Effects of varying energy intake and sire breed on duration of postpartum anestrus, insulin like growth factor-1, and growth hormone in mature crossbred cows[1]

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ABSTRACT: Objectives of this study were to evaluate effects of seven sire breed groups and three levels of daily ME intake (DMEI = 132 or 189 kcal ME/kg $BW^{0.75}$ or ad libitum), beginning 5 mo prepartum, on BCS, length of postpartum anestrus, and circulating concentrations of IGF-1 and GH in F_1 cows (six to eight cows per sire breed in each DMEI group) out of Angus or Hereford dams. At the initiation of the study, BW were 522, 530, 548, 572, 575, 577, and 595 kg for cows sired by Longhorn, Galloway, 1960s Hereford or Angus, 1980s Hereford or Angus, or Nellore, Salers, and Shorthorn bulls, respectively (SE = 13; $P < 0.001$ for sire breed). After 4 mo on DMEI treatment during the prepartum period, cows fed 132 kcal of ME/kg $BW^{0.75}$ gained little to no BW; cows fed 189 kcal ME/kg $BW^{0.75}$ gained 50 kg; and cows fed ad libitum gained 70 kg (all groups differ $P < 0.05$). Concentrations of progesterone in weekly blood samples collected 2 to 14 wk after calving were used to establish when normal luteal function resumed to predict length of postpartum anestrus. Length of anestrus was affected by level of DMEI in cows sired by Galloway, Longhorn, and Nellore bulls, but not other breeds ($P < 0.02$ for interaction of sire breed and DMEI). Level of DMEI, but not sire breed, affected ($P < 0.01$) BCS at wk 2 postpartum. Concentrations of IGF-1 at wk 2 postpartum differed ($P < 0.001$) due to sire breed, and changes in concentrations of IGF-1 from wk 2 to 14 were influenced ($P < 0.03$) by the interaction of sire breed and level of DMEI; which was primarily the result of differences in rate of decrease over time among different sire breed × level of DMEI groupings. Concentrations of GH did not differ due to sire breed but varied ($P < 0.001$) due to the interaction of DMEI and week postpartum, for which concentrations of GH did not differ at wk 2 but increased over time at rates that were inversely proportional to level of DMEI. Length of anestrus was negatively associated ($P < 0.05$) with day of calving, BCS, and BW. When effects of sire breed and level of DMEI were accounted for (residual correlation), length of anestrus was inversely associated ($P < 0.01$) with IGF-1 concentrations. Breed of sire influenced length of postpartum anestrus and energy balance, as predicted by IGF-1, in crossbred cows fed varying levels of DMEI.

Key Words: Bovine, Breed, Energy, Growth Hormone, Insulin-Like Growth Factor-1, Postpartum Anestrus

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Introduction

Feed resources consumed by the cowherd are a major cost associated with beef cattle production. Partitioning nutrient intake toward different biological processes, such as maintenance, resumption of estrous cycles, milk production, and growth, varies among breeds or biological types of cattle (Jenkins and Ferrell, 1992, 1994; Nugent et al., 1993). Therefore, characterizing production responses of different breeds or breed types to variations in levels of feed intake can contribute to improving the efficiency of production by facilitating the ability of producers to match cows with available feed resources and management strategies.

Circulating concentrations of IGF-1 and GH fluctuate in response to level of nutrient intake (McGuire et al., 1992) and seem to provide objective indicators of nutritional status in dairy (Ronge et al., 1988; Spicer et al., 1990) and beef (Roberts et al., 1997) cattle. Because circulating concentrations of these hormones are associated with nutritional status, there is the potential to use

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measurements of these hormones in selecting animals best adapted to particular nutritional environments. Variations in circulating concentrations of IGF-1 have been observed among different breeds or breed types (Echternkamp et al., 1990; Schams et. al., 1991; Spicer et al., 1993, 2002), and genetic selection has been used to alter circulating concentrations of IGF-1 (Davis and Simmen, 1997), providing evidence of genetic sources of variation. Nonetheless, variation in circulating concentrations of IGF-1 across the numerous breeds of cattle is not well described. In previous research, we evaluated the effect of varying levels of energy intake on lactation and calf weights from crossbred cows produced by different sire breeds (Jenkins et al., 2000). The objectives of the present study were to determine the influence of sire breed of these same crossbred cows on length of postpartum anestrus and circulating concentrations of IGF-1 and GH in response to varying energy intake.

Materials and Methods

Mature crossbred cows (5 to 8 yr of age), representing seven different sire breed groups, were obtained from Cycle IV of the Germ Plasm Evaluation Project conducted at the Meat Animal Research Center. These F_1 cows were produced by mating Hereford or Angus dams with Angus, Galloway, Hereford, Longhorn, Nellore, Salers, and Shorthorn sires. Angus and Hereford sires were sampled from two time periods, 1963 through 1970 and the 1980s, and were only used on dams of the opposite breed. Angus and Hereford sires from 1963 through 1970 have served as reference sires for the different cycles of the Germ Plasm Evaluation Project (Cundiff et al., 1998). As F_1 cows produced from Angus and Hereford sires were similar in breed composition (half Angus and half Hereford), these cows were classified as 1960s (1963 through 1970) or 1980s Hereford/Angus rather than Hereford or Angus sire breeds. Upon entry into the present study, cows were determined to be pregnant by rectal palpation, and individual cow BW were obtained at weaning in October. Cows were placed in pens equipped with electronic head gates to allow for control of individual animal feed intake. Cows were assigned randomly to one of three levels of daily ME intake (**DMEI**): 132 or 189 kcal of ME/kg $BW^{0.75}$ based on BW at weaning, or ad libitum (six to eight cows per sire breed by DMEI group). Due the high incidence of calf losses experienced when cows were calved in the pens during previous research trials, cows were transferred on either February 15 (all cows weighed on this date) or March 17 to dormant smooth brome pasture for calving, depending on predicted calving date. All cows were mated to Simmental bulls, and calving dates ranged from March 11 to May 16. Variations in date transferred to pasture and date of calving resulted in cows being on pasture for a range of 14 to 82 d before calving. While on pasture, cows were fed 7 to 8 kg of corn silage per cow (DM basis) as an energy supplement. Cows were returned to their precalving pen assignments 12 to 18 d after calving, and were then fed on an individual basis throughout the remainder of the trial. Calves were maintained with cows until weaned at an average of 170 d of age. Additional details concerning cows, sires, feed and feeding levels, milk traits and preweaning weight traits of calves have been reported previously (Jenkins et al., 2000).

