Analysis of Milk Urea Nitrogen and Lactose and Their Effect on Longevity in Canadian Dairy Cattle

F. Miglior,*†¹ A. Sewalem,*† J. Jamrozik,‡ D. M. Lefebvre,§ and R. K. Moore§

*Agriculture and Agri-Food Canada - Dairy and Swine Research and Development Centre, Sherbrooke, QC, Canada, J1M 1Z3

†Canadian Dairy Network, Guelph, ON, Canada, N1G 4T2

‡Centre for the Genetic Improvement of Livestock, University of Guelph, Guelph, ON, Canada, N1G 2W1

§Valacta, Ste-Anne-de-Bellevue, QC, Canada, H9X 3R4

ABSTRACT

The aim of this study was to assess the phenotypic level of lactose and milk urea nitrogen concentration (MUN) and the association of these traits with functional survival of Canadian dairy cattle using a Weibull proportional hazards model. A total of 1,568,952 test-day records from 283,958 multiparous Holstein cows from 4,758 herds, and 79,036 test-day records from 26,784 multiparous Ayrshire cows from 384 herds, calving from 2001 to 2004, were used for the phenotypic analysis. The overall average lactose percentage and MUN for Ayrshires were 4.49% and 12.20 mg/dL, respectively. The corresponding figures for Holsteins were 4.58% and 11.11 mg/dL. Concentration of MUN increased with parity number, whereas lactose percentage decreased in later parities. Data for survival analysis consisted of 39,536 first-lactation cows from 1,619 herds from 2,755 sires for Holsteins and 2,093 cows in 228 herds from 157 sires for Ayrshires. Test-day lactose percentage and MUN were averaged within first lactation. Average lactose percentage and MUN were grouped into 5 classes (low, medium-low, medium, medium-high, and high) based on mean and standard deviation values. 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, lactose percentage and MUN classes, and sire. The relative culling rate was calculated for animals in each class after accounting for the remaining effects included in the model. Results showed that there was a statistically significant association between lactose percentage and MUN in first lactation with functional survival in both breeds. Ayrshire cows with high and low concentration of MUN tended to be culled at a higher than average rate. Instead,

Holstein cows had a linear association, with decreasing relative risk of culling with increasing levels of MUN concentration. The relationship between lactose percentage and survival was similar across breeds, with higher risk of culling at low level of lactose, and lower risk of culling at high level of lactose percentage.

Key words: milk urea nitrogen, lactose, longevity

INTRODUCTION

Traditional milk recording by DHI organizations includes collection of milk weights and samples for each cow. Milk samples are sent to the lab for analysis of fat and protein content, and for counting of somatic cells. More recently, DHI labs also are analyzing the milk samples for MUN and for the percentage of lactose. Valacta, the DHI organization responsible for milk recording in Québec (previously known as PATLQ), has been collecting data on lactose in Québec dairy herds since 2001 and on MUN since 1997. Although data on MUN are being collected in other Canadian provinces, testing for lactose percentage in Canada is currently done exclusively by Valacta in Québec. Concentrations of MUN are measured at Canadian DHI labs by infrared technology. Infrared MUN values are calculated from prediction equations that use spectrum analyses and are an indirect measure of MUN. Wet chemistry methods, which directly measure concentration of urea nitrogen in milk samples, can also be used to measure MUN. Because of higher costs of wet chemistry analysis, infrared methodology is commonly used by DHI in Canada.

Milk urea nitrogen is a normal NPN component in milk. Urea is a major end-product of nitrogen metabolism in dairy cows. It is synthesized primarily in the liver and transported in blood to the kidney to be excreted in urine. From the blood, its concentration equilibrates rapidly with other body fluids, including milk (Gustafsson and Palmquist, 1993). Urea originates mainly from excess ammonia released from dietary protein degradation in the rumen or from deamination of amino acids in excess of requirements. Small amounts can also be derived from arginine catabolism in the

