the study. During the reliability tests, each observer scored an average of 35 cows for BCS, 25 cows for locomotion, and 28 cows for udder condition. The photographs and videos that were used for the reliability tests provided examples that were evenly distributed across all conditions, except for extreme conditions such as BCS of 1.5 and below and locomotion score of 5, where there was a single photograph or video. In total, the observers were present at 137 sales [spring (Mar–May), 28; summer (Jun–Aug), 37; fall (Sep–Nov), 39; winter (Dec–Feb), 33] and they assessed all cull dairy cows marketed in the auction ring during these sales ($n = 6,263$).

Animals were assessed only if marketed as a single cow in the sales ring not in a group of cows. The assessment included locomotion, body condition, udder condition, and certain quality defects that could affect the cow's suitability for transport. A locomotion assessment was made after cows had walked at least 4 full strides on the sawdust-covered sales ring. A 5-point locomotion score (**LS**) was used, where 1 = not lame and 5 = severely lame (Flower and Weary, 2006). A BCS was assigned using a scoring system for Holstein dairy cows (1–5 scale, 0.5-point increments), where 1 indicated severe under-conditioning (emaciated) and 5 indicated severe over-conditioning (Ferguson et al., 1994). Udder condition (**UC**) was scored using a 3-point scale, where 1 = normal milked (loose) udder, 2 = tight/engorged udder, and 3 = swollen/inflamed udder. Any apparent quality defects were recorded as notes and later coded as 1 = signs of disease/weakness including signs of pneumonia, gastrointestinal conditions (severe diarrhea), severe ocular dysplasia or cancer eye, lump jaw or retained placenta; 2 = body injuries such as bleeding, open wounds, and hobbles (a leather or plas-

tic webbed strap approximately 30 cm in length that connects the hind legs of a cow to provide stability while walking and minimize the risk of falling); 3 = abscesses; and 4 = no defects. The observers also noted the animal's breed, whether the tail had been docked, whether animals were marketed as dry cows, and the cows' weight and price (Can\$/kg; Can\$1.00 = US\$0.78 at the time of the study). Assessments included only cull dairy cows sold for immediate slaughter, not heifers and cows sold for herd replacement.

Fitness for transport of each cow was evaluated using an aggregated measure based on industry standards (NFACC, 2009; DFC-PLC, 2017; CFIA, 2019). Cows were scored as 1 (poor fitness for transport) if they had one or more of the following conditions: BCS ≤ 2 , LS ≥ 4 , udder condition ≥ 2 , or had one or more quality defects (e.g., abscess, hobbles); all others were scored as 0 (good fitness for transport).

Finally, a categorical variable labeled "milk demand" was created for each month to indicate any changes in milk production set by the Milk Marketing Board (**MMB**). In the supply-management system in Canada, each dairy farmer holds a production quota expressed as the daily quantity of butterfat in kilograms that the farmer is required to produce and is allowed to market. For example, 150 kg of butterfat could be a daily quota for a 100-cow dairy farm; this converts to 4,500 kg of butterfat in a 30-d month. The MMB sometimes demands increased production in either of 2 ways. "Additional quota allocation" is a permanent increase in the daily butterfat production of the farm. An "incentive day" requires the farm to increase its monthly butterfat production by the equivalent of one additional day of production in the month when the incentive day was assigned. Incentive days apply only to the assigned month. Milk demand was recorded as 1 when the MMB increased the demand for butterfat production using 1 incentive day (as occurred in May and June 2017); 2 when demand was increased by >1 incentive day, or additional quota allocation (as occurred in July to December 2017), or both; or 0 if demand did not change (January to April 2018).

Statistical Analyses

The FREQ procedure in SAS (version 9.3, SAS Institute Inc., Cary, NC) was used to compute the prevalence of different conditions in cull dairy cows sold at the markets.

The intra- and inter-observer reliability for BCS, LS, and udder condition was tested by calculating linear weighted kappa coefficients (**K_w**) and interpreted as follows: 0.0–0.20 = slight; 0.21–0.40 = fair; 0.41–0.60 =

moderate; 0.61–0.80 = substantial; and 0.81–1 = excellent agreement (Landis and Koch, 1977). Pairwise inter-observer reliability was calculated where the scores of the primary observer were compared with those of the 2 auxiliary observers.

