ABSTRACT: The objectives of this study were to evaluate the effects of pre- and postpartum undegraded intake protein (UIP) supplementation on body condition score (BCS), BW, calf weight, milk production, serum IGF-I concentrations, and postpartum interval in primiparous beef heifers (n = 44). Heifers were maintained on endophyte-free stockpiled tall fescue (11.7% CP, 38% ADF) and individually fed supplement daily beginning 60 d prepartum. Pre- and postpartum supplements provided 19.3% CP, 83.4% TDN (UIP); 14.1% CP, 84.1% TDN (Control); 21.5% CP, 81.5% TDN (UIP); and 14.6% CP, 81.4% TDN (Control); respectively. Blood meal (146 g/d) was the source of UIP. Six heifers were removed from the study due to calf loss unrelated to treatment; therefore, postpartum measurements are based on 19 animals per treatment. Statistical analyses using ANOVA and a split-plot design revealed no effects of treatment (P > 0.2) on BCS, BW, calf weight, milk production, or postpartum interval. There tended to be a treatment × time interaction on BCS (P < 0.09) with UIP heifers having higher BCS than Control at wk 5, 7, and 9 postpartum. There was a treatment × time interaction on serum IGF-I (P < 0.06) during the first 35 d postpartum. In UIP heifers, serum IGF-I was greater at calving compared with Control heifers (117.5 vs 92.4 ng/mL, respectively); however, these differences were not related to changes in BCS or BW. Although serum IGF-I concentrations were increased at calving in heifers receiving UIP, there were no treatment effects on postpartum interval (P > 0.7). During the first 30 d postpartum, IGF-I differed (P < 0.01) among heifers with postpartum intervals defined as short, < 50 d (128.9 ng/mL); medium, 51 to 65 d (115.2 ng/mL); and long, 66 to 130 d (52.9 ng/mL). When analyzed as a regression, a 1 ng/mL increase in IGF-I (UIP and Control heifers) at calving (P < 0.05) and throughout the postpartum period (P < 0.01) corresponded to a decrease in postpartum interval of 0.13 d. Based on the results of this study, the inclusion of UIP in diets for primiparous heifers and its effects on postpartum interval warrant further evaluation.

Key Words: Bred Heifers, Protein Digestibility, Reproduction

Introduction

Postpartum primiparous heifers present unique challenges to achieving a yearly calving interval. When compared with multiparous cows, primiparous heifers may have increased postpartum intervals (Bellows and Short, 1978; Triplett et al., 1995) and lower pregnancy rates (Bellows et al., 1982; Rae et al., 1993). These differences may be due to different nutritional requirements of primiparous heifers compared with multiparous cows. Reproduction may suffer if nutrient intake is not adequate (Randel, 1990; Short et al., 1990). Undegraded intake protein (UIP) has been evaluated as a means to complement the supply of microbial protein to the duodenum in heifers during gestation and lactation. However, response to UIP supplementation in primiparous heifers has been inconsistent (Wiley et al., 1991; Rusche et al., 1993; Triplett et al., 1995). Furthermore, providing rumen-protected methionine and lysine to a basal diet, in which 125% of protein requirements were met, resulted in a redirection of nutrients toward maternal tissue and away from milk production in primiparous heifers (Hess et al., 1998). Across these studies, forage quality, supplemental energy, and protein varied, which may have contributed to differences in response to supplementation. Additionally, supplementation with UIP beginning prepartum and continuing until the breeding season has not been evaluated in primiparous heifers. Therefore, our objective was to evaluate effects of feeding UIP in a supplement to primiparous heifers maintained on medium quality forage. Body condition score (BCS), BW, calf weight, milk pro-
duction, postpartum interval, and first-service conception rate were measured.

