J. Dairy Sci. 97:2135–2144
http://dx.doi.org/10.3168/jds.2013-7158

Association between somatic cell count during the first lactation and the cumulative milk yield of cows in Irish dairy herds

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ABSTRACT

Reduced potential milk yield is an important component of mastitis costs in dairy cows. The first aim of this study was to assess associations between somatic cell count (SCC) during the first lactation, and cumulative milk yield over the first lactation and subsequent lifetime of cows in Irish dairy herds. The second aim was to assess the association between SCC at 5 to 30 d in milk during parity 1 (SCC1), and SCC over the entire first lactation for cows in Irish dairy herds. The data set studied included records from 51,483 cows in 5,900 herds. Somatic cell count throughout the first lactation was summarized using the geometric mean and variance of SCC. Data were analyzed using linear models that included random effects to account for the lack of independence between observations, and herd-level variation in coefficients. Models were developed in a Bayesian framework and parameters were estimated from 10,000 Markov chain Monte Carlo simulations. The final models were a good fit to the data. A 1-unit increase in mean natural logarithm SCC over the first lactation was associated with a median decrease in first lactation and lifetime milk yield of 135 and 1,663 kg, respectively. A 1-unit increase in the variance of natural logarithm SCC over the first lactation was associated with a median decrease in lifetime milk yield of 719 kg. To demonstrate the context of lifetime milk yield results, microsimulation was used to model the trajectory of individual cows and evaluate the expected outcomes for particular changes in herd-level geometric mean SCC over the first lactation. A 75% certainty of savings of at least €199/heifer in the herd was detected if herd-level geometric mean SCC over the first lactation was reduced from ≥120,000 to ≤72,000 cells/mL. The association between SCC1 and SCC over the remainder of the first lactation was highly herd dependent, indicating that control measures for heifer mastitis should be preferentially targeted on an individual-herd basis toward either the pre- and peripartum period, or the lactating period, to optimize the lifetime milk yield of dairy cows.
Key words: dairy heifer, somatic cell count, cumulative milk yield

INTRODUCTION

Increased SCC between 5 and 30 DIM during parity 1 (**SCC1**) has been reported to have a negative effect on both cumulative milk yield and risk of disposal for cows in Irish dairy herds (Archer et al., 2013a,b). Early-lactation SCC in heifers is considered a reflection of the adequacy of control measures during the pre- and peripartum (**ppp**) period (De Vliegher et al., 2012), and improving management for ppp heifers to reduce the prevalence of cows with SCC1 ≥400,000 cells/mL would be expected to have an economically important impact on lifetime milk yield (**LiMY**; Archer et al., 2013a). In Belgian and Dutch heifers, increased SCC early in the first lactation has been associated with increased SCC at subsequent test days throughout the first lactation (De Vliegher et al., 2004; Santman-Berends et al., 2012). For cows that survive, SCC beyond early lactation, therefore, gives information on the legacy of IMI from the ppp period, as well as IMI originating while heifers are in milk. A negative relationship between geometric mean first-lactation SCC and cumulative first-lactation milk yield (**FLMY**) has been reported (Raubertas and Shook, 1982; Hortet and Seegers, 1998). However, to our knowledge, no studies have investigated the association between numeric summaries of SCC throughout the entire first lactation and cumulative milk yield beyond the first lactation. Furthermore, the association between SCC1 and SCC throughout the entire first lactation has not been investigated for cows in Irish dairy herds. These relationships will help understand the relative importance of the ppp and lactating period for the control of heifer mastitis.

The aims of this study were 2-fold: first, to investigate associations between SCC throughout the first lactation and cumulative milk yield over the first lactation

Received June 19, 2013.
Accepted December 4, 2013.
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and the subsequent lifetime of cows in Irish dairy herds. Microsimulation was then used to show the financial impact of herd-level reductions in the prevalence of cows with high SCC during the first lactation in terms of LiMY. The second aim was to assess the association between SCC at 5 to 30 DIM during the first lactation and SCC throughout the entire first lactation of cows in Irish dairy herds.