Logistic regression was used to test the effects of each month of the year and the monthly milk demand score on cows' fitness for transport. Because milk demand was highly correlated with month, the final model included only the month of the year when cows were sold; January 2018 (the first month with demand of 0) was used as a reference month for comparison. Contrasts were set to further test the differences in cows' fitness for transport between months with and without additional demand (i.e., comparing milk demand of 1 vs. 0 and 2 vs. 0).

The effect of the animals' condition (BCS, LS, udder condition, quality defects, and weight) on sale price was tested using a linear mixed-effect model that included all animal-based measures as explanatory variables. To account for any effect of the day of sale on the price, "day of sale" was included as a random effect. To avoid having a small number of observations in some categories and to retain good resolution of the outcome measures, BCS scores were reduced to 5 categories, where $BCS \leq 2$ included the scores 1, 1.5, and 2, and $BCS \geq 4.5$ combined as 4.5 and 5. Similarly for locomotion scores, LS of 4 and 5 were merged into one category $LS \geq 4$. Before fitting the model, correlations among the explanatory variables were calculated. Two variables, "BCS" and "weight" showed high correlation ($r = 0.65$); consequently "weight" was excluded from the final model. Body condition score remained in the final model because it is better than weight as an indicator of fat reserves in dairy cows (Wright and Russel, 1984), is a more useful on-farm tool to evaluate body condition, and showed higher correlation with the dependent variable (sale price). The effect of fitness for transport (poor or good) on price was tested with an additional linear mixed-effect model that included "day of sale" as a random effect. For a subset of 549 cows, DIM and parity were known and included in a separate linear mixed-effect model, but this analysis is not reported because DIM and parity did not influence sale price.

RESULTS

Intra-observer K_w for the primary observer ranged from 0.79 to 0.89 for BCS, from 0.77 to 0.87 for lameness, and from 0.92 to 1.00 for udder condition. The intra-observer K_w for the 2 auxiliary observers ranged from 0.82 to 0.93 for BCS, from 0.74 to 0.89 for lameness, and from 0.92 to 1.00 for udder condition. Inter-

observer K_w for the 3 assessors ranged from 0.69 to 0.82 for BCS, from 0.67 to 0.89 for lameness, and from 0.74 to 0.96 for udder condition.

Condition of Cull Dairy Cows at Livestock Markets

Of the 6,263 cows observed, most (97.7%) were of the Holstein breed with a few Jerseys (1.9%) and Ayrshires (0.4%). Mean ($\pm$ SD) BW was 654 ± 110 kg. Most cows had BCS of 2.5 (35.6%), 3 (27.6%), or 3.5 (14.6%), but 10.3% were very thin ($BCS \leq 2$) and 11.9% were scored with BCS of 4 or higher. The cows had a mean ($\pm$ SD) BCS of 2.9 ± 0.6 . Slight to severe locomotion abnormalities were observed in 59.5% of the cows; of these, 6.8% had severe lameness ($LS \geq 4$). Recently milked (loose) udder was observed in most animals (87.2%) but 9.7% had an engorged udder and 3.0% had a swollen/inflamed udder. Quality defects were observed in 6.2% of the cows; these included abscesses (2.1% of cows), signs of disease/weakness (2.0%), hobbles (0.9%), signs of pneumonia (0.3%), eye injury (0.2%), and lump jaw (0.1%). In addition, docked tails were observed in 5.0% of the cows (Appendix Table A1).

In total, 29.2% of the cows had one or more conditions that could affect fitness for transport; that is, they were thin ($BCS \leq 2$), lame ($LS \geq 4$), had engorged or inflamed udder ($UC \geq 2$), or had quality defects. Of those, 23.2% had only one of these conditions, 5.1% had 2, 0.9% had 3, and 1 cow had 4 conditions.

Among the 6,263 cows, 615 had been marked as part of a different study, and hence were easy to recognize at the livestock markets. Of these, 12 animals (2%) were observed being sold at both livestock markets on different days.