Materials and Methods

Experimental Model and Animal Design

Forty-four crossbred (Angus × Simmental), primiparous beef heifers (22 UIP, 22 Control) were used under the guidance of an approved University of Missouri Animal Care and Use Committee protocol. Heifers were checked for pregnancy via rectal palpation before the second trimester so that only pregnant heifers were used. Pretreatment BW and BCS (1 to 9 scale, Wagner et al., 1988) were recorded, and heifers were assigned to treatment based on originating herd, expected calving date (determined via rectal palpation), BCS, and BW. Beginning 64 d prepartum, heifers were weighed on two consecutive days and BCS was assessed. The average of the two BW was considered the starting BW. Least squares means for BCS and BW were 5.45 and 5.54, and 435 kg and 440 kg for Control and UIP heifers, respectively. Heifers were weighed and BCS assessed again at 31 d prepartum. The mean calving date for the two groups did not differ (February 20 ± 3.3 d for UIP vs February 21 ± 3.3 d for Control; P > 0.88). Immediately after calving, the BCS, BW, and calf weight were recorded. Thereafter, heifer BCS and BW measurements were recorded once weekly. The BCS were assessed by two trained technicians and were averaged because BCS did not differ by technician (P > 0.66). Six heifers were removed from the study because of calf losses, which were unrelated to treatment. Therefore, postpartum measurements are based on 38 animals (19 UIP, 19 Control).

Forage and Supplement

Composition of supplements and forage is presented in Tables 1 and 2, respectively. Supplementation began approximately 64 d before calving. Heifers from both treatments were maintained together in endophyte-free, stockpiled tall fescue pastures. A total of four (4.05 ha) pastures were used throughout the study. Heifers strip-grazed pastures and were moved to a separate pasture when forage was limiting. Supplements were fed according to changes in the heifers’ nutritional requirements during the last stages of gestation, the first 60 d postpartum, 60 d to 90 d postpartum, and after 90 d postpartum; therefore, supplement quantity and composition differed during gestation, from calving to 60 d postpartum, 61 d postpartum to 90 d postpartum, and 91 d postpartum to termination of the study. The most limiting nutrient during the prepartum and postpartum phases was energy (NRC, 1996). Supplements fed to UIP heifers included 146 g of blood meal daily in the meal form. A mineral and vitamin mix was included in the supplement for each treatment and heifers had access to salt at all times. At 1500, heifers were placed in individual feeding stanchions and fed supplement, according to their treatment. Heifers remained in the stanchions until the supplement was consumed.

Using NRC (1996), supplements were evaluated for meeting crude protein, DIP, and metabolizable protein (MP) requirements during the prepartum and 60 d postpartum period. No attempt was made to calculate the intake of MP and DIP for the diets after 60 d postpartum because heifers were grazing the spring regrowth of endophyte-free tall fescue pasture. During the prepartum phase, the forage DMI for the Control and UIP treatments fed stockpiled tall fescue provided 510 and 608 g of DIP (based on DM intakes of 8.9 and 10.6 kg, respectively, CP content of 11.7% and ruminal protein degradability of 45%). With the amounts of supplemental DIP provided by the Control and UIP treatments, both diets exceeded the heifers’ DIP requirements. With MP requirements for a 450-kg gestating heifer of 510 g daily, the MP supplied by the Control (550 g) and UIP (610 g) treatments also exceeded the heifers’ MP requirements.

For the first 60 d of postpartum phase, DMI of tall fescue was predicted to be 7.2 kg (based on NRC, 1996). The lower DMI of tall fescue was based on supplemental intakes of approximately 3.7 kg daily. The consumption of stockpiled tall fescue would yield approximately 410 g of DIP and 430 g of MP daily. With Control and UIP supplemental treatments providing 410 and 451 g of additional DIP for the postpartum primiparous heifer, the supply of DIP for both treatments exceeded the heifers’ requirement (760 g of DIP; NRC, 1996). Likewise, the total supply of MP from Control (760 g of MP) and UIP (790 g of MP) treatments exceeded the requirements (680 g of MP/d) for 445-kg lactating heifers for the first 60 d of the postpartum phase.

Pasture samples were collected from each grazed area by dividing the area into 4 sections. Random samples were collected from each section using a quadrat (30.5 cm²). The forage was clipped from the area and compiled for analysis. The forage samples were dried in a forced-air oven at 50°C and ground through a Wiley mill to pass a 1-mm screen. The samples were later analyzed for DM, N (Leco Corp., St. Joseph, MI), NDF, ADF (nonsequential procedures; Goering and Van Soest, 1970). After calving, heifers and their calves were moved to a separate pasture and fed postpartum supplements at the same time and in the same manner as prepartum heifers. Heifers were offered brome hay along with their supplement from March 7 to 12 because of snow cover. The hay intake was not measured.

