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Genetic associations of test-day fat:protein ratio with milk yield, fertility, and udder health traits in Nordic Red cattle

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ABSTRACT

Interest is growing in finding indicator traits for the evaluation of nutritional or tissue energy status of animals directly at the individual animal level. The development and subsequent use of such traits in practice demands a clear understanding of the genetic and phenotypic associations with the various production and functional traits. In this study, the relationships during lactation between milk fat:protein ratio (FPR) and production and functional traits were estimated for Nordic Red cattle, in which published information is scarce. The objectives of this study were to estimate genetic associations of FPR with milk yield (MY), fertility, and udder health traits during different stages of lactation. Traits included in the analyses were MY, 4 fertility traits—days from calving to insemination (DFI), days open (DO), number of inseminations (NI), and nonreturn rate to 56 d (NRR)—and 2 udder health traits—test-day somatic cell score (SCS) and clinical mastitis (CM). Data were from a total of 22,422 first-lactation cows. Random regression models were used to estimate genetic parameters and associations between traits. The mean FPR in first-lactation cows was 1.28 and ranged from 1.25 to 1.45. During first lactation, the heritability of FPR ranged from 0.14 to 0.25. Genetic correlations between FPR and MY in early lactation (until 50 d in milk) were positive and ranged from 0.05 to 0.22; later in lactation, they were close to zero or negative, indicating that cows may have come out of the negative state of energy balance. The strength of genetic associations between FPR and fertility traits varied during lactation. In early lactation, correlations between FPR and the interval fertility traits DFI and DO were positive and ranged from 0.14 to 0.28. Genetic correlations between FPR and the udder health traits SCS and CM in early lactation ranged from 0.09 to 0.20. Milk fat:protein ratio is a heritable trait and easily available from routine milk-recording schemes. It can be used as a low-cost monitoring tool of poor health and fertility in the most critical phases of lactation and as an important indicator trait to improve robustness in dairy cows through selection.

Key words: milk fat:protein ratio, functional trait, genetic correlation, random regression

INTRODUCTION

Genetic improvement over the years has markedly increased milk yield (**MY**) in dairy cows. Milk yield per cow has more than doubled in the last 40 yr, and many cows now produce more than 20,000 kg of milk per lactation (Sonstegard et al., 2001; Oltenacu and Broom, 2010). This increase in production, however, is associated with reduced fertility and increased health problems (Butler and Smith, 1989; Collard et al., 2000; de Vries and Veerkamp, 2000; Oikonomou et al., 2008). In particular, during early lactation, dietary intake of cows fails to keep pace with the demand for peak milk production (Bauman and Currie, 1980), leading to negative energy balance (**NEB**), which has serious consequences on other body functions (Pryce and Veerkamp, 2001; Banos et al., 2006; Friggens et al., 2007; Løvendahl et al., 2010). Energy balance (**EB**) can be calculated as the difference between energy intake and estimated energy requirements for milk output and maintenance as a function of live weight (Buttchereit et al., 2010); a negative state of EB is detrimental to cows' health and fertility. Breeding schemes designed to improve the milk production potential of dairy cows should be accompanied by means of monitoring and safeguards to prevent the deterioration of cows' health and fertility. This calls for a low-cost and practical means of monitoring tissue EB in dairy cows, particularly during the most critical phases of lactation.

In practice, monitoring EB requires regular measurement of feed intake and other production component variables in individual cows. These are expensive to measure in large populations (Berry et al., 2003; Løvendahl et al., 2010; Thorup et al., 2012) and particularly unfeasible in commercial dairy operations. Therefore, interest exists in finding other traits that could serve as indicators of EB (Coffey et al., 2001). So far, several traits and blood biochemical compounds (metabolites)

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have been considered (Miksa et al., 2004; Konigsson et al., 2008). Body condition score is one of these measures (de Vries and Veerkamp, 2000; Pryce and Veerkamp, 2001, Veerkamp et al., 2001) and it is widely used in many species to assess body composition and energy status of animals. Body condition score is a subjective measure and interest in the trait is growing in several countries (de Vries and Veerkamp, 2000; Loker et al., 2011).