Factors Affecting Fitness for Transport

Cows removed from dairy farms in certain months (notably during summer and fall) were more likely to have poor fitness for transport ($P < 0.0001$; Figure 1). Specifically, cows removed from farms in August and September 2017 had higher odds of poor fitness for transport [odds ratio (OR) 1.8, 95% CI: 1.38–2.28, and OR 2.5, 95% CI: 1.93–3.19, respectively; $P < 0.0001$; Figure 1] than those removed in the reference month (January 2018). Similarly, cows removed from farms during October and November had higher odds of poor fitness for transport (OR 1.3, 95% CI: 1.04–1.67, and OR 1.3, 95% CI: 1.05–1.66, respectively; $P = 0.02$) compared with the reference month. Cows removed in December 2017 tended to have higher odds of poor fitness for transport (OR 1.3, 95% CI: 0.97–1.65; $P = 0.08$).

Fitness for transport of the cows removed in the months when the milk demand was increased by only 1 incentive day (demand = 1) did not differ from fitness for transport of cows removed in the months without increased demand (demand = 0). However, in months when demand was increased by >1 incentive day or by additional quota allocation (demand = 2) cows had higher odds of poor fitness for transport compared with cows removed in months without increased demand (demand = 0; OR 8.6, 95% CI: 4.02–18.22; $P < 0.0001$).

Effect of Cow Condition on Price

The price paid for the cows varied greatly depending on body condition ($F_{5,5918} = 562.9$; $P < 0.0001$). As a base comparison, cows with BCS of 3 were sold for a mean ($\pm$ SE) of Can\$1.33 $\pm$ 0.02/kg. Cows with lower BCS of 2.5 and ≤ 2 had prices reduced by Can\$0.27 $\pm$ 0.01/kg and Can\$0.63 $\pm$ 0.01/kg, respectively ($P < 0.0001$). In contrast, cows with BCS of 3.5 and 4 were sold for slightly higher prices (by \$0.07 $\pm$ 0.01/kg; $P < 0.0001$), whereas over-conditioned cows (BCS ≥ 4.5)

were sold at prices that were slightly reduced (by \$0.05 $\pm$ 0.02/kg, $P = 0.04$; Table 1).

Quality defects had the second largest influence on price ($F_{3,5918} = 243.6$; $P < 0.0001$). Cows without quality defects were sold for (mean $\pm$ SE) Can\$1.45 $\pm$ 0.01/kg (comparison base price), whereas the price was reduced by Can\$0.55 $\pm$ 0.02/kg for cows with visible signs of sickness, by Can\$0.20 $\pm$ 0.04/kg for those with injuries, and by Can\$0.27 $\pm$ 0.03/kg for those with abscesses ($P < 0.0001$; Table 1).

Prices were also associated with LS ($F_{3,5918} = 179.4$; $P < 0.0001$). Nonlame cows (LS = 1; used as comparison) were sold for a mean price of Can\$1.35 $\pm$ 0.02/kg, whereas cows with LS of 2 and 3 were discounted by Can\$0.11 $\pm$ 0.01/kg and by Can\$0.16 $\pm$ 0.01/kg, respectively, and cows with LS ≥ 4 had the highest reduction in price (Can\$0.35 $\pm$ 0.02/kg; $P < 0.0001$; Table 1).

Udder condition also influenced price ($F_{3,5918} = 66.3$; $P < 0.0001$). Cows with UC score of 1 (used as comparison) were sold for Can\$1.27 $\pm$ 0.02/kg. In comparison, cows with UC scores of 2 and 3 were sold for

Figure 1. Odds ratios (with 95% confidence limits) of poor fitness for transport of cows sold at livestock markets in British Columbia in each month from May 2017 to April 2018. Poor fitness for transport was considered when a cow had one or more of the following conditions: BCS ≤ 2 , locomotion score ≥ 4 , udder condition ≥ 2 , or had one or more quality defects. Demand for milk in each month was scored as unchanged (demand = 0), minor increase (1), or major increase (2). January 2018 was used as a reference value because it was the first month with no additional demand.