During the study, ambient temperatures were above normal in January and February (7.7°C for the high and −0.42°C for the low), whereas in March, temperatures were below normal (high of 8.9°C and a low of 0.78°C). For April through June, temperatures were also above normal (high of 24.9°C and a low of 13.6°C). During January through March, the precipitation was above normal (26.3 cm). April and June were also normal (total rainfall of 23.7 cm); however, in May there
Table 1. Ingredient and chemical composition of supplements

<table>
<thead>
<tr>
<th>Item</th>
<th>Supplementa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C-G</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>1.62</td>
</tr>
</tbody>
</table>

| Ingredient, % DM basis      |     |     |     |     |     |     |     |     |
| Cracked corn                | 27.3| 26.5| 30.7| 29.5| 29.3| 28.5| 30.0| 24.5|
| Soybean meal                | 13.0| 6.4 | 19.8| 19.0| 4.9 | 2.4 | —   | —   |
| Soyhulls                    | 63.0| 51.2| 43.7| 42.0| 58.5| 54.7| 60.9| 53.1|
| Blood meal                  | —   | 9.0 | 0   | 4.0 | —   | 8.1 | —   | 13.9|
| Cane molasses               | 6.2 | 6.3 | 2.9 | 2.7 | 2.4 | 2.4 | 1.7 | 1.8 |
| Mineral/vitaminb            | 0.5 | 0.5 | 2.8 | 2.6 | 4.2 | 4.1 | 7.4 | 6.9 |

| Component, % DM basis c     |     |     |     |     |     |     |     |     |
| DM                          | 91.3| 90.9| 88.0| 88.8| 89.9| 91.3| 90.6| 90.8|
| ADF                         | 29.4| 27.2| 25.2| 22.8| 31.5| 29.5| 31.3| 29.1|
| TDN                         | 84.1| 83.4| 83.0| 83.8| 82.9| 78.1| 78.4| 82.7|
| CP                          | 14.1| 19.3| 18.7| 22.3| 13.7| 19.0| 11.5| 23.3|
| DIP g/d                     | 157 | 155 | 410 | 451 | 121 | 138 | 57  | 84  |
| UIP g/d                     | 106 | 190 | 271 | 381 | 93  | 181 | 48  | 140 |
| NEe, Mcal/kg                | —   | 2.58| 2.54| 2.53| 2.46| 2.53| 2.40| —   |
| NEg, Mcal/kg                | 1.37| 1.32| 1.41| 1.39| 1.38| 1.34| 1.37| 1.30|
| NEm, Mcal/kg                | 2.02| 1.97| 2.23| 2.29| 2.28| 2.23| 2.28| 2.18|
| NEpreg, Mcal/kg             | 0.46| 0.44| —   | —   | —   | —   | —   | —   |

C-G and U-G = Control and UIP supplements, respectively, fed during gestation; C30 and U30 = Control and UIP supplements, respectively, fed from calving to 60 d postpartum; C60 and U60 = Control and UIP supplements, respectively, fed from 60 d postpartum to 90 d postpartum; C90 and U90 = Control and UIP supplements, respectively, fed from 90 d postpartum to termination of study.

*Contains 98% NaCl, 0.2% Fe, 0.3% Zn, 0.2% Mn, 0.04% Cu, 0.002% Co, 1,822,002 IU vitamin A, 364,400 IU vitamin D, and 547 IU vitamin E per kilogram.

Values determined by chemical analysis except for TDN, which was calculated (NRC, 1996).

Calculated from NRC (1996). The UIP values were calculated by dividing the grams per day of metabolizable protein supplied by UIP by 80%, the percent efficiency of conversion of UIP to metabolizable protein (NRC, 1996).

The term NEpreg was calculated by dividing NEm by 57.6% (efficiency of use of NE for maintenance) and multiplying the answer by 13% (efficiency of use of the NE for pregnancy; NRC, 1996).

Forage/Supplement Intake

Forage intake was estimated 30 d before calving using chromic oxide (Cr2O3) marker dilution. Heifers were dosed twice daily (0700 and 1900) with 7.5 g of Cr2O3 in a gelatin bolus. An adjustment period of 10 d was used before fecal samples were collected. Fecal grab samples were collected twice daily for 5 d at the time the Cr2O3 boluses were administered. Samples were then dried in a 55°C oven and ground in a Wiley mill (1 mm screen). Composite samples were tested for DM and Cr content. Chromium concentration was determined via atomic absorption spectroscopy (Model SpectrAA30, Varian, Sugarland, TX) with an air-plus acetylene flame (Williams et al., 1962). Fecal output was estimated from DM and Cr amount.