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¹Corresponding author: miglior@cdn.ca

mammary gland (Nousiainen et al., 2004). Milk urea nitrogen has been used as a noninvasive measurement to monitor the animal's protein status and the efficiency of nitrogen utilization (Moore and Varga, 1986; Broderick and Clayton, 1997; Jonker et al., 1998; Eicher et al., 1999). Several studies have been carried out to relate levels of MUN with reproductive performance. Mitchell et al. (2005) found that higher wet chemistry MUN was associated with more days open. However, they did not find any association between infrared MUN and reproduction traits. Guo et al. (2004) found small negative effects of elevated levels of MUN on conception rate within herds, but high MUN was not associated with reduced conception rates among herds. A study in the United Kingdom (Cottrill et al., 2002) found no association between bulk tank MUN and fertility, and no significant difference between the MUN concentration of the cows that became pregnant and those that did not. Concentration of MUN in Ontario herds has been shown to be heritable, but with low genetic correlations with production traits (Wood et al., 2003). Lower heritability values for MUN have been found in 2 US studies (Vallimont et al., 2003; Mitchell et al., 2005).

The level of water secretion into milk largely determines the fat and protein content of milk. The rate of water secretion is mostly determined by the rate of lactose synthesis, because lactose is the major factor responsible for the osmolality of milk. Several studies have investigated the relationship of lactose content with fertility. Francisco et al. (2003) concluded that lactose percentage seemed a good predictor of days to first and second postpartum ovulation. Buckley et al. (2003) found that higher lactose percentage was associated with increased pregnancy rate. Reksen et al. (2002) demonstrated that higher lactose percentage in first 8 wk postpartum was related to early luteal response in second-parity cows. Fat to lactose ratio has been shown to be an indicator of subclinical and clinical ketosis (Steen et al., 1996) and the most informative trait for estimation of energy balance (Reist et al., 2002). Lactose percentage has been found to be highly heritable (0.53) in Holstein cows from Michigan (Welper and Freeman, 1992).

Although there are several studies that have investigated the association of MUN and lactose with fertility, health, or energy balance traits, there are no studies in the literature that have investigated the association of MUN and lactose with longevity. Survival analysis using a Weibull proportional hazards model can offer better fit to survival data due to its ability to properly account for censored records. The model also accounts for the skewed distribution of survival data. Time-dependent variables can be used in the survival analysis to accurately model the effects of environment (Ducrocq

and Sölkner, 1998; Vukasinovic, 1999; Ducrocq, 2002). Survival analysis has been used in numerous studies to assess the effect of various traits on functional longevity (Larroque and Ducrocq, 2001; Caraviello et al., 2003; Schneider et al., 2003; Sewalem et al., 2004). Because MUN concentration and lactose percentage have been associated with fertility, health, or energy balance traits, it might be expected that they indirectly influence the longevity of cows on farms.

Objectives of this study were 1) to perform a phenotypic analysis of MUN concentration and lactose yield and percentage in multiparous Ayrshire and Holstein cows; and 2) to analyze the association of first-lactation MUN and lactose percentage with cow functional longevity in Ayrshire and Holstein cows using the proportional hazards model.

MATERIALS AND METHODS

Test-day records from 2001 to 2004 were provided by Valacta for Québec farms that included test date, milk yield, fat, protein, and lactose percentages, SCC, MUN concentration, number of milkings per day, and a flag indicating supervised/unsupervised control. The data set included all Canadian dairy breeds. However, only records from Holstein and Ayrshire breeds were kept due to the low number of observations in Quebec for other breeds. Records from DIM lower than 5 and greater than 305 d were eliminated. A total of 1,568,952 test-day records from 283,958 multiparous Holstein cows from 4,758 herds, and 79,036 test-day records from 26,784 multiparous Ayrshire cows from 384 herds, calving from 2001 to 2004, were used for the phenotypic analysis. All samples were analyzed by midinfrared spectroscopy using Fossomatic 4000 milk analyzers (Foss Electric, Hillerød, Denmark) calibrated (wavelength = 9.6 μm) weekly. Calibration samples were analyzed for anhydrous lactose by HPLC (IDF Standard 198/ISO 22662; ICAR, 2006) and for MUN by pH difference (IDF Standard 195/ISO 14637). Test-day records of MUN and lactose yield and percentage were averaged and plotted by DIM for the first 3 parities. Also, test-day records of MUN and lactose percentage were averaged by month and by year of testing for the first 3 parities.