Cows were visually appraised for BCS using a nine-point scale (1 = severely emaciated to 9 very obese; Herd and Sprott, 1986) at approximately 2 wk after calving when cows were returned to the individual feeding pens. Cow BW and blood samples from tail vessel venipunctures were collected before the daily feeding from 2 to 14 wk after calving. Concentrations of progesterone in serum (50 μL) from weekly blood samples were determined directly without extraction by RIA, using the protocol, primary antibody, and tracer from ICN Pharmaceuticals, Inc. (Costa Mesa, CA). Serial dilutions of bovine serum resulted in parallel displacement to serial dilutions of progesterone used as the standard curve in the assay. Inter- and intraassay (n = 15) CV were 7.6 and 15.4%, respectively. Concentrations of IGF-1 in serum samples collected at wk 2, 4, 8, and 14 were determined by RIA after acid–ethanol extraction (Roberts et al., 1997). Primary antiserum (UB3-189) used in the IGF-1 RIA was provided by the National Hormone and Pituitary Program (Rockville, MD). Inter- and intraassay (n = 4) CV for IGF-1 were 8.3 and 14.8%, respectively. Concentrations of GH in serum samples collected at wk 2, 8, and 14 were determined by RIA (Klindt et al., 1985) using the reagents reported by Roberts et al. (1997). Primary antiserum (NIAMDD-anti-oGH-2) and hormone for iodination (NIDDK-oGH-I-4) were provided by the USDA hormone program. Interassay (n = 1) CV for GH was 8.2.

Length of postpartum anestrus was defined as the number of weeks from calving to the last week that progesterone concentration was <1 ng/mL preceding two subsequent weeks when progesterone was >1 ng/mL. Thus, the anestrous period was defined to end the week preceding the resumption of normal luteal activity. Animals that failed these criteria were assigned a value of 15 wk for the length of anestrus, and therefore, data concerning length of anestrus are right-censored. Repeated measurements from weigh-suckle-weigh procedures on individual cows (described in Jenkins et al., 2000) were used to estimate lactation curve parameters for the prediction of time (week) and quantity (kg) of peak milk yield for individual cows (n = 121) based on methods reported by Jenkins and Ferrell (1992). Calf weaning weights were adjusted to 170 d of age.

Statistical Analyses

Unless stated otherwise, statistical evaluations were performed using SAS procedures (SAS Inst., Inc., Cary, NC). Cow BW at initiation of the study (October) and in February were compared among sire breeds and levels of DMEI using the GLM procedure, with a model that included fixed effects of sire breed, level of DMEI, and the interaction of these effects. Effects of sire breed and level of DMEI on BW and circulating concentrations of IGF-1 and GH at different times after parturition were analyzed initially using a mixed model for repeated measures. The model included day of calving as a covariate (coded as day of the year) and fixed effects of sire breed, level of DMEI, and week, all two- and the three-way interactions of these fixed effects, and cow within sire breed × DMEI as the subject of the repeated measures. These analyses indicated that some of the two- or three-way interactions of breed and/or DMEI with week postpartum accounted for the variation ($P < 0.05$) in the response variables. To provide insight into the interpretations of these interactions, the GLM procedure was run for each time period using a model that included day of calving as a covariate, fixed effects of sire breed and DMEI, and the interaction of sire breed and DMEI. Dependent variables analyzed were BW, IGF-1, and GH within each time period and the change in these variables between weeks (i.e., difference between two consecutive measurements). This model also was used to analyze BCS measured at wk 2 postpartum and length of anestrus (weeks until resumption of luteal activity). Least squares means for significant ($P < 0.05$) effects in the model were compared using LSD mean separation procedures. Simple and residual correlations were estimated among length of postpartum anestrus, cow BW, BCS, calf weaning weight, cow milk traits, and hormone concentrations. Residual correlation coefficients among these variables were obtained from the MANOVA option in the GLM procedure. Effects of sire breed and level of DMEI on milk traits and weaning weights of calves from the F_1 cows evaluated in this study have been reported previously (Jenkins et al., 2000); thus, presentation of results on these traits is restricted to the correlation analyses. Chi squared analyses were used to evaluate differences in the proportion of cows in which luteal activity had resumed by wk 14 between DMEI groups, without regard to sire breed.

