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Short communication: Increased somatic cell count is associated with milk loss and reduced feed efficiency in lactating dairy cows

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ABSTRACT

The objective was to evaluate the relationship of somatic cell count (SCC; cells/mL) with milk yield, energy-corrected milk yield (ECM; kg/d), dry matter intake (DMI; kg/d), feed efficiency for milk (FE_{MY}; kg of milk/kg of DMI), and feed efficiency for ECM (FE_{ECM}; kg of ECM/kg of DMI) in lactating dairy cows. We analyzed an SCC database consisting of 7 experiments, which were conducted at The Pennsylvania State University's Dairy Teaching and Research Center between 2009 and 2015. The experiments included in the SCC database were randomized block designs and investigated dietary effects on cow performance over 6 to 11 wk. Each experiment took repeated measurements of SCC, milk yield, milk composition, and DMI. After exclusion of records from cows without lactation number, days in milk, and only 1 measurement, the database comprised 1,094 observations of 254 cows for estimating the effect of SCC on milk yield, DMI, and FE_{MY} and 1,079 observations of 250 cows for estimating the effect of SCC on ECM and FE_{ECM}. Data were analyzed in R using a linear mixed model with natural logarithm of SCC, lactation number (1, 2, and $\geq$3), days in milk, and the interactions of the linear predictors as fixed effects and cow within block and experiment as random effect. Natural logarithm of SCC was negatively correlated with milk yield, ECM, DMI, FE_{MY}, and FE_{ECM}. Our results suggest that a cow with relatively high SCC (250,000 cells/mL) compared with a cow with a relatively low SCC (50,000 cells/mL) produces, on average, 1.6 kg/d less milk, consumes 0.3 kg/d less DMI, produces 0.04 kg less milk per kg of DMI, and produces 0.03 less ECM per kg of DMI. The observed decrease of feed efficiency with increased SCC adds to previously known economic losses and environmental impacts associated with mastitis, which should provide a further incentive to control mastitis in dairy cows.

Key words: somatic cell count, milk loss, dry matter intake, feed efficiency

Short Communication

Mastitis is defined as inflammation of the mammary gland due to bacterial infection. It has detrimental effects beyond causing pain and reduced cow welfare (Leslie and Petersson-Wolfe, 2012), including productive losses, increased costs, and reduced returns. Milk losses from mastitis can vary depending on a cow's DIM at the time of infection, previous infections (Cha et al., 2011), parity (Bartlett et al., 1991), and type of pathogen (Cha et al., 2011) and have been observed from as little as 0.24 kg/d (Hortet et al., 1999) to as much as 9.68 kg/d (Dürr et al., 2008). Whereas cost per case of mastitis can vary by the type of pathogen, Cha et al. (2011) reported that, on average, the economic impact of 1 case can be between $95 and $211 for costs of treatment, discarded milk, labor, and culturing tests. Rollin et al. (2015) estimated the average case of clinical mastitis resulted in a total economic cost of $444 ($128 in direct costs and $316 in indirect costs). Increasing prevalence of mastitis on a farm also has a negative effect on milk quality and may cause producers to lose premiums awarded for high-quality milk.

Clinical mastitis is diagnosed by a sudden onset of udder inflammation and abnormal milk, whereas subclinical mastitis often lacks these signs and can be diagnosed by increased SCC. Feed efficiency (**FE**) is broadly described as an amount of product per amount of feed input in dairy cattle with units of product varying from kilogram of milk and ECM to body tissue gain (VandeHaar et al., 2016). Maximizing FE is expected to be even more important in the future to continue to feed the rising global population with limited resources (Godfray et al., 2010). In addition, increasing FE provides a higher income over feed cost for the farmer;

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Arndt et al. (2015) reported that cows selected for high FE produced 98% more milk than cows selected for low FE with only 21% more DMI.

Feed efficiency is based largely on nutrient partitioning (Bauman et al., 1985), which is affected by the health status of the cow and can cause changes to milk yield and DMI (Ballou, 2012). When an IMI occurs, an immune response is elicited, and, depending on the pathogen, a series of local and systemic effects may occur, including a drop in DMI (Ballou, 2012). Rather than mobilizing energy to make up for the drop in DMI, nutrient partitioning changes and milk production drops (Ballou, 2012). Considering this response to infection as well as the decreased dilution of maintenance due to a lower milk yield (Bauman et al., 1985), mastitis may affect the FE of a cow. We investigated milk production, ECM, DMI, and FE losses associated with increased SCC in dairy cows. We hypothesized that increased SCC not only leads to losses in milk production, but also decreases FE, which would further increase costs of mastitis and, thus, possibly increase the incentives to control mastitis.