Data were then additionally edited for inclusion in the survival analysis. Only first-lactation cows were included in the survival analysis. Cows were required to have at least 3 test days, with the first test-day record occurring before 60 DIM. Furthermore, records associated with missing sire identification, incorrect calving dates, age at first calving outside the 18 to 40 mo range, and parities greater than 1 were excluded from the analysis. The final data set for Holsteins con-

Table 1. Distribution of records in each class for milk urea nitrogen (M) and lactose percentage (L) for Holstein (n = 39,536) and Ayrshire (n = 2,093) breeds

Class name	Milk urea nitrogen (mg/dL)				Lactose (%)			
	Holstein		Ayrshire		Holstein		Ayrshire	
	Class	%	Class	%	Class	%	Class	%
Low	M < 6.39	6.8	M < 7.68	9.3	L < 4.49	7.0	L < 4.45	6.7
Medium-Low	6.39 ≤ M < 9.00	22.9	7.68 ≤ M < 10.50	30.0	4.49 ≤ L < 4.63	20.0	4.45 ≤ L < 4.57	21.9
Medium	9.00 ≤ M < 11.61	40.5	10.50 ≤ M < 13.33	36.0	4.63 ≤ L < 4.77	39.4	4.57 ≤ L < 4.70	41.5
Medium-High	11.61 ≤ M < 14.23	24.4	13.33 ≤ M < 16.16	20.1	4.77 ≤ L < 4.91	28.5	4.70 ≤ L < 4.83	23.8
High	M ≥ 14.23	5.4	M ≥ 16.16	4.6	L ≥ 4.91	5.1	L ≥ 4.83	6.1

sisted of 39,536 first-lactation cows from 1,619 herds from 2,755 sires. The corresponding figures for Ayrshires were 2,093, 228, and 157. The reduction in number of cows for this part of the analysis was due to the requirements of including only cows with at least 3 test days; with the first test-day record occurring before 60 DIM. Length of productive life was defined as time (days) from first calving to death, culling or censoring. 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 completed (uncensored) if the cow received a termination code, indicating that the cow was removed from the herd for any reason other than being sold for dairy purposes, exported, or leased to another herd.

The following model was used to analyze the effect of MUN concentration and lactose percentage on survival,

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

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

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 > 235); effect of year and season of calving (season of calving were January–March, April–June, July–September, and October–December); effect of season of production with the same definition as seasons of calving; effect of the annual change in herd size with 3 classes (decreasing = a decrease in herd size of less than –5%, nearly unchanged = no appreciable change; greater than or equal to –5% to less than or equal to 10%, and increasing = increasing in herd size of greater than 10%); effect of the type of

milk recording supervision; effect of age at first calving in months; 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 (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. Finally, average test-day MUN concentration or lactose percentage for first-parity cows were included in the model as fixed covariates, grouped into 5 classes of each based on mean and SD as shown in Table 1 [low < (mean – 1.5 SD); medium-low = (mean – 1.5 SD) to (mean – 0.5 SD); medium = (mean – 0.5 SD) to (mean + 0.5 SD); medium-high = (mean + 0.5 SD) to (mean + 1.5 SD); high > mean + 1.5 SD].

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 $A\sigma_s^2$, where σ_s^2 is the variance among sires and A is the relationship matrix. Sire variances of 0.046 and 0.0039 (Sewalem et al., 2005) were used in the analysis for Holstein and Ayrshire, respectively; the analyses were done by breed. The association of MUN concentration and lactose percentage in first-lactation cows with relative risk of culling at any time during the productive life of the cow were analyzed one at a time.

A Weibull proportional hazards model was fitted using the Survival Kit Version 5.1 (Ducrocq and Sölkner, 1998). One baseline hazard function, $\lambda_{0,s}(t)$, was defined for each lactation (subscript 0 designates a baseline hazard and subscript relates to strata). Detailed descriptions of the model and survival analysis of longevity data in dairy cattle on a lactation basis was described by Ducrocq (2002), Roxstrom et al. (2003), and Sewalem et al. (2005). The overall influence of these traits on functional survival was assessed using the likelihood ratio test. Additional analyses were performed using

