Analysis of the Relationship Between Somatic Cell Score and Functional Longevity in Canadian Dairy Cattle

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ABSTRACT

The aim of this study was to assess the level of somatic cell count (SCC) and to explore the impact of somatic cell score (SCS) on the functional longevity of Canadian dairy cattle by using a Weibull proportional hazards model. Data consisted of 1,911,428 cows from 15,970 herds sired by 7,826 sires for Holsteins, 80,977 cows in 2,036 herds from 1,153 sires for Ayrshires, and 53,114 cows in 1,372 herds from 1,758 sires for Jerseys. Functional longevity was defined as the number of days from the first calving to culling, death, or censoring. The test-day SCC was transformed to a linear score, and the resulting SCS were averaged within each lactation. The average SCS were grouped into 10 classes. The statistical model included the effects of stage of lactation; season of production; annual change in herd size; type of milk recording supervision; age at first calving; effects of milk, fat, and protein yields, calculated as within-herd-year-parity deviations; herd-year-season of calving; SCS class; and sire. The relative culling rate was calculated for animals in each SCS class after accounting for the aforementioned effects. The overall average SCC for Holsteins was 167,000 cells/mL, for Ayrshires was 155,000 cells/mL, and for the Jerseys was 212,000 cells/mL. In all breeds there were no appreciable differences in the relative risk of culling among classes of SCS breed averages (i.e., up to a SCS of 5). However, as the SCS increased beyond the breed average, the relative risk of cows being culled increased considerably. For instance, Holstein, Ayrshire, and Jersey cows with the highest classes of SCS had, respectively, a 4.95, 6.73, and 6.62 times greater risk of being culled than cows with average SCS.

Key words: functional longevity, somatic cell score, Canadian dairy breed

INTRODUCTION

Longevity is a highly desirable trait that considerably affects overall profitability in the dairy industry. With

increased longevity the mean production of the herd increases for 2 reasons: First, a greater proportion of the culling decisions are based on production, and second, the proportion of mature cows, which produce more milk than young cows, is increased (Allaire and Gibson, 1992; VanRaden and Wiggans, 1995). Longevity is determined by voluntary and involuntary culling decisions of individual farmers. In the process of making decisions on culling, the farmers or producers will take into account production, health, fertility, and other auxiliary traits such as milking speed, milking temperament, and calving ease. Culling because of poor production is generally called voluntary culling, and culling other than for production is called involuntary culling. Reduction of the rate of involuntary culling allows a higher voluntary replacement rate, which can increase the economic profit for a dairy farm.

Mastitis is one of the most complex diseases of dairy cattle and is among the most costly to the dairy industry. The widespread occurrence of the disease in dairy herds creates a considerable burden of costs to producers (Poso and Mantysaari, 1996; Carlén et al., 2005). Costs due to clinical mastitis include veterinary and treatment costs, reduced milk production during the remaining lactation period, the loss of milk that must be discarded because of antibiotic contamination, early culling, extra labor, decreased milk quality, and increased disease risk in the future.

Several reports showed that udder health problems are a major reason for culling dairy cattle (Beaudeau et al., 1995; Neerhof et al., 2000; Samoré et al., 2001). Bascom and Young (1998) reported that mastitis was the primary reason for culling 15% of the cows that were culled. Sewalem et al. (2004) showed that udder traits were the second most important traits that influenced the culling decision in Canadian dairy breeds. In Finland, Poso and Mantysaari (1996) noted that 34.8% of culling was due to udder problems. Furthermore, in Sweden udder diseases together with high SCC were the second most important reasons for culling in the year 2001, accounting for nearly 24% of culled cows (Carlén et al., 2005). De Vliegher et al. (2005) reported that udder health problems accounted for 10% of the reasons for culling heifers in their study.

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Various reports have also indicated that udder health and longevity are related traits (Beaudeau et al., 1995; Neerhof et al., 2000). Survival analysis using a Weibull proportional hazards model can offer a better fit for survival data because of its ability to properly account for censored and uncensored records. This could increase precision, accounting for differences in days of productive life among cows that survive for the same number of lactations. The model also accounts for the skewed distribution of survival. Time-dependent variables can be used for the survival analysis to accurately model the effects of environment (Ducrocq and Sölkner, 1998; Vukasinovic, 1999; Ducrocq, 2002).

