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Enhanced early-life nutrition promotes hormone production and reproductive development in Holstein bulls

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ABSTRACT

Holstein bull calves often reach artificial insemination centers in suboptimal body condition. Early-life nutrition is reported to increase reproductive performance in beef bulls. The objective was to determine whether early-life nutrition in Holstein bulls had effects similar to those reported in beef bulls. Twenty-six Holstein bull calves were randomly allocated into 3 groups at approximately 1 wk of age to receive a low-, medium-, or high-nutrition diet, based on levels of energy and protein, from 2 to 31 wk of age. Calves were on their respective diets until 31 wk of age, after which they were all fed a medium-nutrition diet. To evaluate secretion profiles and concentrations of blood hormones, a subset of bulls was subjected to intensive blood sampling every 4 wk from 11 to 31 wk of age. Testes of all bulls were measured once a month; once scrotal circumference reached 26 cm, semen collection was attempted (by electroejaculation) every 2 wk to confirm puberty. Bulls were maintained until approximately 72 wk of age and then slaughtered at a local abattoir. Testes were recovered and weighed. Bulls fed the high-nutrition diet were younger at puberty (high = 324.3 d, low = 369.3 d) and had larger testes for the entire experimental period than bulls fed the low-nutrition diet. Bulls fed the high-nutrition diet also had an earlier and more substantial early rise in LH than those fed the low-nutrition diet and had increased concentrations of insulin-like growth factor-I (IGF-I) earlier than the bulls fed the low-nutrition diet. Furthermore, we detected a temporal association between increased IGF-I concentrations and an early LH rise in bulls fed the high-nutrition diet. Therefore, we inferred that IGF-I had a role in regulating the early gonadotropin rise (in particular, LH) and thus reproductive development of Holstein bulls. Overall, these results support our hypothesis that Holstein bull calves fed a high-nutrition diet reach puberty earlier and have larger testes than those fed a low-nutrition diet, and they provide clear evidence that nutritional modulation of Holstein bull calves during early life has profound effects on reproductive development.
Key words: Holstein bull, nutrition, puberty, testes

INTRODUCTION

Most bulls in Canadian AI centers are Holstein. Future AI sires are typically born and raised on commercial dairy farms and moved to an AI center at approximately 8 mo of age. As soon as postthaw semen quality is acceptable, semen is collected, cryopreserved, and used in AI programs for progeny testing. Bulls that reach puberty faster (facilitating progeny testing) or produce more doses of semen (greater profitability), or both, are clearly desirable. Regardless, many future potential AI sires arrive at the AI center in suboptimal body condition.

The effects of nutrition on the onset of puberty in beef bulls have been studied previously (Wolf et al., 1965; Brito et al., 2007a,b,c). Beef bull calves fed a high level of nutrition (both protein and energy) during early life have increased (∼20–25%) testicular weight and sperm production by 74 wk of age. Therefore, determining the effects of early-life nutrition on puberty and sperm production in Holstein bulls could be of great benefit to the AI industry.

Reproductive development of the bull can be divided into 3 periods: infantile, prepubertal, and pubertal. The infantile period (0–8 wk of age) is characterized by low secretions of both gonadotropins and testosterone (Amann et al., 1986; Rawlings et al., 2008). Thereafter, during the prepubertal period (8 to 20 wk), there is a transient increase in blood gonadotropin concentrations (early gonadotropin rise) and a concurrent increase in testosterone secretion (Amann and Walker, 1983; Barth et al., 2008; Rawlings et al., 2008). Peripheral LH concentrations start to increase at 4 to 5 wk, peak

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at 12 to 16 wk, and then decline, reaching a baseline at 25 wk (Amann and Walker, 1983; Barth et al., 2008). It is noteworthy that LH concentrations during the prepubertal period affect sexual development and are inversely related to age at puberty (Amann and Walker, 1983; Evans et al., 1995). Blood FSH concentrations generally increase during the early increase (less marked than corresponding increases in LH) and decrease to baseline by approximately 25 wk (Amann and Walker, 1983; Evans et al., 1995).