Table 2. Descriptive statistics of test-day records by parity in Holstein breed

Parity	Test-day records, n	Cows, n	Milk, kg		Fat, %		Protein, %		SCC, × 1,000/mL		MUN, mg/dL		Lactose, %	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	515,245	150,614	26.9	6.4	3.83	0.68	3.30	0.32	184	573	10.73	3.34	4.69	0.18
2	393,242	128,359	31.2	9.1	3.80	0.73	3.32	0.35	248	642	11.25	3.44	4.57	0.22
3	275,239	91,201	32.8	9.8	3.81	0.74	3.28	0.35	311	740	11.27	3.45	4.52	0.24
4	176,845	59,456	33.2	10.1	3.81	0.74	3.26	0.35	368	832	11.31	3.45	4.49	0.25
5	102,566	35,233	33.0	10.0	3.81	0.74	3.23	0.35	414	915	11.35	3.45	4.46	0.26
6	54,708	18,907	32.6	10.0	3.81	0.74	3.21	0.35	455	970	11.43	3.47	4.45	0.27
7	28,103	9,907	32.1	9.9	3.80	0.73	3.20	0.35	472	967	11.43	3.50	4.43	0.27
8	13,518	4,795	31.3	9.7	3.79	0.72	3.18	0.34	506	1,119	11.44	3.51	4.42	0.27
9	5,832	2,081	30.3	9.4	3.79	0.72	3.17	0.34	493	1,068	11.71	3.64	4.42	0.28
≥10	3,654	1,332	29.1	9.1	3.77	0.70	3.15	0.34	577	1,191	11.71	3.63	4.42	0.28
Total	1,568,952	283,958 ¹	30.5	9.1	3.82	0.72	3.28	0.34	277	718	11.11	3.42	4.58	0.24

¹Number of unique cows; cows may have more than one parity.

the same model but without the effect of within-herd yield deviations.

RESULTS AND DISCUSSION

Phenotypic Analysis

Descriptive statistics of all production traits by parity are shown in Tables 2 and 3 for Holsteins and Ayrshires, respectively. Distribution of test-day records by parity was similar across breeds. Concentration of MUN increased over parities, whereas lactose percentage decreased in later parities. Average concentration of MUN in Holsteins was lower than in Ayrshires, whereas average lactose percentage in Holsteins was higher than in Ayrshires. Similar trends for lactose differences between breeds and parities were observed by Lefebvre et al. (2002). As expected, average daily milk yield was higher in Holsteins, and average fat and protein percentages were higher in Ayrshires. Average SCC in Holsteins was higher than in Ayrshires. Average Holstein lactation curves in the first 3 parities for MUN

and lactose percentage and yield are plotted in Figures 1 to 3, respectively. Average lactation curve of MUN concentration was similar to lactation curves of percentages of fat and protein: a nadir at 30 DIM and a gradual constant increase over the rest of the lactation. Average curves of lactose percentage and yield resembled the lactation curves of milk yield: a peak in the first 30 to 60 DIM and a constant decrease over the rest of the lactation. The first-parity lactose percentage curve was more persistent than later parities as has been previously observed for milk yield. Interestingly, the average lactation curves of lactose percentage were very different than other milk contents like fat and protein percentages. As for milk yield, the first-parity lactation curve of lactose yield had a lower level than curves of later parities. Patterns of average lactation curves for MUN, lactose percentage and yield of Ayrshires were very similar to curves of Holsteins (Figures 4 to 6).

Figures 7 and 8 show the average test-day MUN concentration and lactose percentage by month of testing for first-parity cows, respectively. In Holsteins, MUN

Table 3. Descriptive statistics of test-day records by parity in Ayrshire breed

Parity	Test-day records, n	Cows, n	Milk, kg		Fat, %		Protein, %		SCC, × 1,000/mL		MUN, mg/dL		Lactose, %	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	24,664	7,681	21.8	5.6	4.11	0.60	3.41	0.33	161	476	11.88	3.54	4.63	0.18
2	18,760	6,433	24.2	8.4	4.03	0.64	3.44	0.37	210	492	12.25	3.64	4.47	0.28
3	13,158	4,624	25.4	9.0	4.03	0.66	3.40	0.36	266	589	12.40	3.72	4.43	0.31
4	9,077	3,245	25.6	9.2	4.00	0.66	3.38	0.36	322	630	12.35	3.69	4.39	0.34
5	5,883	2,113	25.9	9.2	4.00	0.69	3.35	0.36	358	732	12.43	3.60	4.37	0.34
6	3,608	1,274	25.4	9.2	3.96	0.66	3.35	0.36	447	940	12.43	3.73	4.35	0.37
7	1,997	742	25.2	8.6	3.95	0.67	3.32	0.35	479	1,018	12.44	3.65	4.35	0.33
8	1,097	381	25.6	8.6	3.89	0.65	3.29	0.33	469	889	12.47	3.70	4.35	0.33
9	427	173	24.9	8.0	3.91	0.64	3.26	0.34	468	974	12.19	4.06	4.35	0.33
≥10	365	118	23.9	7.7	3.99	0.62	3.34	0.36	563	855	12.65	3.65	4.34	0.29
Total	79,036	15,121 ¹	24.0	8.2	4.04	0.64	3.40	0.35	252	606	12.20	3.64	4.49	0.30

¹Number of unique cows; cows may have more than one parity.