A forage sample was collected during the fecal collection period from an esophageally cannulated cow. The sample was frozen at −20°C, lyophilized, and ground (1 mm screen). The forage sample as well as the supplement samples from the fecal collection period were then tested for IVDMD as described by Tilley and Terry (1963) and modified by Moore (1970). Ruminal inoculum was obtained from a ruminally cannulated steer fed alfalfa hay. Cannulated animals were used under the guidance of an approved University of Missouri Animal Care and Use Committee protocol. The IVDMD was as follows: 56% (forage), 87% (UIP), and 86% (Control). Fecal output was divided by the indigestibility of the feed ingredients to estimate forage DMI.

Table 2. Chemical composition of fescue pasture and brome hay

<table>
<thead>
<tr>
<th>Item*</th>
<th>Fescue pasture</th>
<th>Brome hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM, %</td>
<td>91.0</td>
<td>88.7</td>
</tr>
<tr>
<td>CP, %</td>
<td>11.7</td>
<td>9.8</td>
</tr>
<tr>
<td>ADF, %</td>
<td>38.0</td>
<td>41.2</td>
</tr>
<tr>
<td>NEe, Mcal/kgb</td>
<td>0.48</td>
<td>0.40</td>
</tr>
<tr>
<td>NEp, Mcal/kgb</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>NEm, Mcal/kgb</td>
<td>0.69</td>
<td>0.62</td>
</tr>
<tr>
<td>NEpreg, Mcal/kgb</td>
<td>0.15</td>
<td>0.14</td>
</tr>
</tbody>
</table>

*All values except DM are expressed on a DM basis.

bEnergy values for grass forages were calculated from the ADF percentage of the forage using the calculations of R. L. Belyea (Coppock et al., 1981).

bNEpreg = NE for pregnancy, calculated by dividing NEm by 57.6% (efficiency of use of NE for maintenance) and multiplying the result by 13% (efficiency of use of NE for pregnancy; NRC, 1996).
Blood Samples and Hormone Assays

Blood samples were collected from heifers between 24 and 48 h after calving via coccygeal or jugular venipuncture. Blood samples were collected once weekly for the first 30 d postpartum. After 30 d postpartum, blood samples were collected three times weekly until the first rise in progesterone. Samples were immediately placed on ice, stored at 4°C overnight, and centrifuged at 1,000 × g at 4°C for 30 min. Serum was decanted and frozen at −20°C until analyzed.

Serum samples collected after 30 d postpartum were analyzed for progesterone concentrations via solid-phase RIA (Coat-A-Count, Diagnostic Products Corporation, Los Angeles, CA). Intra- and interassay CV were 3.6 and 8.7%, respectively. Assay sensitivity was 0.28 ng/mL. The first rise in progesterone was measured as an indication of the first ovulation after calving and was defined as 3 d before the first of three consecutive serum samples containing ≥ 1 ng/mL progesterone. Postpartum interval was defined as days from calving to first rise in progesterone.

Weekly serum samples from parturition to the first rise in progesterone were analyzed for serum concentrations of IGF-I using the RIA method described by Bilby et al. (1999). Intra- and interassay CV were 7.8 and 15.2%, respectively. Weekly serum samples from parturition to 35 d postpartum were also analyzed for urea N by colorimetric assay using a commercial kit (Sigma; Chemical Co., St. Louis, MO).

Milk Production

Milk production was determined by measuring calf intake with a modified weigh-suckle-weigh technique (Corah et al., 1975; Marston et al., 1995) using heifers that calved in February (16 UIP, 16 Control). The heifers were divided into two groups with one calving the first 2 wk of the month and the second group calving the last 2 wk of the month. Weigh-suckle-weigh measurements were then conducted at approximately 30 d postpartum and every 2 wk thereafter. Heifers and calves were observed to ensure they were correctly paired during suckling periods. The suckling periods did not last more than 30 min. Heifers had ad libitum access to brome hay and water during calf removal. The heifers were bunk-fed supplements after the calves nursed. Calves were placed in a pen bedded with straw and were not allowed access to water.