Diseases related to udder health increase culling rates and replacement costs. Good udder health is thus essential for high production and longevity in dairy cows, decreasing costs and improving the quality of production, and a strategy to improve udder health is important in any breeding program. Several reports have suggested that health traits could be improved by direct selection for the trait under consideration. Presently, Scandinavian countries are the only countries with national health-recording systems, and genetic evaluations for udder health traits are included in their national breeding objectives (Rogers et al., 1998; Heringstad et al., 2000). Canada is also studying the feasibility of the national recording of health traits, including mastitis, to incorporate this information into the national breeding objective. However, Poso and Mantysaari (1996), among others, argued that direct selection for mastitis resistance is inefficient because of its low heritability. Moreover, many countries do not have a national recording system for such traits because they are often difficult and expensive to measure, and they are usually genetically antagonistic to production traits. Study of the association between SCC and longevity would benefit farmers, who could then use indirect selection decisions for improving udder health. The objective of the present study was to assess the level of SCC in Canadian dairy breeds and to explore the association of SCS on functional longevity in the Canadian Holstein, Ayrshire, and Jersey breeds.

MATERIALS AND METHODS

Data consisted of 1,911,428 cows from 15,970 herds sired by 7,826 sires for Holsteins, 80,977 cows in 2,036 herds from 1,153 sires for Ayrshires, and 53,114 cows in 1,372 herds from 1,758 sires for Jerseys. Data were obtained from lactation and test-day records extracted for the February 2006 genetic evaluation of the Holstein, Jersey, and Ayrshire breeds. All cows were required to have SCC records. Test-day SCC were transformed to SCS and averaged by lactation. Only cows

Table 1. Distribution (in percentage) of records by SCS classes for each breed.

Classes of SCS	Breed		
	Holstein	Ayrshire	Jersey
1	0.58	0.15	0.27
2	1.68	1.26	0.50
3	13.17	13.41	2.75
4	30.79	29.77	13.16
5	24.58	24.16	25.98
6	15.40	16.11	30.52
7	8.03	9.04	18.64
8	3.74	4.26	6.14
9	1.48	1.42	1.53
10	0.80	0.41	0.51

with first-parity records that had calved from 1985 to 2003 were included in the analysis. Somatic cell scores were grouped into 10 categories. The percentage of records in each class of SCS for each breed are shown in Table 1.

Length of productive life was defined in this study as time (days) from first calving to the next calving, death, or culling. Censored records represented cows being sold for dairy purposes, cows exported or leased to another herd, or cows still in the herd. A lifetime record was considered to be completed (uncensored) if the cow had received a termination code, indicating that the cow was removed for any reason. Records associated with missing sire identification, incorrect calving dates, or age at first calving outside the 18- to 40-mo range were excluded from the analysis.

The following model was used to analyze the impact of SCS on survival,

$$\lambda(t) = \lambda_{0,s}(t)\exp\{\mathbf{x}'_m(t)\boldsymbol{\beta} + \mathbf{z}'_m\mathbf{u}\},$$

where $\lambda(t)$ is the hazard of a cow, that is, her probability of being culled at time t given she is alive just before t ; $\lambda_{0,s}(t) = \lambda\rho(\lambda t)^{\rho-1}$ is the Weibull baseline hazard function with scale parameter λ and shape parameter ρ ; and t is the time in days from one calving to the next calving or the date of culling or censoring for each stratum; $\boldsymbol{\beta}$ contains the possibly time-dependent covariates affecting the hazard, with $\mathbf{x}'_m(t)$ being the corresponding design vectors and $\mathbf{u}$ being a vector of random variables with associated incidence vector $\mathbf{z}'_m(t)$.

