Analysis of the relationship between workability traits and functional longevity in Canadian dairy breeds

A. Sewalem,*†¹ F. Miglior,*† and G. J. Kistemaker†

*Guelph Food Research Centre, Agriculture and Agri-Food Canada, Guelph, Ontario, N1G 5C9, Canada

†Canadian Dairy Network, Guelph, Ontario, N1K 1E5, Canada

ABSTRACT

The aim of this study was to assess the effect of workability traits like milking speed and temperament on functional longevity of Canadian dairy cattle using a Weibull proportional hazards model. First-lactation data consisted of the following: 1,728,289 and 2,426,123 Holstein cows for milking temperament and milking speed, respectively, from 18,401 herds and sired by 8,248 sires; 39,618 and 60,121 Jersey cows for milking temperament and milking speed, respectively, from 1,845 herds and sired by 2,413 sires; and 54,391 and 94,847 Ayrshire cows for milking temperament and milking speed, respectively, from 1,316 herds and sired by 2,779 sires. Functional longevity was defined as the number of days from the first calving to culling, death, or censoring adjusted for production. Milking temperament and milking speed were recorded on a 1- to 5-point scale from very nervous to very calm and from very slow to very fast, respectively. The statistical model included the effects of stage of lactation; season of production; the 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; sire; and milking temperament or milking speed class. The relative culling rate was calculated for animals in each milking temperament or milking speed class after accounting for the above-mentioned effects. The study showed that there was a statistically significant association between workability traits and functional longevity. Very nervous cows were 26, 23, and 46% more likely to be culled than very calm cows in Holstein, Ayrshire, and Jersey breeds, respectively. Similarly, very slow milkers were 36, 33, and 28% more likely to be culled than average milkers in Holstein, Ayrshire, and Jersey breeds, respectively. Additionally, very fast milkers were 11, 13, and 15% more likely to be culled than average milkers in Holstein, Ayrshire, and Jersey breeds, respectively.

Producers might want to avoid consequences associated with the fast milkers such as udder health problems.

Key words: survival analysis, milking temperament, milking speed, relative risk of culling

INTRODUCTION

Longevity is a highly desirable trait that considerably affects overall profitability in the dairy industry. With increased functional longevity, the herd-average production increases because of a greater proportion of culling decisions based on production and an increased proportion of mature cows, which produce more milk than young cows (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 dairy producer 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 for reasons other than 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.

Workability traits such as milking temperament and milking speed are important traits for dairy producers. Milking temperament can be defined in terms of milking behavior, ease of handling, or aggressiveness at feeding. Milking speed is an important trait in that a cow that milks out slowly may disrupt the flow of cows through the milking parlor, whereas cows that milk out quickly require less labor in the parlor. However, very fast milking cows may be at increased risk for mastitis (Zwald et al., 2006) and have been linked to high SCS (Rupp and Boichard, 1999). Therefore, intermediate milking cows may be optimal (CDN, 2009). Moreover, several reports have shown that workability traits have been a factor for dairy cow disposal to an amount up to 2.0% (Westell et al., 1982; PATLQ, 1999; CDN, 2009). Although milking temperament and milking speed can be considered as traits of economic importance, relatively

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¹Corresponding author: Asheber.Sewalem@agr.gc.ca

little work has been done to study associations with other economically important traits such as functional longevity of Canadian dairy cattle. In Canada, temperament at the time of milking, referred to as milking temperament, and milking speed have been recorded for many years by milk recording agencies.

Survival analysis using a Weibull proportional hazards model can offer a better fit to 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 between 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 model accurately because they can account for changes in environmental effects over time (Ducrocq and Sölkner, 1998; Vukasinovic, 1999; Ducrocq, 2002). The objective of the present study was to assess the effect of workability traits such as milking temperament and milking speed on functional longevity of Canadian dairy cattle.

MATERIALS AND METHODS

First-lactation data consisted of the following: 1,728,289 and 2,426,123 Holstein cows for milking temperament and milking speed, respectively, from 18,401 herds and sired by 8,248 sires; 39,618 and 60,121 Jersey cows for milking temperament and milking speed, respectively, from 1,845 herds and sired by 2,413 sires; and 54,391 and 94,847 Ayrshire cows for milking temperament and milking speed, respectively, from 1,316 herds and sired by 2,779 sires. Those numbers include all censored animals. Data were obtained from lactation records extracted for the August 2009 genetic evaluation of the Holstein, Jersey, and Ayrshire breeds as performed by Canadian Dairy Network (Guelph, Ontario, Canada). Calving year ranged from 1993 to 2008. Within the first 6 mo in lactation, each cow was evaluated by DHI field staff at the time of milking for their milking temperament and milking speed and given a subjective score based on a 5-point linear scale (1 = very nervous, 2 = nervous, 3 = average, 4 = calm, and 5 = very calm for milking temperament; 1 = very slow, 2 = slow, 3 = average, 4 = fast, and 5 = very fast for milking speed). Scoring of milking temperament and milking speed was done only once during the first 6 mo of the first lactation.

