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Lactation traits associated with short- and long-term once-daily milking performance in New Zealand crossbred dairy cattle

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ABSTRACT

The main objectives of this study were to establish the relative value of milk yields under twice-daily milking (TDM) as a predictor of yield and yield loss under once-daily milking (ODM), and to understand the role of residual milk and udder storage capacity-related traits in regulating yield and yield loss during ODM. A Holstein-Friesian × Jersey crossbred herd was established over 2 seasons (years), as 2 individual cohorts on the same farm, managed on a pasture-based system over 4 lactations. Short-term (1-wk) ODM studies, with a starting total of 690 cows, were undertaken in mid- and late-lactation in lactation 2 and in mid-lactation in lactation 3 for each cohort. A 10-wk study of ODM performance began in mid-lactation in lactation 3, whereas lactation 4 was a full-lactation assessment of ODM. In the short-term studies, milk yield under ODM was well predicted ($R^2 = 0.7$ to 0.8 in 5 of 6 studies) by the daily yield under TDM in the week before ODM. Yield loss (kg/d) increased with increasing milk yield and with increasing somatic cell count (SCC), although predictions were relatively poor ($R^2 = 0.09$ to 0.30). Yield loss (%) decreased with increasing TDM yield in 3 of the 6 studies and was positively correlated with SCC during ODM. Nevertheless, ODM yield loss, in absolute or percentage terms, was a poorly repeatable trait in grazing cows. Part of the variation in yield loss percentage (30%) was positively associated with residual milk (%), measured pretrial, during measurement of functional udder capacity in lactation 3. Total production (kg of milk) over the full-lactation ODM study in lactation 4 was correlated with total production in the 10-wk trial in lactation 3 (r = 0.72 and 0.63 for cohorts 1 and 2, respectively). Identifying the highest- and lowest-producing 10% of animals during the full lactation of ODM indicated that poor production was associated with high yields of residual milk (measured in lactation 3) and, conversely, high production was associated with low yields of residual milk, relative to the other 80% of animals. These same "high" and "low" production groups from lactation 4 had similar differences in performance in the earlier short-term studies and a larger or smaller percentage yield loss associated with the residual milk measurement. Breeding strategies for ODM may benefit, therefore, from greater emphasis on selecting for a low residual milk fraction to optimize milking performance. Nevertheless, the level of milk production under TDM is a strong phenotypic predictor of milk production under ODM.

Key words: milking frequency, residual milk, once-daily milking, udder capacity

INTRODUCTION

Dairy producers in pasture-based dairy industries, such as that found in New Zealand, sometimes choose to milk once daily, for all or part of the lactation, to capture the associated lifestyle, capital, and labor efficiencies of this strategy (Davis et al., 1999; Stelwagen et al., 2013). Milking frequency, however, modulates milk synthesis and secretion in many mammalian species, including dairy cows. The effect of milking frequency is mediated by local regulatory mechanisms within the udder that lead to increased milk output with increased milking frequency or decreased output with reduced frequency (Stelwagen, 2001; Collier et al., 2012; Wall and McFadden, 2012; Stelwagen et al., 2013). Hence, once-daily milking (ODM) results in lower milk yields per cow relative to the standard practice of twice-daily milking (TDM).

Understanding the mechanisms through which reduced milking frequency affects milk production is important for the optimization of milking management under ODM, and to establish the potential for genetic improvement of milk production during ODM. Repeatability of the percentage reduction in milk yield following the transition from TDM to ODM is poor within lactations (Carruthers et al., 1993a; Davis et al., 1998), indicating strong environmental influences (along with measurement errors) on the short-term yield loss measured during ODM. Furthermore, the utility of short-

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term (1–2 wk) ODM as a predictor of ODM performance in a full lactation has never been fully evaluated. This is unfortunate because, in physiological terms, the 2 traits are potentially quite different because the loss in milk production with the introduction of ODM has 2 phases. First, there is an acute decline in milk yield until yield stabilizes at a new, lower level. This phase is mostly reversible, at least out to 7 d of ODM in mid-lactation (Rémond and Pomiès, 2007). Second, there is a chronic effect of ODM on lactational persistency that is associated with an increased rate of loss of secretory tissue relative to TDM, as indicated by reduced total udder capacity after 10 wk of ODM (Carruthers et al., 1993a). In longer-term and full-lactation studies, it is this latter mechanism that is likely to be a significant part of the negative production response to ODM. Indeed, a decrease in lactational persistency and a shortening of lactation length is a characteristic of ODM during a full lactation in some reports (Rémond and Pomies, 2005; Clark et al., 2006; Hickson et al., 2006) although no effect on persistency was seen in a study with well-fed Holstein cows (Rémond et al., 2004). Clarification of the relationships between lactation phenotypes, such as udder capacity, and the milk production response under short- and longer-term ODM may provide insights into strategies that improve cow performance.