Breeding Season

Heifers were not eligible for breeding until they exhibited a normal luteal phase as determined by serum progesterone concentrations. Heifers that exhibited a normal luteal phase by May 24, 1998, were injected with PG (25 mg; Lutalise, Pharmacia & Upjohn, Kalamazoo, MI). Estrus detection began on the day after PG and occurred four times daily (sunrise, 1000, 1400, and sunset). At each time, heifers were observed for estrus for 1 h. Heifers observed in estrus were artificially inseminated on the following morning or evening by one trained technician. Heifers injected with PG remained on feed for 2 wk following the last day of estrus detection and were then placed in a pasture with a fertile Angus bull for the duration of the breeding season. Heifers exhibiting a normal luteal cycle after May 24, 1998, were placed with the bull following a normal luteal cycle and PG injection, but were not artificially inseminated. Heifers artificially inseminated (8 UIP, 10 Control) were used to determine first-service conception rate. The clean-up bull was removed August 1, 1998. Approximately 40 d after the removal of the clean-up bull, all heifers were checked for pregnancy via rectal palpation and ultrasonography by a trained technician.

Statistical Analysis

Effects of dietary treatment on BCS, BCS change, BW, BW change, calf weight, milk production, serum IGF-I, and postpartum interval were analyzed using ANOVA and the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) for a split-plot design with repeated measurements. The statistical model included treatment, heifer within treatment, time, and the time × treatment interaction as main effects. Calving date was included as a covariate. When the time × treatment interaction was significant, time within treatment was analyzed as a main effect for all repeatedly measured traits and treatment effects were analyzed using heifer within treatment as the error term. Means were separated using the PDIF option of SAS. Sex and days in milk were included as covariates for calf weight and milk production analyses, respectively. Four heifers did not return to estrus during the course of the study, three of which belonged to the UIP treatment. The postpartum interval of those four heifers was considered as a missing observation in the statistical analysis. Effects of mean BCS, BCS change, BW, and BW change on mean IGF-I concentrations and the effects of mean BCS, BCS change, BW, BW change, and IGF-I on postpartum interval were analyzed by linear regression in SAS. Data are reported as least squares means ± standard error.

Heifers were placed into postpartum interval groups in an attempt to define differences among heifers with different postpartum intervals. The groups were as follows: short, < 50 d; medium, 51 to 65 d; long, 66 to 130 d; and no return to estrus. These groups were selected based on visual inspection of the distribution of postpartum interval among individual heifers. Data were then analyzed for IGF-I, BCS, BCS change, BW, and BW change as dependent variables at calving, during the first 30 d postpartum, throughout the postpartum period, during the last 30 d postpartum, and at the first rise in progesterone. The last 4 wk of treatment were used as the last 30 d postpartum for heifers that did not return to estrus during the study. The statistical model included postpartum interval group, heifer...
within postpartum interval group, time, and time × postpartum interval group interaction as main effects. The effect of dietary treatment on first-service conception rate was analyzed using the CATMOD procedures of SAS. However, first-service conception rates between Control and UIP heifers were not different ($P < 0.16$; 7 of 8 UIP vs 6 of 10 Control) and will not be discussed in subsequent sections.

Results and Discussion

Forage Dry Matter Intake

Prepartum forage DMI tended to be greater ($P < 0.07$) for heifers supplemented with UIP than those supplemented with Control (10.6 vs 8.9 kg, respectively). These results disagree with Olson (1998), in which increasing supplemental UIP tended to decrease total OM intake from wk 8 to 5 prepartum. Sletmoen et al. (1994) reported no effect of supplemental UIP on intake during the last third of gestation. In both studies, low-quality forage was offered. Olson (1998) speculated that digestible intake protein (DIP) supply might have been marginal during late gestation. Martin and Hibberd (1990) observed decreasing intake with increasing UIP supplementation when DIP supply was inadequate. Given adequate DIP supply, as observed in this study, supplemental UIP may increase forage DMI. Others noted that supplemental UIP increased forage intake of lambs (Phillips et al., 1995) and cows (Forcherio et al., 1995) grazing high-quality forage.

Body Condition Score and Body Weight

There were no effects ($P > 0.2$) of dietary treatment on BCS, BCS change, BW, or BW change. There tended to be a treatment × time interaction on BCS ($P < 0.09$; Figure 1) with UIP heifers tending to have greater BCS than Control heifers at 5 ($P < 0.09$) and 7 ($P < 0.07$) wk postpartum and having greater BCS at 9 ($P < 0.03$) wk postpartum. Control heifers had greater BCS at wk 14 ($P < 0.01$) and 18 ($P < 0.01$).