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, exported, or leased to another herd or cows still in the herd. A lifetime record was considered to be completed (uncensored) if the cow

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 effect of milking temperament and milking speed on survival:

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

where $\lambda(t)$ is the hazard of a cow (i.e., its probability of being culled at time t given it 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 date of culling or censoring for each stratum; β contains both the time-dependent and time-independent covariates affecting the hazard, with $\mathbf{x}'_m(t)$ being the corresponding design vectors; and $\mathbf{u}$ is a vector of random variables with associated incidence vector $\mathbf{z}'_m(t)$.

The fixed effects included in the model were as follows: time-dependent effect of stage of lactation in days (stage 1 = 0–80, 2 = 81–235, 3 >235); year and season of calving (year of calving from 1985 to 2008; seasons of calving = January–March, April–June, July–September, October–December); season of production with the same definition as season of calving; annual change in herd size with 3 classes (decreasing = for a decrease in herd size of <–5%, nearly unchanged = no appreciable change $\geq -5\%$ to $\leq 10\%$, increasing = for an increase in herd size of >10%); type of milk recording supervision [unsupervised, supervised, and unknown (i.e., records that do not fulfill the minimum criteria set by the milk recording agency)]; effects of milk, fat, and protein yields, calculated as within herd-year-parity deviations with 3 classes for each (low = cows producing more than 0.4 SD below the herd-year-parity average, average = cows producing between 0.4 SD below and 0.6 SD above the herd-year-parity average, and high = cows producing above 0.6 SD of the herd-year-parity average); and age at first calving in months as time-independent effect. Categories of milking temperament and milking speed were included as a covariate in the model in 2 separate analyses for each breed. 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 that 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 mean zero and variance $\mathbf{A}\sigma^2_s$, where σ^2_s is the variance among sires and $\mathbf{A}$ is the relation-

Table 1. Overall distribution of percentage of record for each class of milking speed and milking temperament trait

Item	Class	Breed		
		Holstein	Ayrshire	Jersey
Milking temperament	Very nervous	1.22	1.47	1.08
	Nervous	9.62	11.14	7.27
	Average	49.59	42.37	45.16
	Calm	35.46	41.82	39.22
	Very calm	4.11	3.20	7.26
	Desired ¹	89.16	87.39	91.64
Milking speed	Very slow	2.11	1.12	0.94
	Slow	11.31	8.06	7.43
	Average	60.04	52.93	58.94
	Fast	24.43	35.32	30.09
	Very fast	2.11	2.56	2.60
	Desired ¹	84.47	88.25	89.03

¹Numbers in these rows indicate the proportion of records that are desirable by the producers (for milking temperament it includes classes average, calm, and very calm; for milking speed it includes classes average and fast).

ship matrix. Sire variances of 0.046, 0.039, and 0.040 for Holstein, Ayrshire, and Jersey breeds, respectively, were used in the analyses (Sewalem et al., 2005).

The analyses, using a Weibull proportional hazards model, were performed using Survival Kit Version 5.1 (Ducrocq and Sölkner, 1998). One baseline hazard function, $\lambda_{0,s}(t)$, was defined for each lactation (0 designates a baseline hazard and s relates to stratum s). The traditional analysis survival model is fitting the model with stage by lactation as a time-dependent covariate. Stage of lactation is included in the model to account for changes in culling risk within lactation (Ducrocq, 2002). The sole baseline hazard function cannot account for these changes over time. Roxström et al. (2003), however, reparameterized the model and defined the baseline hazard function on a lactation basis. The results showed a better overall fit of the model and also a reduced number of stages of lactation. A detailed description of the model and survival analysis of longevity data in dairy cattle on a lactation basis was described by Ducrocq (2002) and Roxström et al. (2003). The overall influence of milking temperament and milking speed on functional survival was assessed using the likelihood ratio test.

RESULTS AND DISCUSSION

Phenotypic Distributions

Table 1 shows that the desired milking temperament scores, which include average, calm, and very calm, were 89.2, 87.4, and 91.6% for Holstein, Ayrshire, and Jersey breeds, respectively. These figures illustrate the existence of phenotypic variation among the breeds, with the Jersey breed having a lower percentage of

cows nervous and very nervous compared with Holstein and Ayrshire breeds. Table 1 also shows the phenotypic distribution of milking speed for Holstein, Ayrshire, and Jersey breeds. Cows with milking speed categories of average and fast are considered by the producers as desirable, whereas cows with milking speed categories of very slow, slow, and very fast at milking are considered not desirable. The percentages of desired cows for milking speed were 84.5, 88.3, and 89.0% for Holstein, Ayrshire, and Jersey breeds, respectively. Thus, a variance among breeds similar to milking temperament was observed, and the Jersey breed again had the highest percentage of cows with the desired score for milking speed.