Results

Cow BW at the beginning of the study in October varied ($P < 0.001$) due to sire breed, but it did not differ due to randomization into the dietary treatments. Mean BW at the initiation of the study were 522, 530, 548, 572, 575, 577, and 595 kg for cows sired by Longhorn, Galloway, 1960 Hereford/Angus, 1980 Hereford/Angus, Nellore, Salers, and Shorthorn bulls (SE of least squares mean = 13). Differences in BW among sire breed groups persisted throughout the study (see top panel of Figure 1). Subsequent to initiation of the feeding treatments, BW measurement diverged due to level of DMEI. Cows fed 132 kcal of DMEI gained little or no BW during the 4-mo period from initiation of the study in October to the precalving BW in February (mean BW across sire breeds = 559 ± 9 kg). During this same period, cows fed 189 kcal of DMEI gained approximately 50 kg BW (601 ± 9 kg), and ad libitum-fed cows gained approximately 70 kg BW (637 ± 9 kg), resulting in differences ($P < 0.001$) in mean BW among the three levels of feeding. Cow BW at the different times after calving were influenced ($P < 0.006$) by day of calving (correlation coefficients for day of calving and BW at different times shown in Table 1) and the two-way interactions of sire breed × week postpartum ($P < 0.03$) and level of DMEI × week postpartum ($P < 0.001$). Although the differences among BW means across sire breed or DMEI groups generally remained the same over time, an analysis of the change in BW indicated that magnitude of BW loss between the different times of the postpartum period varied among the groupings (Figure 1). Nellore-sired cows lost more BW between wk 2 and 4 than all but the 1960 Hereford/Angus- and Saler-sired cows, which were not different from the other sire breed groups. Differences among the DMEI groups for BW loss between time points are depicted in Figure 1. Cows fed the low level of DMEI lost more BW between each time point than cows fed at higher levels of DMEI.

Body condition scores of cows at 2 wk after calving were influenced by day of calving ($P < 0.001$) and level of DMEI ($P < 0.001$; BCS = 4.4 ± 0.1, 4.7 ± 0.1, and 5.3 ± 0.1, for the low, intermediate, and ad libitum DMEI, respectively), but not sire breed ($P = 0.13$). The simple correlation between BCS measured at wk 2 and day of calving indicated that BCS were higher as cows calved later in the calving season (Table 1). As would be expected, BCS at wk 2 were positively correlated with BW at wk 2, 4, 8, and 14 (Table 1).

The proportion of animals in each DMEI group that resumed normal luteal activity during the 14-wk period after calving was 36/49, 43/50, and 49/51 for the 132, 189, and ad libitum groups, respectively ($P < 0.01$ for 132 vs. ad lib). The proportion of animals in each sire breed group that resumed normal luteal activity during the 14-wk period after calving was 20/21, 16/20, 14/22, 14/21, 21/22, 23/23, and 20/21 for the 1980s Hereford/Angus, Galloway, Longhorn, Nellore, Salers, Shorthorn, and 1960 Hereford/Angus groups, respectively. To analyze length of postpartum anestrus as a continuous variable, cows that failed to exhibit normal luteal activity within 14 wk following parturition were assigned a value of 15. Using this approach on these right-censored data, time to first week of normal luteal activity was influenced by day of calving ($P < 0.001$), and differed by level of DMEI for cows sired by Galloway, Longhorn, and Nellore bulls, but not for cows sired by other breeds ($P < 0.002$ for interaction of sire breed × DMEI; Figure 2). Length of time for resumption of normal luteal activity was associated negatively ($P < 0.001$) with day of calving, BW at wk 2, 4, 8 and 14, and BCS at wk 2 (Table1).

Mean circulating concentrations of IGF-1 varied ($P < 0.03$) due to the three-way interaction of sire breed,

