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Genetic parameters for lactose and its correlation with other milk production traits and fitness traits in pasture-based production systems

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ABSTRACT

Lactose is a major component of milk (typically around 5% of composition) that is not usually directly considered in national genetic improvement programs of dairy cattle. Daily test-day lactose yields and percentage data from pasture-based seasonal calving herds in Australia were analyzed to assess if lactose content can be used for predicting fitness traits and if an additional benefit is achieved by including lactose yield in selecting for milk yield traits. Data on lactose percentage collected from 2007 to 2014, from about 600 herds, were used to estimated genetic parameters for lactose percentage and lactose yield and correlations with other milk yield traits, somatic cell count (SCC), calving interval (CIV), and survival. Daily test-day data were analyzed using bivariate random regression models. In addition, multi-trait models were also performed mainly to assess the value of lactose to predict fitness traits. The heritability of lactose percentage (0.25 to 0.37) was higher than lactose yield (0.11 to 0.20) in the first parity. Genetically, the correlation of lactose percentage with protein percentage varied from 0.3 at the beginning of lactation to −0.24 at the end of the lactation in the first parity. Similar patterns in genetic correlations were also observed in the second and third parity. At all levels (i.e., genetic, permanent environmental, and residual), the correlation between milk yield and lactose yield was close to 1. The genetic and permanent environmental correlations between lactose percentage and SCC were stronger in the second and third parity and toward the end of the lactation (−0.35 to −0.50) when SCC levels are at their maximum. The genetic correlation between lactose percentage in the first 120 d and CIV (−0.23) was similar to correlation of CIV with protein percentage (−0.28), another component trait with the potential to predict fertility. Furthermore, the correlations of estimated breeding values of lactose percentage and estimated breeding values of traits such as survival, fertility, SCC, and angularity suggest that the value of lactose percentage as a predictor of fitness traits is weak. The results also suggest that including lactose yield as a trait into the breeding objective is of limited value due to the high positive genetic correlation between lactose yield and protein yield, the trait highly emphasized in Australia. However, recording lactose percentage as part of the routine milk recording system will enable the Australian dairy industry to respond quickly to any future changes and market signals.
Key words: lactose, fitness trait, genetic parameters and correlations

INTRODUCTION

Lactose is a major component of milk that is not directly considered in genetic improvement of dairy cattle in many countries (Geary et al., 2010). A few studies have explored whether lactose percentage can be used as a predictor of fitness traits (e.g., Reist et al., 2002; Buckley et al., 2003; Francisco et al., 2003), or as an additional yield trait to be included in the breeding objective in dairy cattle selection schemes (Sneddon et al., 2013; Berry, 2015). Reist et al. (2002) showed that the ratio of fat to lactose percentage was one of the most informative traits for precise estimation of energy balance in large dairy herds. Milk lactose concentration has been shown to be associated with resumption of luteal function in second-parity Norwegian dairy cattle (Reksen et al., 2002). In the Irish pasture-based dairy production system, Buckley et al. (2003) observed that a higher lactose percentage was associated with an increase in pregnancy rate, which means that the level of lactose could be a useful tool for identifying cows at risk of poor reproduction. Furthermore, lactose percentage has a moderate genetic correlation with SCC and can be used with SCS for genetic evaluation of udder health (Park et al., 2007; Ptak and Bieniek,

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2012). Lactose content of milk from cows with mastitis is significantly lower than that from healthy cows and thus changes in lactose content over the lactation can be used as a predictor of mastitis incidence (Park et al., 2007). Miglior et al. (2006) also found that cows with low lactose percentages were more likely to be culled than cows with a high lactose percentage, suggesting that it can potentially be used as indicator of longevity. Lactose percentage is a less variable milk component than fat or protein percentage (e.g., Miglior et al., 2007; Ptak and Bieniek, 2012); thus, any unexpected change in lactose content could be associated with negative energy balance or other conditions of poor health. This means lactose content may be a more reliable measure for monitoring the health and well-being of dairy cows.

There is also interest in the possibility of selecting for lactose yield and percentage in some dairy production systems, especially where whole milk powder (**WMP**) is a large component of the dairy manufacturing industry (Geary et al., 2010). In New Zealand, where a large part of the milk produced is exported as WMP, a large deficit is present in milk lactose that is currently filled by importing lactose (Geary et al., 2010). After reviewing milk payment systems in 7 countries including New Zealand, Sneddon et al. (2013) found some form of indirect payment system for lactose yield only in the United States and Ireland. Sneddon et al. (2013) also called for a revision of the milk payment system in New Zealand, which is currently largely based on protein and fat yield with penalty on milk volume, to one based on protein, fat, and lactose yield with a penalty on volume. Although there does not appear to have been a change to the milk payment system in New Zealand since then, the negative price for milk has been replaced by a positive payment for lactose yield in the Netherlands (CRV, 2017). In New Zealand, as a part of the effort to include lactose in the breeding objective, Sneddon et al. (2015) estimated genetic parameters for milk components including lactose using data from New Zealand herds on a lactation basis. With the exception of the work in New Zealand, most genetic parameter estimates for lactose in the literature (Welper and Freeman, 1992; Miglior et al., 2007; Ptak and Bieniek, 2012) are from herds in the Northern hemisphere, where mostly cows are kept indoors and fed TMR. Also, most of the genetic parameters that are available in literature, with few exceptions, are based on relatively small data sets using lactation data rather than test-day data.

Information on the genetic control of lactose content in Australian dairy cattle and its relationship with milk yield traits and other economic traits is lacking. It is also important to examine the genetic trend in lactose percentage as well as yield because the selection in Australia over the last 2 decades has been for increased protein and fat yield (Bowman et al., 1996), with negative economic weight on milk volume a trait highly correlated with lactose yield (e.g., Miglior et al., 2007). The main objective of this study is to estimate genetic parameters for lactose content and its relationship with milk yield traits and SCC using a random regression (**RR**) model as a first step to assess if there is merit in developing genetic evaluation for lactose yield, or content, for Australian Holstein cattle. The secondary objective is to assess if lactose content can be used as an indicator of fertility, survival, and other predicators of fitness with the view to using it as a predictor trait. To do this, test-day data of cows that included lactose percentage in the first 3 parties were used.

MATERIALS AND METHODS

Data

Data on daily milk yield traits including lactose percentage and SCC of cows that calved between 2007 and 2014 were extracted from the Australian Dairy Herd Improvement Scheme (**ADHIS**) database. First, cows that are the progeny of bulls in the AI program with at least 5 daughters were kept. From these data, cows that had at least 1 test-day lactose percentage in the first 120 d were selected. The age at first calving for the animals selected for this study varied from 18 to 36 mo. Based on these criteria, close to 98,000 cows and all their test-day milk yield data recorded between d 1 and 315 DIM from 621 herds were selected. Most of the herds that provided these data were from the Eastern Victoria Region of Australia, where pasture-based seasonal calving systems dominate. Most of the cows with lactose percentage were Holstein (75%), Jersey (10%), and their cross-breeds. The number of tests, cows and mean daily milk, mean daily lactose percentage, and mean protein percentage in the first 3 parities is presented in Table 1. From these data, cows with at least 3 test-day lactose percentage records in the first parity that were born before January 2011 (i.e., cows with opportunity to calve for the second and third time) were selected for genetic parameter estimation.

Statistical Analyses

The analyses in this study included estimation of the relationship of lactose percentage and yield with milk yield, log (natural log) SCC ($\log_e$ SCC), fat, and protein percentage in the first, second, and third parity using a RR model. All the analyses that looked at the relationship between traits used within parity data except those carried out to estimate heritability of lactose