The fixed covariates included in the model were as follows: time-dependent effect of stage of lactation in days (1 = 0 to 80; 2 = 81 to 235; 3 = more than 235 d); effect of year and season of calving (year of calving from 1985 to 2003; seasons of calving were January to March, April to June, July to September, and October to December); effect of season of production, with the same definition as season of calving; effect of the annual change

Figure 1. Effect of stage of lactation on SCC (cells/mL) for first parity in Canadian dairy breeds.

in herd size, with 3 classes (“decreasing” = for a decrease in herd size of <−5%; “nearly unchanged” = change of ≥−5% to ≤10%; and “increasing” = increasing in herd size of >10%); effect of the type of milk-recording supervision, with 3 classes (unsupervised, supervised, and unknown, i.e., records that do not fulfill the minimum criteria set by the milk-recording agency); effect of age at first calving in months; and effects of milk, fat, and protein yields. The latter effects were calculated as within herd-year-parity deviations with 3 classes for each: “low” = cows producing more than 0.4 standard deviations below the herd-year-parity average, “average” = cows producing between 0.4 standard deviations below and 0.6 standard deviations above the herd-year-parity average, and “high” = cows producing above 0.6 standard deviations of the herd-year-parity average. Ten categories of SCS were included as a covariate in the model. The term “length of productive life” refers to functional longevity, which is corrected for production.

The random effects included were the effect of herd-year-season class, which was assumed to follow a $\log\gamma$ distribution, and the genetic effect of the cow’s sire, which was assumed to follow a multivariate normal distribution with a mean of zero and variance of $A\sigma^2_s$, where σ^2_s is the variance among sires and A is the relationship matrix. Sire variances of 0.046, 0.039, and 0.040 for Holsteins, Ayrshires, and Jerseys, respectively, were used in the analyses (Sewalem et al., 2005).

The analyses, using a Weibull proportional hazards model, were performed with the Survival Kit Version 5.1 (Ducrocq and Sölkner, 1998). One baseline hazard function $\lambda_{0,s}(t)$ was defined for each lactation (the subscript 0 designates a baseline hazard, and the subscript

s relates to stratum s). Detailed descriptions of the model and survival analysis of longevity data in dairy cattle on a lactation basis were described by Ducrocq (2002) and Roxstrom et al. (2003). The overall influence of SCS on functional survival was assessed using the likelihood ratio test. The analysis was done separately by breed.

RESULTS AND DISCUSSION

Phenotypic Analysis of SCC

The overall mean SCC for Holsteins was 167,000 cells/mL, with a standard deviation of 324,000. The corresponding figure for Jerseys was 212,000 cells/mL (SD = 300,000), and for Ayrshires was 155,000 cells/mL (SD = 262,000). The observed maximum levels of SCC were 14,983,000 cells/mL for Jerseys, 7,142,000 cells/mL for Ayrshires, and 28,522,000 cells/mL for Holsteins. However, in all 3 breeds the number of animals with this level of SCC was low. The mean SCC in 2003 were 190,000 cells/mL for Holsteins, 212,000 cells/mL for Jerseys, and 170,000 cells/mL for Ayrshires. Norman et al. (2000) reported a mean SCC in the United States of 307,100 cells/mL. Caraviello et al. (2005), using US Holstein and Jersey cows with first calvings from 1990 to 2000, reported mean SCC of 200,000 to 250,000 cells/mL.

Level of SCC by Stage of Lactation

Figure 1 shows the effect of DIM on SCC for the first parity, which is inverted relative to the milk production curve for all breeds. In all breeds, the SCC was elevated

Figure 2. Seasonal variation in SCC (cells/mL) for the 3 Canadian dairy breeds.

immediately after calving. Thereafter, a sharp decline in SCC was observed. After 30 d of calving, the SCC increased steadily throughout the lactation period. De Vliegher et al. (2004) also observed an elevated level of test-day SCC.

Seasonal Variation in SCC

Figure 2 shows trends in monthly SCC for the 3 breeds. The figure provides the opportunity to observe monthly trends as well as breed differences for SCC. Trends were similar for all 3 breeds. All breeds had higher SCC in the months of July, August, and September and the lowest values during the winter and spring months. In Jerseys higher SCC were also observed in the months of May and June. Differences in SCC on season of calving suggest that temperature and humidity may contribute to seasonal differences. This situation suggests that the udder disease prevention and control programs being used by dairy producers vary greatly with season of calving. Similar seasonal differences were also observed by Norman et al. (2000) in the United States and by De Vliegher et al. (2004) in Belgium.