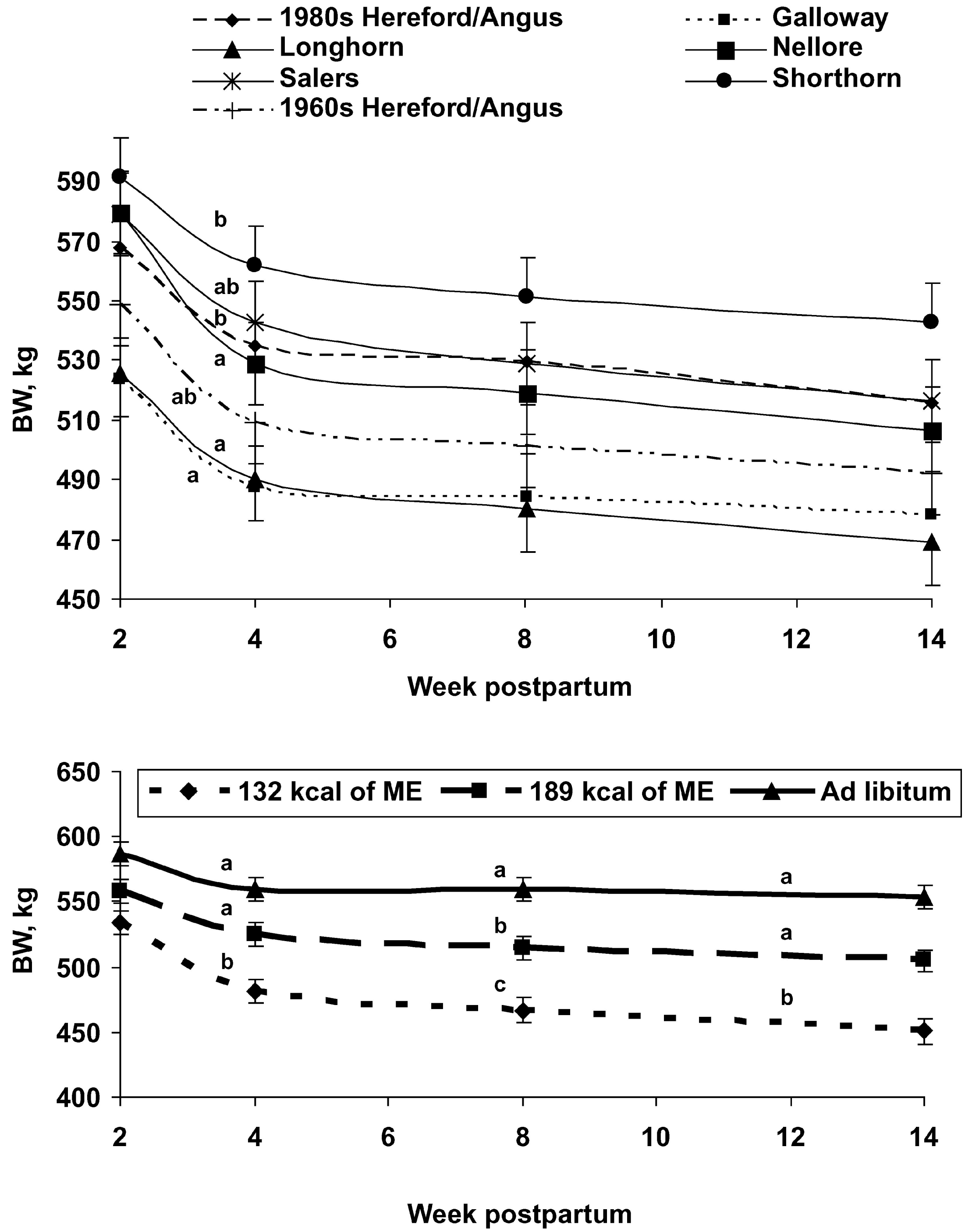

Figure 1. Least squares means (±SE) for BW at different weeks after calving for cows grouped by sire breed (top panel) or level of daily ME intake (DMEI = 132 or 189 kcal of ME/kg $BW^{0.75}$ or ad libitum; bottom panel). Mean BW varied ($P < 0.006$) due to day of calving, main effects of sire breed, level of DMEI and week, and the interactions of sire breed × week ($P < 0.03$) and level of DMEI × week ($P < 0.001$). Rankings of BW means by sire breed or DMEI groupings generally remained the same over time, but magnitude of BW loss between wk 2 and 4 tended ($P < 0.10$) to differ due to sire breed, and BW loss during each weigh interval differed ($P < 0.004$) due to level of DMEI. Lines between common time points without similar letters indicate differences ($P < 0.05$) in rate of BW loss.

level of DMEI, and week postpartum. To provide insight into this three-way interaction, separate analyses were performed on concentrations of IGF-1 at individual weeks after parturition and on the change between weeks. Circulating concentrations of IGF-1 at each week differed ($P < 0.001$) due to sire breed. Circulating concentrations of IGF-1 at wk 4, 8 and 14, but not at wk 2, differed due to level of DMEI (Figure 3). At wk

Table 1. Simple correlation coefficients (first line), and probabilities (second line) for length of anestrus, day of calving, body condition score, body weight, and insulin-like growth factor-1 at wk 2, 4, 8, and 14 postpartum; growth hormone at wk 2, 8, and 14 postpartum; adjusted weaning weight of calf (Adj ww); and the peak week and peak weight of milk production

Item	Length of anestrus	BCS	BW, wk 2	BW, wk 4	BW, wk 8	BW, wk 14	GH, wk 14	Adj ww	Peak week	Peak weight
Anestrus		–0.326	–0.288	–0.336	–0.342	–0.327	0.155	–0.159	–0.052	–0.143
		0.001	0.001	0.001	0.001	0.001	0.059	0.054	0.571	0.117
Day of calving	–0.394	0.388	0.176	0.158	0.148	0.160	–0.141	–0.035	–0.001	–0.098
	0.001	0.001	0.032	0.053	0.071	0.052	0.086	0.672	0.989	0.287
BCS	–0.326		0.535	0.572	0.590	0.594	–0.307	0.145	0.030	–0.089
	0.001		0.0001	0.001	0.001	0.001	0.001	0.069	0.741	0.332
IGF-1, wk 2	–0.055	0.216	0.017	0.009	0.033	0.049	–0.254	–0.052	0.083	–0.213
	0.507	0.008	0.838	0.912	0.685	0.552	0.002	0.523	0.364	0.019
IGF-1, wk 4	–0.101	0.251	0.230	0.285	0.328	0.310	–0.337	0.141	0.114	–0.115
	0.220	0.002	0.005	0.001	0.001	0.001	0.001	0.088	0.216	0.212
IGF-1, wk 8	–0.113	0.336	0.299	0.372	0.434	0.450	–0.377	0.138	0.027	–0.157
	0.168	0.001	0.001	0.001	0.001	0.001	0.001	0.095	0.769	0.086
IGF-1 wk 14	–0.112	0.388	0.342	0.409	0.450	0.472	–0.397	0.187	0.165	–0.137
	0.174	0.001	0.001	0.001	0.001	0.001	0.001	0.023	0.070	0.133
GH, wk 2	–0.002	–0.054	–0.021	0.018	0.020	0.001	0.158	–0.126	0.210	–0.067
	0.980	0.508	0.799	0.829	0.809	0.993	0.053	0.126	0.021	0.409
GH, wk 8	0.068	0.007	–0.183	0.218	0.242	–0.263	0.232	–0.042	–0.169	–0.069
	0.410	0.931	0.025	0.008	0.003	0.001	0.004	0.613	0.064	0.450
GH, wk 14	0.155	–0.307	–0.378	0.399	0.416	–0.454		–0.313	–0.072	–0.040
	0.059	0.001	0.001	0.001	0.001	0.001		0.001	0.430	0.661