Figure 1. Average 305-d lactation curve for MUN concentration by parity in Holstein breed (parity 1: —; parity 2: ---; parity 3 —).

Figure 3. Average 305-d lactation curve for lactose yield by parity in Holstein breed (parity 1: —; parity 2: ---; parity 3 —).

concentration tended to be lower in winter and early summer, and higher in spring, late summer, and fall. Lactose percentage in Holsteins was lower in late summer and fall and higher in other months. Trends for Ayrshires were different in scale but similar to those for Holsteins. Patterns of trends in second and third parities (not shown) were different in scale but parallel to trends of first-parity cows. Yearly trends of average test-day MUN concentration and lactose percentage were slightly irregular but flat for both breeds and 3 parities (not shown).

In the current study the test-day average lactose percentage across parities was 4.49% for Ayrshires and 4.58% for Holsteins. A similar value (4.60%) was found by Buckley et al. (2003) in Irish Holsteins. Higher values were estimated by Sloth et al. (2003): a test-day average of 4.73% in Danish herds, composed of Holstein, Jersey, and Red Danish breeds, and by Welper and Freeman (1992): a 305-d average of 4.97% in US Holsteins. The Holstein averages of MUN concentration found in the current study were 10.73, 11.25, and 11.27 mg/dL for first, second, and third parities, respectively. Table 4 shows averages of MUN concentration in the

first 3 parities from the studies of Wood et al. (2003) and Mitchell et al. (2005). Results from this study (in Québec cows), were lower than results from the Wood et al. (2003) study that used Ontario Holstein cows calving between 1997 and 1999. The period difference and different region may be the cause of this discrepancy. Mitchell et al. (2005) found that MUN concentration was higher when analyzed via wet chemistry than when it was analyzed with infrared technology. Both sets of values from Mitchell et al. (2005) were higher than those obtained in the current study.

Relative Risk of Culling

Both MUN and lactose percentage had statistically significant association ($P < 0.001$) with functional longevity in Holsteins and Ayrshires; this was determined by comparing the full model (with classes of MUN or lactose percentage) to the reduced model (without classes of MUN or lactose percentage). The results are expressed in relative culling risk, defined as the ratio of the estimated risk of being culled under the influence

Figure 2. Average 305-d lactation curve for lactose percentage by parity in Holstein breed (parity 1: —; parity 2: ---; parity 3 —).

Figure 4. Average 305-d lactation curve for MUN concentration by parity in Ayrshire breed (parity 1: —; parity 2: ---; parity 3 —).

Figure 5. Average 305-d lactation curve for lactose percentage by parity in Ayrshire breed (parity 1: —; parity 2: ---; parity 3: —).

of certain environmental factors relative to the average risk (or reference risk), which is usually set to 1, corresponding to the respective breed average for MUN and lactose percentage. Values greater than 1 indicate higher culling risk associated with that environmental factor. Relative culling risks lower than 1 indicates lower culling risks; that is, increasing effect of environmental factor on longevity, following the approach by 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 9 shows the relationship between first-lactation MUN and longevity in Ayrshire and Holstein cows. Cows with low concentrations of MUN were found to have shorter longevity compared with the average group. For instance, Ayrshire cows with MUN concentrations less than 1.5 SD from the mean were 1.58 times more likely to be culled compared with cows with

Figure 7. Average test-day MUN concentration by month of milk testing in Holsteins (black squares) and Ayrshires (gray squares).

average MUN concentrations. The corresponding figure for Holsteins was 1.23. Relative risk of culling for MUN concentration in Ayrshires had an intermediate optimum related to longevity indicating that cows with high and low concentrations of MUN tended to be culled at a higher rate compared with the average group. On the other hand, as the MUN concentration in Holsteins increased beyond the breed average, there was a slightly decreased relative risk of culling compared with the average group. The difference in relative risk of culling between the 2 breeds might be due to the difference in mean concentration between Holsteins and Ayrshires, as shown in Tables 2 and 3.