The early gonadotropin increase may play a pivotal role in sexual development and maturation of the bull calf (Rawlings et al., 2008). Specifically, the magnitude of prepubertal gonadotropin secretion may be critical in the initiation and extent of testicular development in bulls (Barth et al., 2008). Before 25 wk of age, testicular growth occurs slowly. Thereafter (pubertal period), there is rapid testicular development through puberty, despite low serum gonadotropin concentrations, suggesting that gonadotropin-independent mechanisms regulate testicular development in bulls. Ultimately, decreased sensitivity of the hypothalamus to testosterone and estrogen, with a concomitant increase in concentrations of GnRH, LH, FSH, and testosterone, culminates in puberty.

Experimental evidence indicates that GnRH neurons communicate with a neural system (so-called metabolic sensor) that relays nutritional status to GnRH neurons by detecting concentrations of metabolic hormones (e.g., leptin, IGF-I, insulin, and growth hormone) and nutrients (Blache et al., 2000). Apparently, this communication enables GnRH neurons to overcome the negative feedback effects of testosterone and estradiol, and initiate pulsatile release of GnRH. Determining what metabolic hormones influence GnRH concentrations is important in order to elucidate the effects of nutritional status on reproduction. For example, concentrations of IGF-I are higher during the early gonadotropin rise in beef bulls (Brito et al., 2007a); indeed, because IGF-I concentrations are directly related to LH concentrations, it is thought that IGF-I may be involved in regulating the early gonadotropin rise in bulls (Brito et al., 2007b).

Most of the previous research on the effects of early-life nutrition on reproductive development in bulls was done in beef cattle. The overall objective of this study was to determine whether early-life nutrition in Holstein bulls had effects similar to those reported in beef bulls. We hypothesized that the Holstein bull calves on a high nutrition diet will have greater LH concentrations during the prepubertal phase, reach puberty earlier, and have larger testes than those maintained on a low-nutrition diet.

MATERIALS AND METHODS

Bulls and Treatments

Twenty-six Holstein bull calves were randomly allocated into 3 groups at approximately 1 wk of age to receive either a low-, medium-, or high-nutrition diet from 2 to 31 wk of age. Typically, calves raised in intensive systems are fed milk (twice daily) to 10% of the calves' BW (approximately 6 L of milk per day; Jasper and Weary, 2002). Therefore, in the present study, calves were fed milk (4, 6, and 8 L/d in the low, medium and high groups, respectively) from 2 to 8 wk of age and thereafter transitioned onto diets based on barley silage (the forage source for all diets). All diets contained 1.6% vitamin-mineral premix (as fed). The low-nutrition diet (n = 8) was barley silage (plus premix, but no concentrate) and had 12.2% CP and 62.9% TDN (note that for this and all other diets, CP and TDN are reported on a DM basis). The medium-nutrition diet (n = 9) contained 4.8% rolled barley, 4.8% rolled corn, 3.8% canola meal, and 3.8% soybean meal (overall, 17.0% CP and 66.0% TDN). The high-nutrition diet (n = 9) consisted of 49.7% rolled barley, 9.7% rolled corn, 7.6% canola meal, and 7.6% soybean meal (20.0% CP and 67.9% TDN). These diets were created and classified as low, medium, and high levels of nutrition based on diets used in a previous study (Brito et al., 2007a,b), and roughly on National Research Council requirements (NRC, 2001). The high-nutrition group was fed ad libitum and, based on their intake, the same amount of feed (on an as-fed basis) was offered to the low- and medium-nutrition groups. Calves were on their respective diets until 31 wk of age, after which they were all fed the medium-nutrition diet. This experiment was conducted in accordance with the guidelines of the Canadian Council on Animal Care and was reviewed and approved by the Lethbridge Research Centre institutional animal care committee.

Sexual Development

Testicular Characteristics. Once monthly, from 8 to 71 wk of age, all bulls were weighed, and scrotal circumference (**SC**) was determined with a Coulter Scrotal Tape (Trueman Manufacturing, Edmonton, AB, Canada). In addition, the length and width of each testis were measured with calipers, and paired testes volume (**PTV**) was calculated using the following formula: $PTV = 0.5236 \times length \times width^2$ (Bailey et al., 1998). The PTV as a percentage of overall BW was also calculated for each bull. Concurrent with determination of testicular size, testes were examined by conventional