2, concentrations of IGF-1 were greatest ($P < 0.05$) for Nellore-sired cows (20.4 ng/mL), followed by Longhorn-sired cows (16.0 ng/mL), which did not differ from cows sired by Salers (14.3 ng/mL), Shorthorn (13.6 ng/mL), or 1960s Hereford/Angus (12.9 ng/mL), but were greater ($P < 0.05$) than for cows sired by Galloway (12.5 ng/mL)

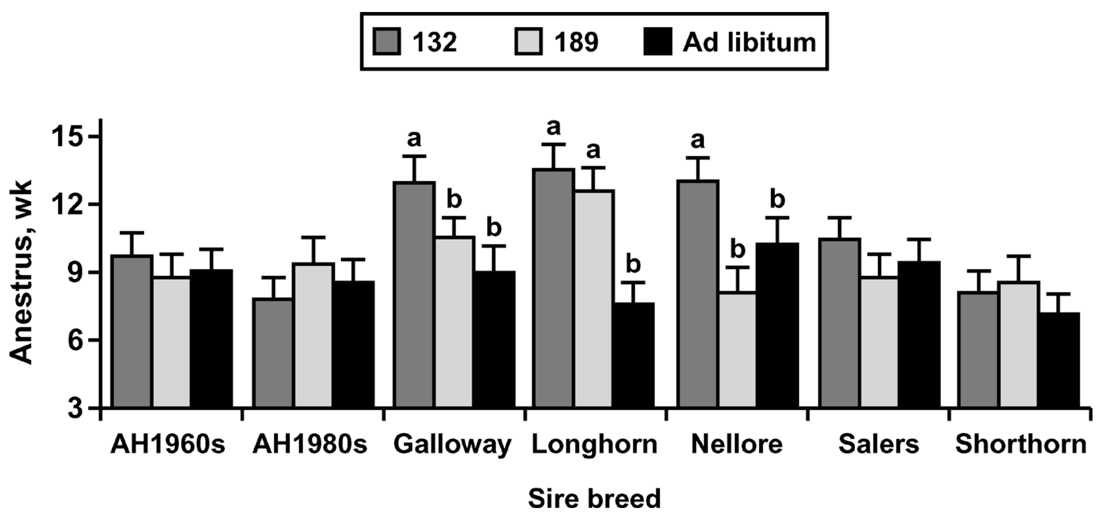

Figure 2. Duration (least squares mean ± SE) of postpartum anestrus for cows out of different sire breeds (shown on the x-axis; AH1960s and AH1980s correspond to Hereford or Angus sires from the 1960s and 1980s, respectively) that were fed one of three levels of daily ME intake (DMEI = 132 or 189 kcal ME/kg $BW^{0.75}$ or ad libitum). Length of anestrus was predicted by time from parturition to resumption of normal luteal function. Data are right-censored due to the fact that blood samples were not collected beyond wk 14. Animals that failed to resume normal luteal function by wk 14 were assigned a value of 15. Factors influencing length of anestrus included calving date ($P < 0.001$), sire breed ($P < 0.001$), level of DMEI ($P < 0.001$), and the interaction of sire breed and level of DMEI ($P < 0.002$). Bars without common superscripts represent differences ($P < 0.05$) among levels of DMEI within each sire breed.