Table 1. Least squares means (LSM $\pm$ SE) from the final linear mixed-effect model indicating all factors that influenced the price of cull dairy cows ($n = 6,263$) sold at 2 livestock markets in British Columbia

Variable	Estimated price (Can\$/kg) ¹	SE	95% Confidence limits	
			Lower	Upper
BCS				
BCS ≤ 2	0.70	0.02	0.66	0.73
BCS 2.5	1.05	0.02	1.02	1.08
BCS 3	1.33	0.02	1.29	1.36
BCS 3.5	1.39	0.02	1.35	1.43
BCS 4	1.40	0.02	1.36	1.44
BCS ≥ 4.5	1.28	0.03	1.22	1.33
Locomotion score (LS)				
LS 1	1.35	0.02	1.31	1.38
LS 2	1.23	0.02	1.20	1.27
LS 3	1.18	0.02	1.15	1.22
LS ≥ 4	1.00	0.02	0.96	1.04
Quality defects				
Disease	0.89	0.02	0.84	0.94
Body injuries	1.24	0.04	1.17	1.32
Abscesses	1.18	0.03	1.12	1.23
Absence of defects	1.45	0.01	1.42	1.47
Udder condition (US) score				
UC 1	1.27	0.02	1.24	1.31
UC 2	1.22	0.02	1.18	1.26
UC 3	0.98	0.03	0.93	1.03
Udder dry	1.29	0.03	1.24	1.34

¹Can\$1.00 = US\$0.78 at the time of the study.

prices discounted by Can\$0.06 $\pm$ 0.01/kg and Can\$0.30 $\pm$ 0.02/kg, respectively ($P < 0.0001$). Dry cows were sold slightly above the price of the cows with UC 1 (+increased by Can\$0.02 $\pm$ 0.02/kg; $P = 0.4$; Table 1).

Fitness for transport influenced sale price ($F_{1,5978} = 2,473.6$; $P < 0.0001$). Compared with cows with good fitness for transport (sold for mean price of Can\$1.70 $\pm$ 0.01/kg), cows with poor fitness for transport were sold for Can\$1.19 $\pm$ 0.01/kg (reduction of Can\$0.51 $\pm$ 0.01/kg; $P < 0.0001$; Table 2).

DISCUSSION

Condition of Cull Dairy Cows at Livestock Markets

Around 10% of cull dairy cows sold at the livestock markets were very thin (BCS ≤ 2). Low body condi-

tion has not been cited as a direct reason for removing cows from dairy herds (Bascom and Young, 1998; CDIC, 2019), but BCS is highly correlated with the cow's energy (fat) reserves and BCS ≤ 2 has been linked to reduced productivity and reproductive performance (reviewed by Roche et al., 2009). Because body condition mirrors cows' feed intake and nutritional status (Burkholder, 2000), low BCS can be associated with certain health problems or with reduced feed intake due to illness, or it can indicate reduced care (reviewed by Roche et al., 2009). In all such cases, thin cows can be expected to have reduced welfare and reduced ability to withstand transport. Moreover, according to the Canadian proAction animal care standards, thin cows (BCS ≤ 2) should be given prompt attention and appropriate health care and should not be transported (DFC-PLC, 2017); however, some other programs are

Table 2. Least squares means (LSM $\pm$ SE) from the linear mixed-effect model indicating the effect of fitness for transport (poor or good) on the price of cull dairy cows ($n = 6,263$) sold at 2 livestock markets in British Columbia

Variable	Estimated price (Can\$/kg) ¹	SE	95% Confidence limits	
			Lower	Upper
Good fitness for transport	1.70	0.01	1.67	1.72
Poor fitness for transport ²	1.19	0.01	1.16	1.21

¹Can\$1.00 = US\$0.78 at the time of the study.

²Poor fitness for transport was considered when a cow had one or more of the following conditions: BCS ≤ 2 , locomotion score ≥ 4 , udder condition ≥ 2 , or had one or more quality defects.

more lenient, focusing their concern on emaciated cows (BCS <2; FARM, 2017).