During early lactation, postpartum lipolysis results in increasing fat percentage. This is coupled with a decrease in protein percentage because of inadequate intake of fermentable energy-spending carbohydrates, resulting in insufficient protein synthesis by ruminal bacteria (Gürtler and Schweigert, 2005), which leads to the marked changes in milk component ratios that are typical of this critical phase of a cow's lactation. This biological relationship between tissue mobilization and changes in milk component ratios, particularly that of the milk fat:protein ratio (**FPR**), could be used as an indicator of a cow's tissue energy status (Heuer et al., 1999) and its susceptibility to health and fertility problems.

In contrast to other measures of EB such as blood metabolites, which are invasive, difficult, and expensive to measure, MY and milk composition data are available in almost all milk-recorded herds. The use of milk compositional data to identify between-cow variations in EB could therefore be a low-cost alternative to measuring blood metabolites or feed intake. For this, it is essential to assess the genetic associations between milk component ratios and the various fertility and udder health traits that are sensitive to tissue EB during different stages of the whole lactation.

Several studies have reported the relationships between early-lactation milk composition and changes in health and fertility associated with NEB at the phenotypic level (Von Farries, 1983; Grieve et al., 1986; Butler and Smith, 1989; Loeffler et al., 1999). Kaufmann (1979) illustrated a positive association between milk protein percentage in early lactation and fertility of cows, which may be attributed to the relationship of milk protein to energy supply. Reid and Roberts (1983) reported reduced reproductive performance in cows with fatty liver after calving, a condition associated with the generalized fat mobilization syndrome that occurs in response to energy deficit in early lactation. Grieve et al. (1986) suggested that FPR is negatively related to EB and Loeffler et al. (1999) indicated that a change in FPR and milk fat percentage during early lactation had a negative effect on conception at first insemination. Friggens et al. (2007) assessed the use of various milk composition measures to predict EB in dairy cows. They reported that a reduced model with only 6 variables, including FPR and dFPR (difference as current minus the previous value of FPR), DIM, milk fat and lactose contents, and fat:lactose ratios, explained about 94% of the variation in EB with only 0.071 MJ/d more in prediction error compared with a 25-variable model.

Recently, Buttchereit et al. (2011, 2012) reported genetic associations between FPR and EB and some health traits in German Holsteins. They estimated genetic correlations between FPR and EB and between FPR and BCS ranging from −0.5 to −0.62 and from 0.17 to 0.19, respectively, and concluded that in early lactation, FPR can be an adequate measure of EB. Jamrozik and Schaeffer (2012) considered FPR as an indicator of subclinical mastitis in first-lactation Canadian Holsteins. Nevertheless, FPR has so far received relatively little attention in genetic studies of dairy cattle and, hence, estimates of genetic parameters are generally scarce (Buttchereit et al., 2012; Jamrozik and Schaeffer, 2012). In particular, literature is lacking on estimates of genetic variation and genetic associations between FPR and udder health and fertility traits involving the Nordic Red cattle. Furthermore, most studies to date have been based on data from experimental herds, often including a small data set. Genetic analyses that used data from a routine milk recording scheme, including a large number of cows, and modeling the entire lactation are lacking. The objectives of this study were to estimate the genetic associations of test-day FPR with MY and cow fertility and udder health traits during different stages of lactation using random regression models (**RRM**).

MATERIALS AND METHODS

Data and Trait Definition

Records on test-day milk, protein, and fat yields, as well as fertility and udder health traits of first-lactation cows calving during years from 1990 to 2006 were provided by the Finnish Animal Breeders Association (Faba, Vantaa, Finland). Data used were from randomly selected herds with at least 25 cows with complete udder health and fertility records. Test-day FPR was calculated for all test-days during lactation for cows with at least 2 test-day records for fat and protein yield.

Fertility traits included were number of inseminations (**NI**) in service period, days from calving to first insemination (**DFI**), nonreturn rate to 56 d after first insemination (**NRR**), and days open (**DO**) as the number of days from calving to successful conception. In addition, the data included 2 udder health traits: test-day SCS, and clinical mastitis (**CM**). Somatic cell score was expressed as $\log_e$-transformed SCC ($\log_e$SCC)