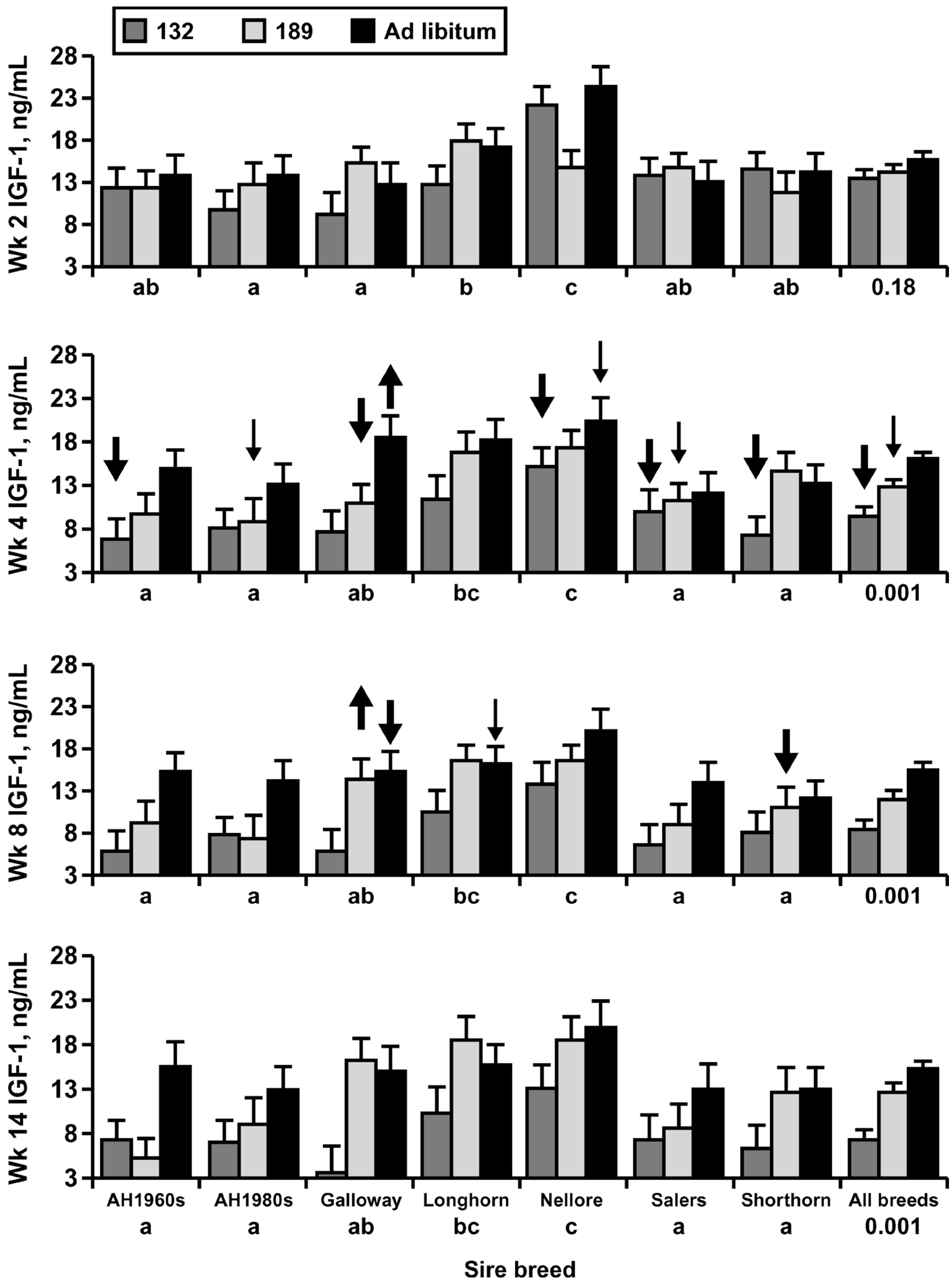

Figure 3. Concentrations (least squares mean ± SE) of IGF-1 at different weeks during the postpartum period for cows out of different sire breeds (shown on x-axis of bottom panel; AH1960s and AH1980s correspond to Hereford or Angus sires from the 1960s and 1980s, respectively) that were fed one of three levels of daily ME intake (DMEI = 132 or 189 kcal of ME/kg $BW^{0.75}$ or ad libitum). Concentrations of IGF-1 were influenced ($P < 0.03$) by the three-way interaction among sire breed, level of DMEI, and week postpartum. Sire breed groups without a common letter along the x-axis of each panel differed ($P < 0.05$) when evaluated in separate analyses for each time period ($P < 0.001$ for effect of sire breed at each week). Probability values for effect of DMEI at each week are shown under the far right bars in each panel. Arrows above bars indicate changes from previous time period ($P < 0.05$ for bold arrows; $P < 0.10$ for light arrows).

and 1980s Hereford/Angus (12.2 ng/mL). Mean concentrations of IGF-1 at wk 2 for the three levels of DMEI were 13.7, 14.3, and 15.7 ng/mL for the 132, 189, and ad libitum groups (SE = 0.8; $P = 0.18$; P = 0.14 for interaction of sire breed × DMEI). Changes in IGF-1 concentrations from wk 2 to wk 4 were influenced ($P < 0.02$) by the interaction of sire breed × level of DMEI. This interaction resulted from decreases in IGF-1 concentrations within some, but not all sire breeds groups fed restricted levels of DMEI, and an increase in IGF-1 in ad libitum fed Galloway sired cows (see arrows on second panel of Figure 3). Because of these changes, mean concentrations of IGF-1 at wk 4 differed among the three levels of DMEI and mean separations among sire breeds changed slightly from those observed at wk 2 (Figure 3). Differences in concentrations of IGF-1 observed across the sire breed × DMEI groups at wk 4 were generally maintained throughout subsequent weeks, with a few exceptions resulting from a tendency ($P = 0.12$) for an interaction of sire breed × level of DMEI on changes observed from wk 4 to 8 (denoted by arrows on third panel of Figure 3) and the trend ($P = 0.10$) for continued decreases in mean concentrations of IGF-1 over time in the 132 DMEI group, but not the other two levels of DMEI. Mean concentrations of IGF-1 at each week during the postpartum period were correlated ($P < 0.01$) with BCS at wk 2 (Table 1). Concentrations of IGF-1 at wk 4, 8, and 14, but not wk 2, were correlated with BW measured during the postpartum period, and there was a pattern for the magnitude of the correlation to become larger as time postpartum increased (Table 1).

Circulating concentrations of GH varied due to the interaction between level of DMEI and week postpartum ($P < 0.001$; Figure 4), but they did not differ due to sire breed or day of calving. Circulating concentrations of GH at wk 2 did not differ among the three levels of DMEI, but diverged overtime due to differences in rates of increases among the dietary treatments. As with IGF-1, circulating concentrations of GH measured after wk 2, but not at wk 2, were correlated with BW measurements taken postpartum; however, correlations between BW and GH were negative, whereas correlations between BW and IGF-1 were positive (Table 1). Circulating concentrations of GH at wk 14, but not earlier weeks, were correlated negatively with BCS measured at wk 2 and with concentrations of IGF-1 measured throughout the postpartum period (Table 1). Circulating concentrations of GH at wk 14 also tended ($P = 0.06$) to be associated with time to resumption of normal luteal activity.

Residual correlations among different production traits (length of postpartum anestrus, adjusted weaning weight of calf, and peak week and amount of milk production) and indicators of nutritional status (BW, BCS, and hormone measurements) are shown in Table 2. After accounting for variation associated with day of calving, sire breed, and DMEI, an inverse relationship was noted between length of postpartum anestrus and concentrations of IGF-1 at the different weeks postpartum; however, BCS and BW were no longer associated with length of anestrus. As was observed in the simple correlations, BCS was associated positively with BW, and BCS and BW were correlated with concentrations of IGF-1 at wk 4, 8, and 14.

