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Associations of high and low milk protein concentrations with energy allocation, milk production, and concentrations of blood plasma metabolites and hormones in Holstein-Friesian cows

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ABSTRACT

A positive association between milk protein concentration (MPC) and reproductive performance in dairy cows has been shown in several studies globally. This association may positively influence farm productivity and profitability, particularly in seasonally calving, pasture-based herds. However, the differences in milk production and energy allocation, physical characteristics, and blood plasma nutrient status between cows with differing MPC have not been examined, and the underlying mechanisms responsible for the association remain undefined. The objective of this study was to examine associations between MPC and nutrient partitioning in primiparous Holstein-Friesian cows managed under pasture-based dairying conditions, and to identify differences that may indicate the underlying mechanisms. Data were collected from 85 cows at regular intervals during the early part of the 2013 to 2014 seasonal lactation, including daily milk yield, weekly milk composition, weekly body condition score measurements, as well as weekly blood plasma metabolite and hormone concentrations. Cows were retrospectively separated into quartiles based on their average MPC during the first 120 d of lactation, and comparisons were made between cows within the highest (high; 3.22 to 3.40%) and the lowest (low; 2.87 to 3.00%) MPC quartiles. The high-MPC cows had lower daily milk yields, yet did not differ in the daily yields of milk solids (protein + fat) compared with the low-MPC cows. After parturition, the high-MPC cows had greater blood plasma concentrations of glucose, insulin, insulin-like growth factor-1 and leptin compared with the low-MPC cows and maintained their body condition score, despite no differences in these variables prepartum. These results indicate an increased partitioning of nutrients toward milk synthesis at the expense of body condition for cows in the low MPC quartile. However, average daily energy outputs in milk were similar in the high- and low-MPC cows. The high-MPC cows calved 12 d earlier in the seasonal calving period, reflecting superior reproductive performance when cows in this quartile were 15 mo of age. These results suggest that at least part, but not all, of the reported associations between MPC and dairy cow fertility are related to nutrient status during early lactation. Further research is required to understand and use the association.
Key words: reproductive performance, energy allocation

INTRODUCTION

The well-documented decline in the fertility of dairy cattle in many countries over several decades has generally been associated with increased milk yield and an increase in the proportion of genes derived from Holstein-Friesian sires of North American origin (Buckley et al., 2003; Butler, 2003). Seasonally concentrated calving patterns found in the pasture-based dairy industries of Australia, New Zealand, and Ireland optimize pasture utilization and enhance profitability in low-cost production systems. In these systems, declining reproductive performance is exacerbated by the need to breed cows when they are at peak milk yield less than 12 wk after calving and gradually recovering from negative energy balance (**NEB**). Many herd owners have difficulty maintaining the 12-mo annual calving interval essential to seasonally concentrated calving patterns, and the cow wastage that results from culling cows that fail to conceive in time is a substantial cost (Auldist et al., 2007; Morton, 2011).

Two studies conducted mainly in Victoria, Australia, showed that one of the factors having the strongest association with the probability of conception within

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6 wk following the start of a seasonal breeding program was a cow's milk protein concentration (**MPC**; Morton, 2000, 2011). This positive association between MPC and dairy cow fertility has also been shown in New Zealand (Xu and Burton, 1996), but it is strongest in cows in the pasture-based production systems of southeastern Australia (Morton, 2000) and Ireland (Buckley et al., 2003). If the factors underpinning this association can be understood, substantial benefits may exist for the Australian dairy industry, due not only to improved reproductive performance but also to increased milk value, as each kilogram of milk protein is more than twice as valuable as each kilogram of milk fat under many milk payment systems in Australia (Downey and Doyle, 2007).

Differences in the way that cows partition energy in early lactation and the extent of postpartum NEB, when energy demands for maintenance plus lactation exceed energy intake, provide one possible explanation for the association. Postpartum NEB can reduce MPC due to a shortage of glucose for milk protein synthesis in the mammary gland (de Vries and Veerkamp, 2000). Negative energy balance is, in turn, associated with poor reproductive performance (Butler, 2003; Reist et al., 2003). However, Fahey et al. (2008) demonstrated a positive association between the reproductive performance of nonlactating heifers and their subsequent MPC in their first lactation. These animals were bred when they were around 15 mo of age, which shows that the biological determinants underpinning the association are not restricted to lactation-specific factors.

The objective of this experiment was to compare milk production variables, physical characteristics, and blood plasma concentrations of selected metabolites and hormones in primiparous Holstein-Friesian cows with either high or low MPC to gain an understanding of possible mechanisms behind the association. The hypotheses tested were (1) that the low-MPC cows would preferentially partition nutrients and energy toward milk synthesis in early lactation at the expense of BCS compared with their high MPC contemporaries, and that these partitioning differences would be reflected in plasma metabolite and hormone concentrations; (2) that the cows with high MPC would maintain a greater BCS during early lactation compared with the low-MPC cows; and (3) that milk energy output in early lactation would be greater for the low-MPC cows.

MATERIALS AND METHODS

Cows and Management

Data were collected from 85 primiparous Holstein-Friesian cows at the research farm of the Department of Economic Development, Jobs, Transport and Resources at Ellinbank, Victoria (38°14′S, 145°56′E). Cows had been reared as a single group from 12 wk of age and calved for the first time in July, August, and September 2013 (average calving date of August 1) when they were aged between 1.8 and 2.1 yr. After calving, all enrolled cows were managed as a single herd for the entire lactation and received a common nutritional and management regimen. Their pasture-based diet consisted mainly of grazed perennial ryegrass pasture, with pasture silage and hay fed in the paddock in summer and autumn. They were milked twice daily through a common dairy at approximately 0600 and 1500 h, where they received an average of 3.7 kg of DM/cow per day of grain (wheat and canola meal). All experimental procedures were approved by the Department of Economic Development, Jobs, Transport and Resources Agricultural Research and Extension Animal Ethics Committee.

Breeding Program

The seasonally concentrated breeding program during early lactation commenced on October 15, 2013, and initially involved the use of AI for 6 wk, after which time Holstein-Friesian bulls were introduced into the herd for a further 6 wk. Thirty cows were diagnosed as anestrus in late October, and were treated with a controlled internal drug-releasing device (Pfizer Australia, West Ryde, NSW, Australia) inserted vaginally for 8 d concurrently, with an injection of GnRH at device insertion (1 mL of GONAbreed, Parnell Technologies, Australia) and then an injection of $PGF_{2\alpha}$ (5 mL of Lutalyse, Pfizer Australia) at removal, followed by AI at observed heat. Conception dates were identified using rectal ultrasound pregnancy testing conducted in late January 2014.

Measurements and Analyses

Milk yield was measured at each milking using a DeLaval Alpro milk metering system (DeLaval International, Tumba, Sweden), whereas a composite milk sample (p.m. and a.m.) was taken weekly using in-line milk meters from calving until November, and then fortnightly until each cow had reached 120 DIM (the final sample for the last cow was taken in January 2014). Samples were tested for concentrations of protein, fat, and lactose using a near-infrared milk analyzer (Model 2000, Bentley Instruments, Chaska, MN), which allowed the calculation of yields of each component. Daily milk energy output and concentration for each cow was estimated by assigning protein, fat, and lactose net en-