Table 2 shows the phenotypic trend of milking temperament for the last few years for Holstein, Ayrshire, and Jersey breeds. In the Holstein breed, the percentage of cows scored average, calm, and very calm slightly decreased by 1.84% from 2001 to 2008. The same pattern but with different magnitude was observed for Ayrshire and Jersey breeds as well.

Table 3 shows the phenotypic trend of milking speed for the last few years for Holstein, Ayrshire, and Jersey breeds. Cows classified as average and fast decreased by 1.58, 2.34, and 2.47% from 2001 to 2008 for Holstein, Ayrshire, and Jersey breeds, respectively. The percentage of very fast milkers increased by less than 1 percentage point in the 3 breeds. The percentage of very slow and slow milkers slightly increased over the last 8 yr in all breeds.

The slight shift in terms of percentage of milking temperament score and milking speed from desirable to undesirable for cows from average and calm to nervous and very nervous over time may be attributed to the fact that producers have realized the importance of

Table 2. Distribution of percentage of milking temperament score by year of calving

Calving year	Holstein			Ayrshire			Jersey		
	Very nervous	Nervous	Average and calm	Very nervous	Nervous	Average and calm	Very nervous	Nervous	Average and calm
≤1999 ¹	0.95	9.16	89.39	1.18	9.52	89.30	1.03	7.67	91.30
2000	0.96	7.76	91.29	1.23	8.69	90.09	0.97	5.03	94.00
2001	1.09	8.64	90.26	1.13	9.50	89.37	0.73	6.18	93.09
2002	1.35	10.11	88.54	1.57	11.51	88.92	0.94	7.11	91.94
2003	1.42	10.74	87.84	1.85	12.27	85.89	0.98	5.82	93.20
2004	1.57	10.88	87.55	1.96	15.07	82.97	1.32	7.03	91.65
2005	1.32	10.00	88.68	1.63	12.05	86.32	1.14	8.10	90.76
2006	1.48	10.12	88.40	2.10	13.09	84.80	1.45	7.08	91.47
2007	1.51	10.38	88.11	2.08	12.87	85.09	1.21	8.06	90.73
2008	1.41	10.17	88.42	2.26	13.23	84.91	1.10	7.40	91.50

¹Average of 1993–1999.

these traits and might have started paying attention in grading the cow across the different classes of scores after the implementation of genetic evaluation of these traits (1996 for milking speed and 2001 for milking temperament).

Relative Risk of Culling by Breed

A total of 74.6, 79.9, and 74.8% of the lactation records were right censored for Holstein, Jersey, and Ayrshire breeds, respectively. The mean censoring time and failure time for uncensored records after first calving in the Holstein breed was 374 and 272 d, respectively. The corresponding figures for the Jersey breed were 359 and 258 d, respectively, and for the Ayrshire breed were 374 and 260 d, respectively. In all breeds, all effects included in the model were highly significant ($P < 0.001$).

Milking speed and milking temperament had a highly statistically significant ($P < 0.001$) association with functional longevity in Holstein, Ayrshire, and Jersey breeds. This was determined by comparing the full models (with classes of milking speed or milking tem-

perament) with the reduced models (without classes of milking speed or milking temperament). The coefficient of determination of Maddala for milking speed and milking temperament in the Holstein breed were 4.24 and 4.36%, respectively. The corresponding figures in the Ayrshire breed were 3.14 and 3.24%, respectively, and in the Jersey breed were 3.36 and 3.05%, respectively. For the other effects fitted in the model, results obtained were similar to those by Sewalem et al. (2005).

The results are expressed in 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 set to 1 for the average classes of milking speed and milking temperament.

Figure 1 shows a clear linear relationship between milking temperament and longevity in Holstein, Ayrshire, and Jersey breeds. In general, in all breeds cows with classes of very nervous and nervous were at higher risk of being culled compared with the reference class. For instance, cows that were considered as very nervous