Discussion

The present study demonstrates that sire breed and level of DMEI interact to affect cow BW, length of postpartum anestrus and concentrations of IGF-1 after calving. Thus, differences among breeds of sires and/or period when sires were sampled (i.e., Hereford and Angus sires from 1960s vs. 1980s) contribute to variations in BW, IGF-1 concentrations, and time to resumption of normal luteal activity in response to different levels of DMEI.

Precedence for evaluating breed associated differences in circulating concentrations of IGF-1 was provided by earlier research, where circulating concentrations of IGF-1 were shown to be greater in a herd of cows selected for increased frequency of twinning compared with cows not selected for twining when measured in postpartum cows after resumption of estrus (Echternkamp et al., 1990). In addition, dairy breeds of cattle have been shown to have lower circulating concentrations of IGF-1 during the postpartum period than dual-purpose or beef breeds of cows (Shams et al., 1991; Spicer et al., 1993). Large differences in energy required for lactation were proposed to contribute to the breed differences in IGF-1 observed in these earlier studies. However, comparisons of purebred *Bos taurus* breeds of beef cows classified into biological types based on breed variations in mature size and genetic potential for milk production did not reveal differences in circulating concentrations of IGF-1 at wk 3 postpartum, even though biological type accounted for significant variation in the effect of dietary restriction on length of postpartum anestrus (Nugent et al., 1993). Circulating concentrations of IGF-1 also have been shown to differ among *Bos indicus* and *Bos taurus* cattle. Brahman cows (*Bos indicus*) were shown to have greater circulating concentrations of IGF-1 during superovulation treatments and after ovariectomy than Angus (*Bos taurus*) cattle (Simpson et al., 1994, 1997). Recently, Spicer et al. (2002) reported that Angus and Charolais cows had lower circulating concentrations of IGF-1 during the postpartum period than Brahman crosses with either of these breeds. Furthermore, circulating concentrations of IGF-1 in straight-bred Brahman cows were greater than in the crossbred cows. In the present study, the greatest circulating concentrations of IGF-1 observed were in Nellore sired cows. This finding expands evidence that circulating concentrations of IGF-1 are greater in cows with *Bos indicus* breeds than in the *Bos taurus* breeds. The one major difference in IGF-1

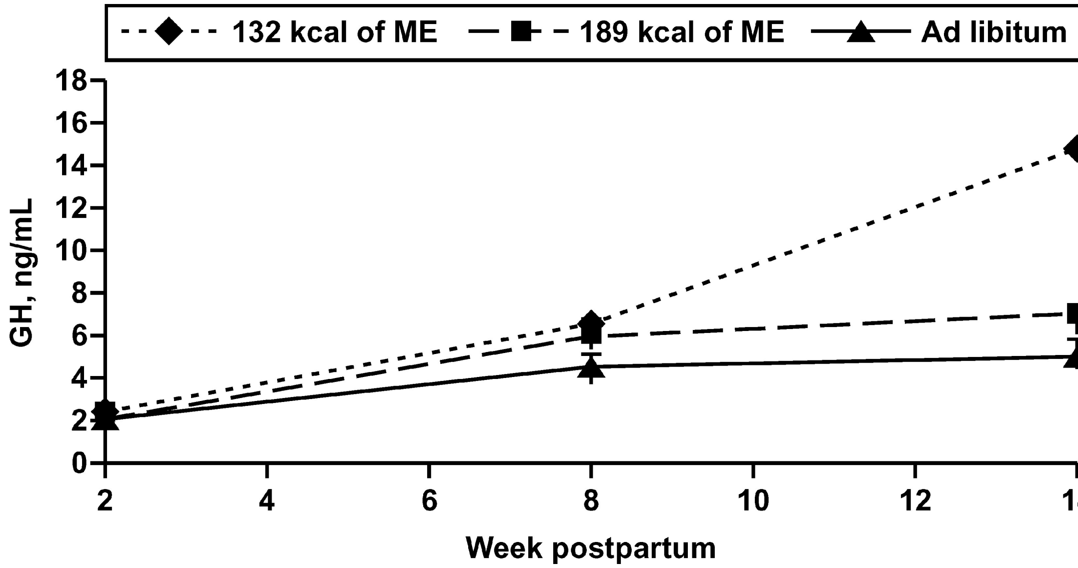

Figure 4. Least squares mean concentrations (±SE) of GH during the postpartum period for cows that were fed one of three levels of daily ME intake (DMEI = 132 or 189 kcal ME/kg $BW^{0.75}$ or ad libitum). Concentrations of GH were influenced by the interaction between level of DMEI and week postpartum ($P < 0.001$), where level of DMEI did not influence GH at wk 2, tended ($P < 0.07$) to result in differences at wk 4, and resulted in differences ($P < 0.05$) among all three levels of DMEI at wk 14.

observed among *Bos taurus* cows in the present study was the greater concentrations of IGF-1 in Longhorn-sired cows than in cows sired by other *Bos taurus* breeds. Compared on a DMEI-adjusted basis, milk production by Nellore- and Longhorn-sired cows was among the lowest of the sire breeds evaluated (Jenkins et al., 2000). Thus, an inverse relationship among circulating concentrations of IGF-1 and potential for milk