Around 7% of the cows had severe lameness (LS ≥ 4). This corresponds to the percentage of cows that are removed from dairy farms in Canada because of feet and leg problems as reported by farmers (CDIC, 2019) and with the prevalence of severe lameness recorded for herds in BC (7%; von Keyserlingk et al., 2012). However, because lameness is frequently cited as a reason for culling, we might expect severe lameness to be more common among culled cows at livestock markets than those on farms. The scores recorded in this study may have underestimated the true prevalence of severe lameness at livestock markets because of the softer (sawdust) flooring versus concrete that is common on farms. In addition, the novelty of the environment combined with unfamiliar animals and handlers could distract animals and reduce limping as observed in other cases (Gentle, 2001; reviewed by Cook and Nordlund, 2009).

Lameness is a painful condition (Whay et al., 1998; Rushen et al., 2007) as is recognized by farmers and veterinarians (Leach et al., 2010; Fajt et al., 2011). Even though assessment of some painful conditions that cause lameness; for example, digital dermatitis, differs among farmers and veterinarians (Thomsen et al., 2012), lameness is considered a major animal welfare problem in the dairy industry (von Keyserlingk et al., 2009). Severe lameness influences the general mobility of cows and reduces their ability to walk through the corridors in livestock markets and climb loading ramps. Moreover, lameness leads to prolonged lying bouts and increased lying time (Chapinal et al., 2009; Ito et al., 2010; Solano et al., 2016), but livestock markets do not always provide an opportunity for cows to lie comfortably in the holding pens. Thus, there are good reasons why cows with severe lameness should not be shipped to livestock markets. According to industry guidelines, farm managers should provide these cows with proper care (DFC-PLC, 2017) and consider alternatives including euthanasia and shipping directly to slaughter (Stojkov et al., 2018).

Some cows sold at the livestock markets showed signs of udder inflammation (3%) or acute milk accumulation and engorgement (10%). Some of these cows may have had mastitis, as mastitis is often reported to be a reason for culling (CDIC, 2019). Moreover, both mild and severe mastitis are considered painful (Leslie and Petersson-Wolfe, 2012; Fitzpatrick et al., 2013). For other cows, poor udder score may reflect simple milk accumulation due to cessation of milking; this has been associated with increased udder pressure and fecal cortisol, even in cows with low milk production (around 10 kg/d; Odensten et al., 2007; Bertulat et al., 2013). Ces-

sation of milking is experienced by all cows that enter the marketing system. Because many cows remain in the system for several days before slaughter (Stojkov et al., 2018), they are at increased risk for udder engorgement and edema. Specific guidelines regarding udder health are needed that will underline the importance of drying off cows before shipping.

The journeys of cull dairy cows from farm to abattoir sometimes involve inter-provincial transport (in Canada) and often include change of ownership and shared responsibility regarding the animals' health and welfare (Stojkov et al., 2018). Farmers are aware of cows' pre-existing conditions and are required to transfer this information to others involved in this process. However, when different stakeholders evaluated fitness for transport of cull dairy cows, farmers showed the largest inconsistencies (Dahl-Pedersen et al., 2018a). Therefore, specific guidelines and training for evaluating fitness for transport should be available to all stakeholders, so they can consistently identify and manage compromised animals.

Factors Affecting Fitness for Transport

The condition of the cows at livestock markets showed a seasonal pattern, possibly related to seasonal occurrence of some diseases. In particular, cows with severe lameness were more frequently observed during summer and fall months (July to November) when the incidence of claw horn lesions is greatly increased (Sanders et al., 2009). The frequency of udder problems, emaciation, and other quality defects did not indicate seasonality.

Cull dairy cows with poor fitness for transport were more frequently observed during some summer and fall months, roughly coinciding with increased demand for milk in the province (Appendix Table A2). When the demand for milk initially increased to a score of 2 (July 2017), the number of cows sold per month declined steadily over the next few months, dropping to 409 cows in September, and 45.7% of these cows were deemed to have poor fitness for transport compared with only 22.4% 3 mo before. We speculate that this change may reflect producers retaining "cull" cows longer to meet the higher milk demand. It was only in January 2018, when demand for additional production returned to 0, that we observed a dramatic increase in the numbers of cows sold ($n = 813$) and an associated decline in cows showing poor fitness (25%), possibly reflecting producers resuming culling practices typical of the period before the increase in demand.