Significant variation also exists among cows in their milk production under ODM, which has been attributed, in part, to breed. Jersey cows appear to be more tolerant of ODM than Holstein-Friesian cows because they have a smaller milk production loss during longer-term ODM (Carruthers et al., 1993a; Clark et al., 2006). The French Montbéliarde breed has also been cited as being more tolerant of ODM than Holstein-Friesian cows (Pomiès et al., 2007). Nevertheless, regardless of breed, the need for an ODM-specific breeding program has been questioned if the proportion of the national herd under full-lactation ODM is very small (~3% of farms in New Zealand) and the absolute milk yields under ODM are highly correlated, genetically and phenotypically, with those under TDM milking (McPherson et al., 2007). Therefore, the use of traits under TDM to predict the best (and worst) performing animals under ODM requires investigation.

The phenotypic analysis in the current paper was undertaken to examine inter-relationships among short- and long-term ODM yield and yield loss. A major objective was also to establish the relative value of TDM yield as a predictor of yield loss under ODM and the role of milk and udder storage capacity-related traits in regulating yield under ODM.

The data presented below were gathered as phenotypic measures over 3 lactations in 2 cohorts of cows, in a broader study of the genetics associated with production traits of Holstein-Friesian × Jersey crossbred cows in New Zealand (Spelman et al., 2001). Analysis of parts of the ODM data set has been reported previously (Davis et al., 2006; Littlejohn et al., 2010).

MATERIALS AND METHODS

Approval for all sample collection procedures, manipulations and measurements performed on the dairy cows in the trial was granted by the Ruakura Animal Ethics Committee, Hamilton, New Zealand.

For clarity, and in summary, up to 690 dairy cows (managed in 2 cohorts a year apart) were tested on ODM in 3 short-term (7-d) milking trials (lactations 2 and 3), a 10-wk period in mid to late lactation (lactation 3), and a full lactation (lactation 4). Milk yield was measured daily, and milk fat, protein, and lactose contents and SCC measured before and during all trials (see below for specific details). Additional measurements of functional udder capacity (maximum contained milk weight) and residual milk were taken before and after the 10-wk trial.

Animals and Experimental Design

The herd consisted of a pedigree with a half-sibling, family structure (Spelman et al., 2001) based on 864 F_2 Holstein-Friesian × Jersey crossbred daughters of 6 F_1 sires. The 6 F_1 bulls were born from planned matings in 1998. The bulls were sired by 3 Jersey bulls and 3 Friesian bulls (mated to Friesian and Jersey dams, respectively) of genetic merit comparable to that of bulls entering the New Zealand progeny test scheme at that time. The establishment and study of this herd has been described previously (Spelman et al., 2001; Berry et al., 2009). Briefly, the herd was formed over 2 seasons (years) from contracted breeding of cows in commercial herds, calving in August 2000 and 2001. The 2 cohorts of animals were studied over 4 lactations following first calving at 2 yr of age. The ODM studies began in lactation 2 (Table 1) when 690 cows were available for study. The cohorts were managed on a single farm under typical New Zealand dairy farming practices, using a seasonal, pasture-based system. Calving for more than 90% of the cows in the herd was over an 8-wk period in early spring for lactations 2 and 3 and over 10 wk for lactation 4. Cows grazed perennial rye grass and white clover pasture, supplemented as needed with grass silage. Milking was undertaken in a 60-bale rotary parlor normally twice daily, with 10-h and 14-h intervals between milkings. Milk yield (kg) was recorded daily by Westfalia Metatron 21 milk meters (GEA Farm Technologies GmbH, Bönen, Germany). The timing of the ODM challenges and cow