MATERIALS AND METHODS

Data Selection

Data were provided by the Irish Cattle Breeding Federation (Bandon, Co. Cork, Ireland), and 51,483 cows in 5,900 herds were selected. Selection criteria were ≥2 SCC recordings during parity 1 (the first at 5 to 30 DIM between January 2005 and March 2007), and age at first calving (**AFC**) ≥700 d (to remove 6% of heifers with increased risk of culling due to dystocia; Berry and Cromie, 2009). The median number of heifers included per herd was 7 (range of 1 to 98). Cumulative milk yields for all lactations up to July 25, 2012, were calculated using a recognized method (Olori et al., 1999). Lactation milk yields were summed for each cow to give an estimate of LiMY from the date of first calving to the end of the study period. Descriptive statistics were calculated for cows in a subset of 5,413 herds (with ≥2 eligible cows/herd) that was split into quartiles based on herd-level geometric mean first-lactation SCC (**herd_gSCC_p1**; quartile 1: <72,000 cells/mL; quartile 2: 72,000 to 93,000 cells/mL; quartile 3: 94,000 to 119,000 cells/mL; quartile 4: ≥120,000 cells/mL). Descriptive statistics included number of cows, first-lactation SCC parameters, proportion of cows with SCC1 ≥400,000 cells/mL, number of recordings in the first lactation, proportion of cows surviving up to the fourth lactation, and first-lactation and LiMY.

First-Lactation SCC and Cumulative Milk Yield

Statistical Analysis. First-lactation SCC was summarized by its geometric mean and variance, which were positively associated. For comparison, the outcomes of interest (y_{ij}) were (1) FLMY or (2) LiMY for the ith cow in the jth herd. Random effects models were developed that took the form

$$y_{ij} = \alpha + \mathbf{X_{ij}}\boldsymbol{\beta_1} + \mathbf{X_j}\boldsymbol{\beta_2} + u_j + e_{ij},$$

$$u_j \sim \text{Normal}\left(0, \sigma_u^2\right),$$

$$e_{ij} \sim \text{Normal}\left(0, \sigma_e^2\right),$$

where α = intercept value, $\mathbf{X_{ij}}$ = matrix of exposure variables for each cow, $\boldsymbol{\beta_1}$ = vector of coefficients for $\mathbf{X_{ij}}$, $\mathbf{X_j}$ = matrix of exposure variables for each herd, $\boldsymbol{\beta_2}$ = vector of coefficients for $\mathbf{X_j}$, u_j = a random effect to account for residual variation between herds (assumed to be normally distributed, with mean = 0 and variance = σ_u^2), and e_{ij} = residual level 1 error (assumed to be normally distributed, with mean = 0 and variance = σ_e^2). The geometric mean and variance of first-lactation SCC, SCC1, and AFC were investigated for inclusion as polynomial terms (to powers of 5) on a natural logarithmic scale to account for nonlinear associations with cumulative milk yield. Month and year of first calving were investigated for inclusion as linear or categorical terms. Biologically plausible interactions and herd-level random slopes (herd × fixed effect interactions) were assessed. To facilitate posterior predictions from the models that incorporated all uncertainty in parameters, the models for FLMY and LiMY were developed in a Bayesian framework using WinBUGS 1.4.3 software (Lunn et al., 2000). This approach required initial values for covariates to run a Markov chain Monte Carlo (**MCMC**) procedure and these were generated in MLwiN software (Rasbash et al., 2012), using the iterative generalized least squares procedure (Goldstein, 2003). Parameters were estimated from 10,000 MCMC simulations, following a burn-in of 1,000 simulations, during which time chain convergence occurred, determined by visual inspection of 3 chains to ensure that a stationary distribution had been reached (Gilks et al., 1996). Vague prior distributions were used for the random effect variances σ_u^{-2} ~Gamma (0.001, 0.001), σ_e^{-2} ~Gamma (0.001, 0.001), and $\boldsymbol{\beta}$ ~Normal (0, 10^6), to give major influence to the data in the estimation of parameters (Green et al., 2004). Distributions of covariates and interaction terms were inspected; these remained in the model based on biological plausibility and if the 95% Bayesian credible interval (**BCI**) excluded 0. Sensitivity of the results to prior distributions for the herd-level random effect variance (Spiegelhalter et al., 2004) was evaluated by repeating simulations using the prior σ_u^2 ~Uniform (10^{-9}, 10^9).

Model Checking. Fixed and random effects were used to predict cow FLMY and LiMY ($y.pred_{ij}$); thus,

$$y.pred_{ij} \sim P(y.pred_{ij}|\boldsymbol{\beta}, \text{data}, u_j),$$

where $y.pred_{ij}$ are posterior predictions of cumulative milk yield for the ith cow in the jth herd, $\boldsymbol{\beta}$ is the vector of model coefficient distributions, and u_j is the random effect for the jth herd. Predicted and observed mean FLMY and LiMY were calculated at the cow level for quartiles of cows categorized by geometric mean of first-lactation SCC (quartile 1: <55,000 cells/