Relative Risk of Culling

Somatic cell scores had a highly statistically significant ($P < 0.001$) association with functional longevity in Holsteins, Ayrshires, and Jerseys. This was determined by comparing the full model (with classes of SCS) to the reduced model (without classes of SCS). The results are expressed as relative culling risk, defined as the ratio of the estimated risk of being culled under the

influence of certain environmental factors relative to the average risk (or reference risk). This is usually set to 1 for the average SCS (a score of 5). Values greater than 1 indicate a higher culling risk associated with a specific environmental factor. A relative culling risk lower than 1 indicates a low culling risk, following the approaches of Larroque and Ducrocq (2001), Caraviello et al. (2003), and Schneider et al. (2003). For example, if the relative culling risk for a given class is 2, a cow in that class has twice the risk of being culled compared with a cow in the reference class for that effect. Conversely, if the relative culling risk for a given class is 0.5, then a cow in that particular class has 50% less chance of being culled than a cow in the reference class.

Figure 3 shows the relationship between SCS and longevity in the 3 breeds. As the SCS increased, the relative risk of culling increased considerably in all breeds. Cows with a first-lactation SCS average beyond 5 were more likely to be culled than were breed-average cows with an SCS of 5. For instance, Holstein cows with SCS of 8 and 9 were, respectively, 1.49 and 2.05 more likely to be culled than those in the reference risk group. The corresponding figures for Ayrshires were 1.67 and 2.77, and for Jerseys were 1.35 and 2.26. Furthermore, Holstein cows with a SCS of 10 had a 4.95 times higher risk of being culled than cows with SCS at the reference level; for Ayrshires the risk was 6.73 times higher, and for Jerseys it was 6.62 times higher. On the other hand, Holstein cows with a first-lactation average SCS of 1 were 1.14 and 5.63 times more likely to survive than were cows in the reference group and cows with a SCS of 10, respectively. The corresponding figures for Ayrshires were 1.18 and 7.93, and for Jerseys were 1.16 and 7.68.

Figure 3. Relative risk of culling (RRC) by classes for SCS in the 3 breeds (RRC for the class of SCS of 5 was set to 1).

As shown in Figure 3, the relationship between longevity and SCS up to 7 was linear for all the breeds. However, as the SCS increased beyond 7, the relationship was somewhat nonlinear. Caraviello et al. (2005), working on US Holsteins and Jerseys, also reported that overall, cows with SCC of lactation averages greater than 700,000 cells/mL were more than 3 times as likely to be culled than the average group. For the same group of cows, the authors also reported that when culling was due to mastitis, the relative risk of culling were more than 19 times higher in Holsteins and 8 times higher in Jerseys. Samoré et al. (2001) reported that cows with test-day SCS in the highest classes had a rate of culling almost 3 times higher than test-day scores on the average level. De Vliegher et al. (2005) also reported that in Belgian dairy cows, heifers with elevated SCC were at an increased risk of being culled during first lactation. Neerhof et al. (2000) reported that for Danish Black and White dairy cows, the risk of a cow with mastitis being culled was 1.69 times greater than that of a healthy herdmate, with all other effects being the same.

Comparison of the 3 breeds relative to the reference group within each breed showed that the relative risk of culling for Ayrshire cows was higher than that for Jerseys and Holsteins. For instance, Ayrshire cows with a SCS of 10 had a 35% greater likelihood of being culled than did Holstein cows with the same score. However,

there were no differences in terms of relative risk of culling among the 3 breeds when the SCS was less than the average of 5.

CONCLUSIONS

The survival analysis showed a significant relationship between SCS and longevity of Canadian dairy breeds. However, the impact of SCS on longevity was high in cows with high SCS. In all the breeds considered, no appreciable differences in the relative risk of culling were observed among classes of mean SCS up to nearly the breed average. However, as the SCS exceeded the breed average, the relative risk of culling increased drastically, particularly for the most extreme class of SCS. These results suggest that using SCS for indirect selection for improved udder health, as is currently done in Canada, can also be expected to have a positive impact on longevity.

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