Data from recent years in Canada show that changes in milk production levels are closely related to culling and herd turnover rates. From 2010 to 2014, milk pro-

duction in Canada was relatively constant, increasing by only about 2 million hectoliters. During this time, culling rate was around 31% and herd turnover rate was 38%. In the following 3 yr (2015–2017), milk production increased by around 11 million hectoliters, indicating increased demand. During this period, culling and herd turnover rates declined steadily and in 2017 reached 26% and 33%, respectively (CDIC, 2019). This suggests that a substantial increase in demand, even in the Canadian supply-management system where milk production is relatively stable, can encourage farmers to delay culling and thus reduce herd removal rate. In the free-market system, herds expand by retaining cows that would otherwise be removed and culling only the more severe cases (Weigel et al., 2003; Fetrow et al., 2006; Hadley et al., 2006). The MMB should consider developing a process that would allow an increase in milk production without causing farmers to delay culling decisions and thus retain animals until their welfare is compromised.

Effect of Cows' Condition on Price

Low body condition of cull dairy cows reduced their sale price at livestock markets, with thin cows (BCS of ≤ 2) selling for a mean price of only Can\$0.70 $\pm$ 0.02/kg, averaging Can\$385 per cow (Appendix, Table A3). The extremely low prices for thin cows could be associated with health problems (e.g., pneumonia) that a buyer might take into account because they reduce the ability of cows to withstand transport and increase the risk of condemnation at the abattoir. Nonetheless, buyers were willing to buy thin cows because some slaughter plants specialize in slaughtering Holstein cows whose lean carcasses can supplement products such as ground beef, and also achieve better cut-out and price value (CanFax, 2003).

The price difference between nonlame cows and cows with some abnormal locomotion was relatively small, whereas a larger difference was observed between nonlame and severely lame cows (Can\$1.35/kg vs. Can\$1.00/kg, respectively). This suggests that severe lameness was probably associated with certain negative outcomes such as reduced mobility, increased lying time, or increased risk of condemnation, and hence had a larger effect on price. The willingness to purchase lame cows may reflect their resilience, as very few become nonambulatory during transport (González et al., 2012), and the fact that cows are required to walk only short distances in a slaughter facility. However, even short transport duration (e.g., 3 h and <130 km) can negatively affect locomotion of cull dairy cows (Dahl-Pedersen et al., 2018b). Moreover, the *Code of Practice*

for the Care and Handling of Dairy Cattle recommends that cows with severe lameness should be treated and not shipped (NFACC, 2009).

Udder engorgement had a slight effect on the price, whereas udder inflammation reduced the sale price by around Can\$0.30/kg (Table 1). Buyers purchased cows with engorged udders presumably because this condition does not imply systemic illness that could cause carcass condemnation, whereas the opposite may be true for cows with udder inflammation.

Other quality defects had a negative effect on sale price. Buyers were visibly hesitant to purchase cows with pneumonia and watery diarrhea probably because they were thin and had reduced ability to withstand transport. Abscesses (2%) reduced the price (by Can\$0.27/kg), likely because of the partial condemnation associated with abscesses.

The price paid for cull dairy cows at livestock markets may have some effect on culling decisions. The income generated from culling is relatively small and typically contributes less than 10% of the income of a dairy farm (Lehenbauer and Oltjen, 1998). In this study, we did not quantify the effect of the market price on culling and the condition of culled dairy cows. Future studies may consider quantifying the effect of the price at different regional markets on farmers' culling decisions and the condition of cull dairy cows sold at livestock markets.

CONCLUSIONS

Around 30% of the cows sold at livestock markets in British Columbia had poor fitness for transport because they were thin, severely lame, had udder engorgement or inflammation, or other quality defects. These animals were sold for lower prices, particularly if they were thin or showed visible signs of sickness. In months when demand for milk increased, cows arriving at livestock markets were more likely to be compromised, likely because culling was delayed in an effort to achieve higher production. We recommend the use of specific fitness-for-transport guidelines that will improve on-farm culling decisions, training of all stakeholders to consistently evaluate fitness for transport, and greater use of alternative options such as direct-to-slaughter, emergency slaughter and euthanasia for compromised animals.