We analyzed an SCC database consisting of 7 experiments (Lee et al., 2011, 2012a,b; Giallongo et al., 2015; Hristov et al., 2015; Giallongo et al., 2016, 2017), which were conducted at The Pennsylvania State University's Dairy Teaching and Research Center between 2009 and 2015. The experiments were randomized block designs that investigated dietary effects on cow performance over 6 to 11 wk. In each experiment, each cow received only 1 dietary treatment. Measurements included SCC, milk yield, ECM, DMI, FE for milk (**$\mathbf{FE_{MY}}$**; kg of milk/kg of DMI), and FE for ECM (**$\mathbf{FE_{ECM}}$**; kg of ECM/kg of DMI). Observations that did not include lactation number, DIM, or at least 2 measurements per cow were excluded, resulting in a database that consisted of 1,094 observations of 254 cows (208 cows were used only in 1 experiment, 42 cows were used in 2 experiments, and 4 cows were used in 3 experiments; Table 1). As milk composition data were not available for all observations, fewer data were used to study the effect of SCC on ECM and FE_{ECM} (1,079 observations of 250 cows, of which 208 cows were used only in 1 experiment, 39 cows were used in 2 experiments, and 3 cows were used in 3 experiments). Cow within block within experiment was included as random effect because it has been shown that mastitis in 1 lactation can affect milk production in subsequent lactations (Hortet and Seegers, 1998). The statistical analyses were carried out using R statistical language (version 3.2.1, R Core Team, Vienna, Austria). The lmer function (Bates et al., 2015) was used to analyze the following linear mixed model:

$$\begin{aligned} Y_{hijk} = {} & \beta_0 + \beta_1 \times \mathrm{lnSCC} + \beta_2 \times \mathrm{lactation}_h + \beta_3 \\ & \times \mathrm{DIM} + \beta_4 \times \mathrm{lactation}_h \times \mathrm{DIM} + \beta_5 \times \mathrm{lactation}_h \\ & \times \mathrm{lnSCC} + \beta_6 \times \mathrm{lnSCC} \times \mathrm{DIM} + \beta_7 \times \mathrm{lactation}_h \\ & \times \mathrm{lnSCC} \times \mathrm{DIM} + \mathrm{cow}_i[\mathrm{block}_j(\mathrm{exp}_k)] + e_{hijk}, \end{aligned}$$

where Y_{hijk} is the response variable; β_0 is the overall mean; β_1 is the regression coefficient of the natural logarithm of SCC; lnSCC is the fixed effect of the natural logarithm of SCC; β_2 is the regression coefficient of the hth class of lactation; $\mathrm{lactation}_h$ is the fixed effect of class h of lactation (3 classes, lactation = 1, 2, and ≥ 3); β_3 is the regression coefficient of DIM; DIM is the fixed effect of the days in milk; β_4 is the regression coefficient of interaction of $\mathrm{lactation}_h$ and DIM; β_5 is the regression coefficient of interaction of $\mathrm{lactation}_h$ and lnSCC; β_6 is the regression coefficient of interaction of lnSCC and DIM; β_7 is the regression coefficient of interaction of $\mathrm{lactation}_h$, lnSCC, and DIM; $\mathrm{cow}_i[\mathrm{block}_j(\mathrm{exp}_k)]$ is the random effect of cow i (classes, i = 1 to 254) within block j (classes, block = 1 to 12) within experiment *k* (classes, experiment = 1 to 7); and e_{hijk} is the residual error. Backward selection and the likelihood ratio test were used to select the model. The following interaction terms were not retained for all response variables because they were not significant ($P > 0.05$): lactation × lnSCC × DIM, lnSCC × DIM, and lactation × lnSCC. Furthermore, the interaction of lactation × DIM was not significant ($P > 0.05$) for FE_{MY} and FE_{ECM} and, thus, was not retained in the respective models.

In the SCC database, lnSCC was negatively correlated with milk production, ECM, DMI, FE_{MY}, and FE_{ECM} (Table 2). The 95% confidence interval of predicted milk yield, ECM, DMI, FE_{MY}, and FE_{ECM} losses for SCC up to 750,000 cells/mL based on the SCC database are reported in Table 3. At SCC of 250,000 cells/mL, with referent SCC of 1, 7,400, 50,000, and 100,000 cells/mL, predicted milk loss was 4.5 to 6.2, 2.9 to 4.0, 1.3 to 1.8, and 1.1 to 1.6 kg/d, respectively. The predicted milk losses were similar to losses predicted by using the partial regression coefficients reported by Raubertas and Shock (1982) and a referent SCC of 1 cell/mL. A referent SCC of 1 cell/mL was used because the natural logarithm of zero is undefined and Raubertas and Shook (1982) did not report a referent SCC. Furthermore, our predicted losses were similar to losses predicted by Hortet and Seegers (1998), Dürr et al. (2008), and Hand et al. (2012), but not to losses reported by Halasa et al. (2009). At SCC of 250,000 cells/mL, Raubertas and Shock (1982), Hortet et al. (1999), Dürr et al. (2008), and Hand et al. (2012) predicted milk loss of 2.4 to 5.1, 0.6 to 2.8, 1.2 to 6.3, and 0.5 to