The lack of treatment differences in BCS and BW was attributed to MP from forage and supplement exceeding MP requirements of heifers during the prepartum and postpartum phase as previously described and calculated based on NRC (1996). Even though MP requirements were met from forage and supplement intake for both dietary treatments, the increase in BCS in UIP vs Control cows for wk 5, 7, and 9 postpartum suggests that the greater supply of UIP complemented the amino acid supply from microbial protein. This explanation is supported by the findings of Hess et al. (1998), who observed that the supply of ruminally protected methionine and lysine to primiparous beef cows fed annual rye hay and a supplement that exceeded CP requirements by 125% (NRC, 1996) resulted in a repartitioning of nutrients to maternal tissue. Previous studies (Vogel et al., 1989; Forcherio, 1994), in which high-quality forage was consumed, revealed that supplemental UIP increased BW gain and milk production, respectively, and thus support the explanation that UIP redirected nutrients to increase maternal tissue or milk production.

Calf Weights and Milk Production

Calf birth weight, BW throughout the weigh-suckle-weigh periods, weaning weight ($P > 0.68$), and heifer milk production ($P > 0.8$) were not affected by treatment. This agrees with reports by Blasi et al. (1991), Wiley et al. (1991), and Dhuyvetter et al. (1993), who noted no increase in calf ADG or milk production of lactating heifers and cows maintained on high-quality forage and supplemented with UIP. Supplementation of UIP to lactating dairy cows resulted in no change in milk production (Keery and Amos, 1993; Son et al., 1996) with the exception of the highest producing cows, in which milk production was increased (Armentano et al., 1993). Negative effects of UIP supplementation on calf ADG and milk production of lactating cows fed high-quality forage have also been reported (Blasi et al., 1991; Forcherio et al., 1995); however, when low-quality forages were fed, supplemental UIP increased calf ADG (Rusche et al., 1993; Sletmoen et al., 1994). The quantity of supplemental UIP fed to Control and UIP heifers in this experiment was 0.59 and 0.83 (calving to 60 d postpartum) and 0.20 and 0.39 g/kg BW daily (60 to 90 d postpartum), respectively. With the

![Figure 1](image-url)
exception of the 0.20 g/kg BW supplemented to Control heifers from 60 to 90 d postpartum, these quantities of UIP supplemented daily have been shown to decrease milk production in mature lactating cows (Blasi et al., 1991; Forcherio et al., 1995). Therefore, in the present study, responses to UIP may depend on a threshold level of supplemental UIP or MP. The supplemental quantities fed to both treatments during this time period may have been above this level and thus no treatment differences were observed.

**Postpartum Interval, Insulin-Like Growth Factor-I, and Serum Urea Nitrogen**

There was no difference in postpartum interval due to treatment \((P > 0.68)\). These results disagree with those of Wiley et al. (1991), in which supplementation with 0.76 vs 0.10 g/kg BW daily of UIP decreased postpartum interval of lactating primiparous heifers. Dhuyvetter et al. (1993) reported that late-calving cows supplemented with 0.20 g UIP/kg BW daily had decreased postpartum interval compared with cows supplemented with 0.41 g UIP/kg BW daily. However, Dhuyvetter et al. (1993) also reported that the percentage of late-calving cows serviced in the first 21 d of the breeding season tended to be greater for cows fed 0.41 g UIP/kg BW daily when compared with cows fed 0.20 g UIP/kg BW daily, which seems contradictory to reported differences in postpartum interval. In the present study, the small differences in UIP levels in supplements (0.59 vs 0.83 g/kg BW from calving to 60 d postpartum; 0.2 vs 0.39 g/kg BW from 60 to 90 d postpartum, respectively) between Control vs UIP supplemental treatments as well as the supply of MP precluded any effect of supplemental UIP on postpartum interval.