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APPENDIX

Table A1. The distribution of animal-based measures (BCS, locomotion score, udder condition score, quality defects, fitness for transport, and tail condition) for cull dairy cows (n = 6,263) sold at 2 livestock markets in British Columbia

Measure	Frequency	Percent
BCS ¹		
BCS ≤2	645	10.3
BCS 2.5	2,226	35.6
BCS 3	1,724	27.6
BCS 3.5	910	14.6
BCS 4	578	9.3
BCS ≥4.5	165	2.6
Locomotion score (LS) ²		
LS 1	2,514	40.5
LS 2	2,121	34.2
LS 3	1,150	18.5
LS ≥4	423	6.8
Udder condition (UC) score		
UC 1	5,270	84.1
UC 2	609	9.7
UC 3	190	3.0
Udder dry	194	3.1
Quality defects		
Disease	189	3.0
Body injuries	70	1.1
Abscesses	129	2.1
Absence of defects	5,875	93.8
Fitness for transport		
Good fitness for transport	4,436	70.8
Poor fitness for transport	1,827	29.2
Tail		
Full tail	5,952	95.0
Docked tail	311	5.0

¹Body condition was not assessed for 15 cows (missing values n = 15).²Locomotion was not assessed for 55 cows (missing values n = 55).**Table A2.** Number and percentage of cows with good and poor fitness for transport sold each month at the livestock markets from May 2017 to April 2018¹

Month and year of the sale (demand ¹)	Fitness for transport				Total
	Good (no.)	Good (%)	Poor (no.)	Poor (%)	
May 2017 (1)	373	74.3	129	25.7	502
Jun 2017 (1)	377	77.6	109	22.4	486
Jul 2017 (2)	345	72.9	128	27.1	473
Aug 2017 (2)	264	62.4	159	37.6	423
Sep 2017 (2)	222	54.3	187	45.7	409
Oct 2017 (2)	408	69.0	183	31.0	591
Nov 2017 (2)	443	69.1	198	30.9	641
Dec 2017 ² (2)	281	69.9	121	30.1	402
Jan 2018 (0)	607	74.7	206	25.3	813
Feb 2018 ³ (0)	520	73.2	190	26.8	710
Mar 2018 ⁴ (0)	315	74.6	107	25.4	422
Apr 2018 ⁵ (0)	281	71.9	110	28.1	391
Total	4,436	70.8	1,827	29.2	6,263

¹Demand for milk in each month was scored as unchanged (demand = 0), minor increase (1), or major increase (2).²Missing data for 3 sales.³Missing data for 1 sale.⁴Missing data for 5 sales.⁵Missing data for 4 sales.

Table A3. Estimated price (Canadian \$; where Can\$1 = US\$0.78 at the time of the study) of cows with different scores for BCS, locomotion, udder condition, quality defects, and fitness for transport, together with the mean weight of cows in each category and the mean price per head paid for cows in each category at livestock markets

Variable	Estimated price (Can\$/kg)	Mean weight (kg)	Mean price per head (Can\$)
BCS			
BCS ≤ 2	0.70	553	385
BCS 2.5	1.05	601	631
BCS 3	1.33	661	876
BCS 3.5	1.39	723	1,007
BCS 4	1.40	785	1,098
BCS ≥ 4.5	1.28	830	1,059
Locomotion score (LS)			
LS 1	1.35	672	904
LS 2	1.23	654	807
LS 3	1.18	636	752
LS ≥ 4	1.00	590	590
Quality defects			
Absence of defects	0.89	657	587
Disease	1.24	564	701
Body injuries	1.18	618	728
Abscesses	1.45	641	928
Udder condition (UC) score			
UC 1	1.27	656	836
UC 2	1.22	612	745
UC 3	0.98	615	601
Udder dry	1.29	749	968
Fitness for transport			
Good fitness for transport	1.70	678	1,150
Poor fitness for transport	1.19	594	705