Figure 10 shows the relationship between lactose percentage in first lactation and functional longevity in Holstein and Ayrshire cows. In both breeds, cows with low lactose percentages were at higher risk of being culled compared with cows in the reference group. On the other hand, cows with high lactose percentages were at a lower risk of being culled compared with the reference group. When lactose percentage was low, the association of lactose percentage with survival seemed larger in Ayrshires than in Holsteins. In Ayrshires,

Figure 6. Average 305-d lactation curve for lactose yield by parity in Ayrshire breed (parity 1: —; parity 2: ---; parity 3: —).

Figure 8. Average test-day lactose percentage by month of milk testing in Holsteins (black squares) and Ayrshires (gray squares).

Table 4. Test-day averages of MUN concentration in Holstein cows from previous studies

Reference	MUN, mg/dL	Parity	Country	Type of analysis
Wood et al. (2003)	12.41	First	Canada	Infrared
	12.80	Second	Canada	Infrared
	12.74	Third	Canada	Infrared
Mitchell et al. (2005)	12.62	First	US	Infrared
	13.21	Second	US	Infrared
	12.92	Third	US	Infrared
	13.91	First	US	Wet chemistry
	14.70	Second	US	Wet chemistry
	14.30	Third	US	Wet chemistry

cows with low lactose percentage were 1.64 times more likely to be culled compared with cows with average lactose percentage. The corresponding figure for Holsteins was 1.26. The impact of low lactose percentage on longevity could be an indirect effect of increased culling rate because of high SCS. Lefebvre et al. (2002) found a negative phenotypic correlation between test-day SCS and lactose percentage (-0.40). Thus, cows with a high level of SCS tended to have lower percentage of lactose, suggesting perhaps a higher rate of culling at low lactose percentage for cows with high SCS. Also, cows with udder infections may have also lower lactose percentage, because salts from affected udder cells also account for osmolality.

Three additional analyses were performed without the inclusion of within-herd yield deviations (milk; milk and protein; milk, protein, and fat yield). Results (not shown) of relative risk of culling for lactose percentage or MUN concentration were very similar to results from

models in which the effects of within-herd yield deviations were included.

The present study reveals the phenotypic differences and environmental factors that influence lactose and MUN between Ayrshire and Holstein breeds. Moreover, results showed that there was a statistically significant association between lactose percentage and MUN in the first lactation with functional survival in both breeds. Currently, both farmers and researchers are paying close attention to functional traits due to the growing trends of impaired fertility and increased health costs of animals in the dairy industry. Both fertility and health traits are important elements of genetic improvement in a herd due to the high replacement costs. Several reports have indicated that lactose percentage and MUN concentration are indicators of metabolic disorders and physiological imbalance, which in turn affect the reproductive and health status of a given animal. The significant association found in this study between functional longevity with MUN and lactose in first lactation is likely indirect, because both traits have been found to directly affect the health and fertility status of cows, and indirectly, their longevity on farms. Hence, quantifying the genetic component of these traits and also studying the direct genetic association between these traits and production, fertility, or disease incidence such as reproductive problems and metabolic disorders would be of major interest in future research.

CONCLUSIONS

The average concentration of MUN in Holsteins was lower than in Ayrshires, whereas average lactose per-

Figure 9. Relative risk of culling by class of MUN concentration in Holsteins (black bars) and Ayrshires (gray bars); average class set to 1.

Figure 10. Relative risk of culling by class of lactose percentage in Holsteins (black bars) and Ayrshires (gray bars); average class set to 1.

centage in Holsteins was higher than in Ayrshires. In both breeds, concentration of MUN increased over parities, whereas lactose percentage decreased in later parities. The survival analysis showed that there was a significant association between lactose percentage and MUN concentration in first lactation and longevity in Canadian dairy breeds. Relative risk of culling for MUN concentration in Ayrshires had an intermediate optimum related to longevity, indicating that cows with high and low MUN concentrations and lactose percentages tended to be culled at a higher rate compared with the average group. Holstein cows showed instead a linear association, with decreasing relative risk of culling with increasing levels of MUN concentration. The relationship between lactose percentage and survival was similar across breeds, with a higher risk of culling at low level of lactose, and lower risk of culling at high level of lactose percentage.

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