Table 2. Residual correlation coefficients (first line), after accounting for effects of day of calving, sire breed and level of daily metabolizable intake, and probabilities (second line) for length of anestrus, body condition score, body weight and insulin-like growth factor-1 at wk 2, 4, 8, and 14 postpartum; growth hormone at wk 2, 8, and 14 postpartum; adjusted weaning weight of calf (Adj ww); and the peak week and peak weight of milk production

Item	Length of anestrus	BCS	BW, wk 2	BW, wk 4	BW, wk 8	BW, wk 14	GH, wk 14	Adj ww	Peak week	Peak weight
Anestrus		–0.090	–0.062	–0.106	–0.135	–0.102	–0.071	0.000	–0.119	–0.031
		0.317	0.488	0.238	0.132	0.255	0.430	0.999	0.241	0.757
BCS	–0.090		0.498	0.531	0.542	0.526	–0.099	0.005	0.056	–0.054
	0.317		<0.001	<0.001	<0.001	<0.001	0.272	0.953	0.583	0.592
IGF-1 wk 2	–0.159	0.140	–0.092	–0.088	–0.059	–0.041	–0.159	–0.258	0.128	–0.169
	0.076	0.118	0.304	0.326	0.509	0.648	0.076	0.004	0.208	0.095
IGF-1 wk 4	–0.282	0.251	0.243	0.286	0.320	0.292	–0.182	–0.132	0.122	–0.152
	0.001	0.005	0.006	0.001	<0.001	0.001	0.042	0.141	0.230	0.133
IGF-1 wk 8	–0.239	0.335	0.313	0.379	0.439	0.449	–0.151	–0.126	0.005	–0.100
	0.007	<0.001	<0.001	<0.001	<0.001	<0.001	0.092	0.160	0.959	0.324
IGF-1 wk 14	–0.193	0.361	0.329	0.389	0.431	0.455	–0.212	–0.068	0.176	–0.136
	0.030	<0.001	<0.001	<0.001	<0.001	<0.001	0.017	0.452	0.082	0.179
GH wk 2	0.027	–0.050	–0.013	–0.006	0.001	0.030	0.134	–0.170	0.182	–0.222
	0.764	0.580	0.886	0.947	0.989	0.738	0.135	0.057	0.071	0.027
GH wk 8	0.045	0.110	–0.128	–0.150	–0.182	–0.211	0.174	0.113	–0.157	0.009
	0.617	0.219	0.153	0.093	0.042	0.018	0.051	0.208	0.120	0.929
GH wk 14	–0.071	–0.099	–0.236	–0.197	–0.192	–0.225		0.037	–0.016	0.173
	0.430	0.272	0.008	0.027	0.032	0.011		0.677	0.879	0.086

production does seem to exist, as supported by the negative correlation between IGF-1 at wk 2 and milk production in the present study. Although the selection pressures resulting in the evolution of these breed-associated differences in circulating concentrations of IGF-1 remain to be determined, increases in circulating concentrations of IGF-1 in Angus cattle have been achieved by direct selection for this trait (Davis and Simmen, 1997), indicating the potential for alteration of this trait through direct or indirect selection pressure.

It is well established that nutritional restriction results in increases in concentrations of GH and decreases in concentrations of IGF-1 after calving, and that these changes are consistent with nutritional uncoupling of the hypothalamic-pituitary regulation of these hormones that occurs when animals are in a negative energy balance (discussed previously in Roberts et al., 1997). Residual correlations among IGF-1 measurements and BCS or BW are consistent with these interpretations, where greater concentrations of IGF-1 were associated with higher BCS and heavier BW. In contrast, greater concentrations of GH were associated (simple correlations) with lower BW. In general, associations among hormone concentrations with BCS or BW became stronger as time postpartum increased, as would be expected if the severity of energy deficit increased overtime after calving.

The present research demonstrated that changes in concentrations of IGF-1in response to nutritional restriction differed according to sire breed, especially when changes in IGF-1 were evaluated between wk 2 to 4 after calving. Thus, genetic sources of variation should not be ignored when using IGF-1 as an indicator of energy balance. In addition, timing of when IGF-1 is measured should be considered. The present study also provided evidence that responses of IGF-1 to level of DMEI occurred earlier in the postpartum period than did the responses in GH; thus, IGF-1 may be a more sensitive indicator of nutritional status than GH.

One of the main reasons for interest in metabolic status during the postpartum period is the influence nutrition has on resumption of reproductive function. The influence of day of calving on time required for resumption of normal luteal activity in the present study likely reflects an improved nutritional status of cows that calved later because these animals had longer access to any new growth of forage while on pasture before calving. Correlations among day of birth with BCS and BW support this conclusion. Results that level of DMEI only influenced time required for resumption of normal luteal activity in three of the seven sire breed groups may reflect breed-specific differences in the ability to partition limited nutrients toward reinitiation of reproductive function. Nonetheless, the challenge remains to identify animals within a breed or breed type that have greater capacity for resuming reproductive function under limited nutritional environments. Results of the present research indicate that relative differences in concentrations of IGF-1 at common times during the postpartum period among animals with similar breed composition may be indicative of capacity to resume estrous cyclicity, as supported by the residual correlations between IGF-1 and length of anestrus.

Unlike concentrations of IGF-1, sire breed did not influence concentrations of GH; however, it is important to consider that GH was only evaluated in single samples taken at different times during the postpartum period when interpreting these results. Regardless, the use of a single sample of GH as an indicator of nutrient status seems to be limited because of the long duration required to detect effects of dietary treatment. It is of interest to note that a simple correlation existed between GH at wk 2 and week of peak milk production, and the residual correlation existed between GH at wk 2 and peak weight of milk production.

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