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Effects of Genetic Selection for Milk Yield on Somatotropin, Insulin-Like Growth Factor-I, and Placental Lactogen in Holstein Cows[1]

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ABSTRACT

Cows from static, low-merit control (CL) and contemporary, high-merit select (SL) lines that differed in milk yield by more than 4,000 kg/305-d lactation (SL > CL) were used to determine effects of selection for milk yield on blood serum concentrations of somatotropin (ST), insulin-like growth factor (IGF-I), and placental lactogen (PL). Cows were exposed to the same environment and management conditions and fed the same diets. Serum and milk samples were collected from primiparous (18 CL, 18 SL) and multiparous (12 CL, 18 SL) cows relative to day of lactation (from –28 to 280 d for nonpregnant cows and to subsequent calving for cows that conceived). Data were analyzed as repeated measures using mixed model procedures. Serum ST increased at calving, remained elevated for a longer interval in SL than in CL cows, and was greater in SL than in CL cows. Serum IGF-I decreased at calving, remained low through 14 DIM, and gradually returned to precalving concentrations as lactation progressed. Postpartum concentrations of IGF-I were less in SL than CL through 84 DIM and were similar through the remainder of lactation, resulting in a line by day interaction. Serum IGF-I and PL were not affected by merit during gestation. There was an interaction of merit and postconception interval on IGF-I, with the difference in IGF-I concentration between lines decreasing as gestation progressed. Change in serum IGF-I and PL appeared to be synchronous. Results indicate that selection for milk yield increased serum ST, prolonged the postpartum reduction in serum IGF-I, and did not alter serum PL. Results also indicate a positive relationship between PL and IGF-I and support the concept that PL plays a role in the regulation of serum IGF-I during gestation.

Key words: milk yield, somatotropin, insulin-like growth factor-I, placental lactogen

INTRODUCTION

Somatotropin (**ST**) and IGF-I are important regulators of nutrient use and tissue function (Bauman, 2000). Vascular concentrations of ST and IGF-I are coupled (positive relationship) when animals are in positive nutrient and energy balance and are uncoupled (negative or no relationship) during periods of nutrient and energy insufficiency (Vicini et al., 1991; Thissen et al., 1994; McGuire et al., 1995). The relationship between ST and IGF-I is not constant and can be influenced by several other factors including environment (Collier et al., 2005), physiological status (Vicini et al., 1991; Reist et al., 2003), and genetic merit (Knight et al., 2004).

Cows experience several endocrine alterations as they transition through each lactation cycle. The relationship between vascular ST and IGF-I during these transitions has been characterized for the contemporary cow (Abribat et al., 1990; Sharma et al., 1994) but apparently not in the same set of cows through this complete series of transitions (Reist et al., 2003). Increased genetic merit for milk yield has been associated with increased serum ST (Beerepoot et al., 1991) and decreased IGF-I (Knight et al., 2004), but other than the early lactation data from Knight et al. (2004), there appear to be no published reports on circulating ST and IGF-I concentrations in cows of different genetic merit that were sampled repeatedly during these transitions.

Placental lactogen (**PL**) increases during gestation, and the magnitude of this increase has been suggested to have roles in alterations of maternal and fetal metabolism that differ among species (Gootwine, 2004). There is evidence that PL exerts at least part of its effects through the IGF system (Handwerger and Freemark, 2000) and administration of bovine PL to dairy cows has increased circulating IGF-I concentrations (Byatt et al., 1992, 1997; Lucy et al., 1994); however, elucidation of the regulation of PL secretion and its functions remain incomplete (Bertolini et al., 2006). In addition, evaluations of the relationship between endogenous PL

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and IGF-I in the cow (Holland et al., 1997; Hossner et al., 1997) are scarce, have used few animals, and have not included effects of selection for increased milk yield.

The overall objective of this study was to describe lactational and physiological characteristics of Holstein cows from genetic lines that differ substantially in milk yield. Our specific objective was to determine the effects of genetic selection for milk yield on blood serum concentration profiles of ST, IGF-I, and PL and their interrelationships during lactation and gestation.