Table 3. Distribution of percentage of milking speed score by year of calving

Calving year	Holstein				Ayrshire				Jersey			
	Very slow	Slow	Average and fast	Very fast	Very slow	Slow	Average and fast	Very fast	Very slow	Slow	Average and fast	Very fast
≤1999 ¹	2.20	11.87	84.21	1.73	1.12	8.17	88.46	2.26	1.02	7.77	89.36	1.85
2000	1.66	9.43	87.34	1.57	1.08	6.60	90.35	1.95	0.77	5.59	91.49	2.14
2001	2.01	9.43	86.08	2.26	1.24	7.24	89.27	2.78	0.81	0.81	90.08	2.30
2002	2.27	9.65	84.24	2.94	1.67	7.90	87.79	2.64	0.52	6.59	89.02	3.81
2003	2.20	10.56	84.62	2.53	0.65	7.89	88.71	2.75	1.19	6.03	88.64	4.14
2004	2.43	11.04	84.17	2.36	0.75	9.34	87.50	2.41	0.88	6.05	91.97	1.10
2005	2.02	10.00	85.83	2.15	1.09	7.89	89.57	1.45	0.64	6.78	89.74	2.84
2006	2.09	10.50	85.41	2.00	1.28	8.24	89.04	1.46	1.04	6.95	87.63	4.38
2007	1.88	10.53	85.35	2.24	1.06	8.29	88.95	1.78	0.82	8.19	87.06	3.93
2008	1.87	10.32	85.76	2.06	1.34	9.05	88.01	1.60	1.61	6.89	89.02	2.78

¹Average of 1993–1999.

Figure 1. Relative risk of culling (RRC) by class for milking temperament in Holstein, Ayrshire, and Jersey breeds (RRC for class of average set to 1).

were 18, 16, and 32% more likely to be culled than the average class of milking temperament for Holstein, Ayrshire, and Jersey breeds, respectively. On the other hand, in the Holstein breed, cows that were categorized as very calm had 7 and 26% lower risk of being culled compared with the average and very nervous classes of milking temperament, respectively. The corresponding figures for the Ayrshire breed were 7 and 23%, respectively, and for the Jersey breed were 10 and 46%, respectively. The herd-year variances were 0.271, 0.690, and 0.483 for Holstein, Ayrshire, and Jersey breeds, respectively. These values were close to those estimates obtained by Sewalem et al. (2005).

Figure 2 also shows a clear relationship between milking speed and longevity in Holstein, Ayrshire, and Jersey breeds. However, the relationship was nonlinear. In general, in all breeds cows with classes of very slow and slow were at higher risk of being culled compared with the reference class (average). For instance, cows classified as very slow were 36, 33, and 28% more likely to be culled than the average class of milking speed for Holstein, Ayrshire, and Jersey breeds, respectively. Additionally, cows classified as very fast were at 11, 13, and 15% higher risk of culling compared with the average milkers in Holstein, Ayrshire, and Jersey breeds, respectively. In all breeds, cows classified as fast were

found to have longer functional longevity than the average class of milking speed. Comparison of very slow and slow milkers shows that the former were found to be at slightly higher risk of being culled in Holstein and Jersey breeds.

Milking speed has been regarded as an intermediate optimum trait, indicating that neither very slow nor very fast cows are wanted by the producers. This study confirms this consideration because selection against very slow milkers will reduce the labor costs and selection of very fast milkers will increase SCC. Several reports indicated that milking speed has been found to be associated with mastitis and high SCC (Van de Geer et al., 1988; Rupp and Boichard, 1999). Sewalem et al. (2004), working on Canadian dairy breeds, showed that udder traits were the second most important traits that influenced the culling decision of Canadian dairy breeds. In Finland, Poso and Mantysaari (1996) found that 34.8% of culling was attributed to udder problems. Furthermore, in Sweden udder diseases together with high SCC was the second most important reason for culling in the year 2001, accounting for approximately 24% of culled cows (Carlén et al., 2005). De Vliegher et al. (2005) reported that udder health problems accounted for 10% of the culling reasons for culled heifers in their study. Various reports also indicated that udder

Figure 2. Relative risk of culling (RRC) by class for milking speed in Holstein, Ayrshire, and Jersey breeds (RRC for class of average set to 1).

health and longevity are related traits (Beaudeau et al., 1995; Neerhof et al., 2000).

In Canada, national genetic evaluations of milking speed and milking temperament have been implemented since 1996 and 2001, respectively. The national selection index in Canada (Lifetime Profit Index) includes milking speed directly within the health and fertility component (CDN, 2010). Additionally, both milking temperament and milking speed are included indirectly as early predictors of herd life in the durability component of Lifetime Profit Index. In both instances, the weight within the index is positive. Thus, bulls are penalized if their daughters are more nervous or slower milkers than average or both. Moreover, the outcome of this study provided evidence to explore better prediction by including a quadratic term for milking speed.

CONCLUSIONS

The survival analysis showed that there was a significant relationship between workability traits and longevity of Canadian dairy breeds. Cows classified as very nervous and nervous were found to have shorter functional longevity compared with cows classified as average, calm, and very calm in all breeds. Very slow, slow, and very fast milkers were found to be at higher risk of being culled compared with the other cows.

Given the importance of these traits, further studies are warranted to analyze the genetic relationship of workability traits with all traits of economic importance in Canadian dairy breeds.

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