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Metabolic Regulation in Danish Bull Calves and the Relationship to the Fertility of Their Female Offspring

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ABSTRACT

The objective of this work was to estimate the genetic variation of free fatty acids (FFA), glucose, growth hormone (GH), and insulin in juvenile male dairy calves and to assess the relationships, if present, with the fertility of their female offspring. This study used data from 1,498 (269.5 d of age ± 11.1) male calves from a multiple ovulation and embryo transfer breeding scheme (data collected from 1997 to 2002). Calves were Danish Holstein (n = 1,047), Danish Jersey (n = 200), and Red Dane (n = 251), and were sampled following an overnight fast at approximately 9 mo of age. Plasma samples were assayed for basal FFA, glucose, GH, and insulin. Estimated breeding values of female fertility (high values indicating better fertility), based on progeny-test results for approximately 100 daughters per sire, were available for a subset (n = 810) of the male calves as adult sires. Data from Danish Holstein alone or Danish Holstein, Red Dane, and Danish Jersey combined (all breeds) were analyzed for each trait. In both data sets, the estimates of heritabilities of glucose (0.27 ± 0.06), FFA (0.11 ± 0.05), and insulin (0.21 ± 0.06) were moderate, and that of GH (0.09 ± 0.05) was low. Correlations of estimated breeding values for fertility traits with glucose and FFA breeding values were negative, indicating that male calves with high glucose or FFA had female offspring with reduced fertility. Selection for bull calves with lower concentrations of glucose and FFA following an overnight fast could result in female offspring with genetically better fertility. Glucose and FFA may therefore be of interest to enhance selection for improved female fertility, as a measurement in young bulls.

Key words: fertility, metabolic hormones, heritability, correlation

INTRODUCTION

In the past, most dairy cattle breeding programs have focused on increasing production. In fact, milk yield has increased dramatically over the last 30 yr, particularly in the Holstein-Friesian population. Although, this remains a major economic factor today, there is growing evidence of unfavorable genetic correlations of production traits with others of economic importance such as fertility (e.g., Pryce et al., 1997; Veerkamp et al., 2000; Royal et al., 2002a). Therefore, broader selection goals have been introduced and are being continually developed to include traits, such as fertility, that are associated with longevity (Miglior et al., 2005). Although many countries now have the opportunity to select for fertility, the available selection tools are not perfect. Therefore, the challenge facing the dairy industry is to regain a balance between milk yield and fertility by placing more emphasis on selection for fertility while maintaining selection for milk yield.

The Danish dairy industry has published a fertility index since 1995 (Pedersen and Jensen, 1996). The current fertility index combines information on several fertility measures (days from first to last insemination in heifers and cows, days from calving to first insemination in cows, nonreturn rate in heifers and cows, estrus expression in heifers and cows, and fertility treatments in cows), which are combined and weighted according to their economic values. A greater fertility index indicates better fertility. One limitation of all current fertility indices worldwide is that the traits are measured in mature daughters of bulls and have low heritability, so genetic progress in fertility is slow. The addition to female fertility indices of an appropriate indicator trait that is measurable in the juvenile male could increase the rate of genetic improvement.

Subsequent to work by Land (1973), who first proposed that sex-linked characters in the female are expressed in the male, several studies in calves and lambs have looked at potential physiological juvenile indicator traits for female reproduction (e.g., Haley et al., 1989; Mackinnon et al., 1991; Royal et al., 2000). These studies have focused on reproductive hormones (testosterone, LH); however, no known studies have investigated the potential of metabolic hormones as genetic indicators of fertility.