MATERIALS AND METHODS

Animal Management

Cows were from 2 genetic lines of Holsteins maintained under identical environment and management practices in free-stall facilities at the University of Minnesota Southern Experiment Station in Waseca, Minnesota. Development of the static, low-merit control line (**CL**) and the contemporary, high-merit select line (**SL**) was initiated in 1964 by Charles Young as a component of a multistate, north central regional project (NC-2; Young, 1977; Hansen, 2000). The original foundation cows were paired by genetic merit and assigned to either a low- or high-merit line. The high-merit SL cows and their female descendants were inseminated with semen from the highest PTA-milk sires (n = 4) available each year. From 1964 to 1991, the low-merit CL cows and their female descendants were bred with semen from sires (4 sires/yr in a 5-yr rotation) that were breed average for PTA-milk in 1964. Since 1991, breeding the low-merit CL cows and their female descendants has continued according to the original design, except semen was from sons of the original 20 low-merit CL bulls. Coefficients of inbreeding were not allowed to exceed 6.25% for low- or high-merit cows (Jones et al., 1994; Hansen, 2000). Genetic merit (PTA-milk) of the low-merit CL cows remained stable while PTA-milk for the high-merit SL cows continued to increase (Figure 1). Thus, the high-merit SL cows represent contemporary US Holsteins and the low-merit CL cows represent average US Holsteins in 1964. The primiparous (18 CL, 18 SL) and multiparous (12 CL, 18 SL) cows used in this study were born within a 4-yr period and represented offspring from 12 CL sires and 28 CL dams or 20 SL sires and 33 SL dams.

Animal care and experimental procedures were approved by the University of Minnesota Institutional Animal Care and Use Committee. Animals were observed daily for health abnormalities and treated when warranted. Cows were milked at 12-h intervals and daily yields were determined from recorded milk weights. Cows were group-fed a TMR designed to meet their nutritional needs (NRC, 1989). All nonlactating

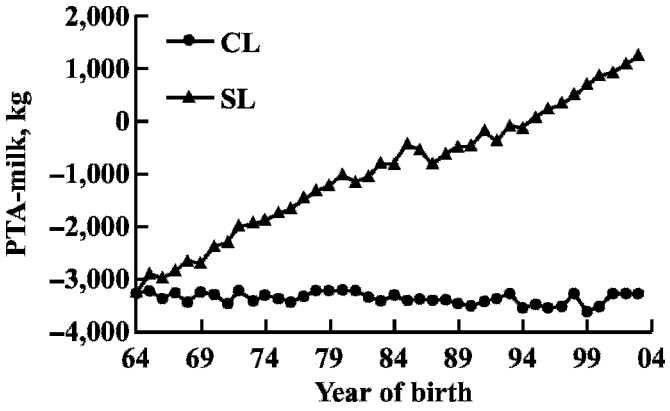

Figure 1. Effect of selection for milk yield on PTA-milk of static, low-merit control line (CL) cows and contemporary, high-merit select line (SL) cows. The PTA-milk values for individual cows were obtained (USDA, May 2005) and summarized by line and year of birth. Data points are means (from an average of 19 CL and 23 SL cows per year). The average SE was 105 kg for CL and 150 kg for SL cows.

cows consumed the same dry-cow TMR. All cows consumed the same early-lactation TMR from calving until at least 45 DIM. After 45 DIM, they were switched to a less energy-dense TMR when milk production warranted. These rations were composed primarily of corn silage, alfalfa haylage, high-moisture corn, cottonseed, and soybean meal. Reproductive management data (insemination, dry-off, and calving dates) were recorded.

Coccygeal blood samples were collected at –28 ± 7, –14 ± 3, –7 ± 2, 1, 2, 3, 7, 14, 21, and 28 DIM and at 28 ± 3 d intervals thereafter until 280 DIM (nonpregnant) or throughout pregnancy. Cows that conceived after 235 DIM were considered nonpregnant for the purposes of this study. Blood was collected into evacuated tubes (Vacutainer Beckton Dickinson and Co., Franklin Lakes, NJ) and stored overnight at 4°C. Serum was harvested (1,200 × *g*, 15 min) and stored at –20°C until assayed. All serum samples were analyzed for ST and IGF-I, and all samples collected after conception were analyzed for PL. Samples collected on –28, –14, –7, 2, 7, 21, 28, 56, 84, 168, and 280 DIM were analyzed for NEFA.

Milk samples from the morning milking were obtained at 1, 2, 3, 7, 14, 21, and 28 DIM and at 28-d intervals thereafter until 280 DIM. Milk samples (30 mL) were preserved with potassium dichromate and analyzed for fat, protein, and lactose by infrared analyses and for SCC by fluorescent detection of ethidium bromide incorporation into DNA (Minnesota DHIA, Zumbrota, MN). Body weights were determined at time of blood sampling except at 2 and 3 DIM.

Serum Analyses

Serum IGF-I concentrations were quantified by using a validated double-antibody RIA (Johnson et al., 1996)