There was a treatment \(\times\) time interaction for IGF-I concentrations \((P < 0.06;\) Figure 2) during the first 35 d postpartum. In UIP heifers, IGF-I was greater at calving \((P < 0.01)\) compared with Control heifers; however, these differences were not related to changes in BCS or BW. This agreed with the studies of Houseknecht et al. (1992) and Reecy et al. (1994), who noted an increase in serum concentrations of IGF-I with abomasal infusion of casein. Increasing serum concentration of IGF-I from 2 to 10 wk postpartum was observed in cows that returned to estrus compared with cows that remained anestrous (Roberts et al., 1997). Gong et al. (1991) and Spicer et al. (1993) have shown that IGF-I stimulates granulosa cell function in the bovine, whereas Stewart et al. (1995) demonstrated an increased number of LH binding sites and enhanced LH-induced production of progesterone attributed to IGF-I. Beam and Butler (1997, 1998) reported increased concentration of plasma IGF-I in dairy cows that developed ovulatory dominant follicles during the first follicular wave postpartum. Although concentrations of IGF-I were increased at calving in heifers receiving UIP, there was no treatment effect on postpartum interval \((P > 0.7)\). However, regression analysis revealed a 1 ng/mL increase in IGF-I (UIP and Control heifers) at calving \((P < 0.04)\) and throughout the postpartum period \((P < 0.01)\) decreased the postpartum interval by 0.13 d. Although UIP supplementation increased serum concentrations of IGF-I at calving compared with Control, there was no treatment effect throughout the postpartum period.

There was no effect of treatment on serum urea N concentration during the first 35 d postpartum \((15.0 \pm 0.39\) UIP vs 14.1 \pm 0.44 Control mg/100 mL; \(P > 0.33)\), nor was there a treatment \(\times\) time interaction \((P > 0.64)\). This was in contrast to reports in which supplementation with UIP increased (Wiley et al., 1991; Dhuyvetter et al., 1993) or decreased (Rusche et al., 1993) urea N concentrations of lactating heifers and cows. In the study by Wiley et al. (1991), there was an increase in the quantity of MP fed, but in the studies by Dhuyvetter et al. (1993) and Rusche et al. (1993) there were negligible differences in MP intake. Likewise, Hess et al. (1998) observed greater serum urea N concentration in primiparous heifers fed CP at 125% of NRC (1996) requirements, whereas supplemental rumen-protected amino acids had no effect on serum urea N concentration.

**Heifers with Different Postpartum Intervals**

There were significant differences among heifers with postpartum interval defined as short \((< 50\) d; \(n = 15)\), medium \((51\) to 65 d; \(n = 11)\), long \((66\) to 140 d; \(n = 8)\), and no return to estrus, \((n = 4;\) Table 3). Numerically, BCS was higher at all time points for heifers with short and medium postpartum intervals compared with heif-
hers with long postpartum intervals and no return to estrus, and was significantly different \((P < 0.01)\) throughout the postpartum period, during the last 30 d postpartum, and at the first rise in progesterone. Heifer BCS change and BW were not different at any time point, and BW change was different \((P < 0.05)\) only during the last 30 d postpartum. Heifers with long postpartum intervals gained weight during this time period. Because these heifers had a postpartum interval of 66 to 130 d, they were probably at or past peak lactation \((\text{Pond and Pond, 2000})\), and thus their lactational demands during the last 30 d postpartum were decreasing compared with heifers with short and medium postpartum intervals whose last 30 d postpartum occurred between 0 to 66 d postpartum. This may have contributed to the weight gain in heifers with long postpartum intervals during the last 30 d postpartum.

Serum concentrations of IGF-I were different among groups at calving \((P < 0.05)\), during the first 30 d postpartum \((P < 0.01)\), throughout the postpartum period \((P < 0.02)\), during the last 30 d postpartum \((P < 0.02)\), and at the first rise in progesterone \((P < 0.06)\). When analyzed by regression analysis, a 1 ng/mL increase in IGF-I at calving \((P < 0.05)\), during the first 30 d postpartum \((P < 0.01)\), throughout the postpartum period \((P < 0.01)\), and during the last 30 d postpartum \((P < 0.02)\) was associated with a decrease in postpartum interval of 0.13, 0.22, 0.13, and 0.17 d, respectively. The correlation coefficients between serum concentrations of IGF-I and postpartum interval for those time points were \(-0.33, -0.51, -0.45, \) and \(-0.40, \) respectively.

**Implications**

Supplemental undegraded intake protein did not reduce postpartum interval or increase milk production in primiparous beef heifers when metabolizable protein intake was adequate. The study, however, revealed the potential for supplemental undegraded intake protein to increase the serum concentration of insulin-like growth factor I and demonstrated a relationship between increased serum concentration of insulin-like growth factor I and reduced postpartum interval. Additional research is needed to elucidate the relationship between supplemental undegraded intake protein, insulin-like growth factor I, and postpartum interval. Advances made in this area of research will aid in improving the reproductive efficiency of beef cattle herds.

**Literature Cited**

Supplemental UIP for lactating beef heifers