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Following parturition, many cows enter a period of negative energy balance (**NEB**) that can last for several weeks (Butler, 2000). Furthermore, the duration and severity of NEB postpartum, often determined by changes in BCS, is unfavorably correlated (phenotypically and genetically) with the interval to first ovulation (Butler, 2000; de Vries and Veerkamp, 2000; Dechow et al., 2002; Royal et al., 2002b). During this period of NEB, changes are seen in the concentrations of FFA, glucose, growth hormone (**GH**), insulin, IGF-I, and other regulatory hormones (Hart, 1983; Butler, 2000; Roche et al., 2000). Synthesis of GH by the anterior pituitary gland increases (Diskin et al., 2003) causing an increase in lipolysis, which results in elevated levels of circulating FFA (Hart, 1983). Some FFA in turn is transported to the liver, where it can accumulate and lead to liver ketosis (Bobe et al., 2004). Furthermore, concentrations of circulating insulin and glucose decrease, and liver GH receptors decrease causing IGF-I production by the liver to decrease (Butler et al., 2003).

It has been suggested that FFA, glucose, GH, and insulin could be used as indicators of energy balance (Reist et al., 2002), and thus for NEB. However, in addition to their involvement in metabolic regulation, these metabolites and hormones per se have links with many aspects of reproduction including follicle growth and steroidogenesis (reviewed by Webb et al., 2004) such that altered concentrations during NEB could impair follicle growth and steroidogenesis (Roche et al., 2000). This therefore highlights the possible route for a genetic link between energy balance and fertility.

To be an efficient juvenile indicator trait for female fertility, it is important that the parameter in question (e.g., a metabolite or hormone) has moderate heritability and sufficient genetic correlation with female fertility. To date, there have been no studies investigating the genetic relationship of metabolic regulation in calves with female fertility and few estimating the heritability of these possible indicators. Previous studies have found estimates of the heritability of GH ranging from 0.04 to 0.60 in 9-mo-old dairy calves (Løvendahl et al., 1994; Sørensen et al., 2002) and of glucose at 0.41 in 3- to 15-mo-old dairy calves (Rowlands et al., 1983).

The aim of this study was to estimate the genetic variation in FFA, glucose, GH, and insulin plasma concentrations in 9-mo-old male dairy calves and to assess the strength of any genetic link with the fertility of their female offspring.

MATERIALS AND METHODS

For this study, data collected during a Danish project investigating physiological indicator traits in Danish dairy cattle were used (1997–2002; Danish Institute of Agricultural Sciences, Foulum, Denmark; Løvendahl and Sørensen, 2001). All procedures involving animals were approved by the Danish Animal Experiments Inspectorate and complied with the Danish Ministry of Justice Law no. 382 (June 10, 1987) and Acts 739 (December 6, 1988) and 333 (May 19, 1990) concerning animal experimentation and care of experimental animals.

Table 1. Number and age of male calves of each breed sampled at each of the 4 stations (A to D)

Station	Breed	n	Mean (± SD) age at sampling, d
A	Red Dane	23	267 ± 7
	Danish Holstein	193	264 ± 9
	Danish Jersey	16	265 ± 5
B	Red Dane	228	270 ± 11
	Danish Holstein	508	269 ± 10
	Danish Jersey	184	272 ± 12
C	Danish Holstein	269	273 ± 13
D	Danish Holstein	77	268 ± 10
Total		1,498	269 ± 11

Animals and Experimental Design

A cohort quantitative genetic study was designed. All animals were male calves from the Danish progeny-testing scheme (269.5 d of age ± 11.1). Breeds represented included Danish Holstein (n = 1047), Danish Jersey (n = 200), and Red Dane (n = 251), as shown in Table 1. Physiological data including plasma samples were collected, and progeny-test results for these animals were collated at a later stage (Danish Cattle Federation, Aarhus, Denmark). Ancestry was traced back at least 3 generations to construct a pedigree file with 59,243 animals.

Housing and Management

Calves were housed at 4 experimental stations (A, B, C, and D) where they arrived ideally before 3 mo of age; calves arriving up to 5 mo of age were still accepted for further testing. Calves were born in several private herds (468 herds submitting from 1 to 37 calves each) and transferred to the experimental stations following the necessary health checks. A diet based on dried grass pellets supplemented with barley straw was fed ad libitum. Pellets were offered from feed troughs, and water was freely available throughout.

Experimental Procedure

Two sampling protocols were used during this study. Initially, blood samples were taken by jugular venipuncture (protocol 1; 1997–1999) and later by jugular cannulation (protocol 2; 1999–2002).