Effect of dried corn distillers grains plus solubles compared with soybean hulls, in late gestation heifer diets, on animal and reproductive performance

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ABSTRACT: Dried distillers grains plus solubles (DDGS) contain fat and rumen undegradable intake protein, both of which have been shown to increase reproductive performance in heifers. The mechanisms leading to enhanced reproduction have not been fully defined. The objectives of this research were to evaluate effects of DDGS in late gestation heifer diets on animal and reproductive performance and on blood plasma concentrations of GH, IGF-I, and NEFA. Over 2 yr, 201 heifers were randomly allotted to 1 of 2 diets, which were similar in energy and adequate in rumen degradable intake protein and were fed from d 190 of gestation through calving. Diets were grass hay with DDGS or soybean hulls (SBH) and a supplement. Cow BW and BCS were measured from the beginning of treatment through weaning. Blood samples were collected preparum on d 71 and 69 of the feeding period and weekly after calving for 4 and 6 wk (d 84 to 105 and d 76 to 111 relative to the feeding period) during yr 1 and 2, respectively. No treatment × year interactions were detected for any of the performance, hormonal, or reproductive dependent variables. Both treatments caused positive BW changes over the feeding period, but DDGS heifers had a greater ($P < 0.01$) positive BW change compared with SBH heifers. Initial and final BCS and BCS change were similar ($P > 0.26$) between DDGS and SBH treatments. Treatment did not influence ($P > 0.12$) BW or BCS change during the postpartum period. Calving ease, calf vigor, and calf birth weight, weaning weight, and ADG (birth to weaning) were similar ($P > 0.41$) between treatments. The proportion of cows that had initiated estrous cycles ($P = 0.46$) and the pregnancy distribution ($P > 0.21$) were similar between treatments. However, a greater ($P = 0.058$) percentage of DDGS cows became pregnant compared with SBH cows (94 and 84%). In both years, there were no effects of treatment ($P > 0.17$) or treatment × time ($P > 0.52$), but time influenced ($P < 0.05$) the concentrations of GH, IGF-I, and NEFA. Concentrations of GH were greater ($P < 0.05$) at calving and decreased through d 4 after calving. The IGF-I concentrations were greater ($P < 0.01$) around calving and decreased ($P < 0.05$) through d 8 or 6 (yr 1 or 2) and remained similar ($P > 0.10$) for the duration of the sampling period. Concentrations of NEFA increased from calving through d 8 and gradually declined through d 20. Prepartum diets containing DDGS, a source of fat and UIP, benefited pregnancy rates in well-maintained, primiparous beef heifers.

Key words: beef cattle, dried distillers grains plus solubles, fat, undegradable intake protein, reproduction

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INTRODUCTION

Effects of nutritional interactions on reproductive efficiency is well established (Wiltbank et al., 1962; Wiltbank, 1970; Short et al., 1990). Prepartum supplementation with fat, rumen undegradable intake protein (UIP), or both may optimize reproduction in young beef cows. Heifers supplemented with UIP (Patterson et al.,...

Mechanisms by which fat, UIP, or both act to influence reproductive function have not yet been fully elucidated. Fat supplementation has been reported to influence follicular growth (Wehrman et al., 1991; Ryan et al., 1992; Thomas et al., 1997). Dietary fat supplementation also causes changes in several metabolic hormones (Williams and Stanko, 2000). More specifically, dietary fats have increased insulin (Ryan et al., 1995; Thomas and Williams, 1996) and GH (Ryan et al., 1995; Thomas and Williams, 1996; Thomas et al., 1997). The role of GH on reproduction may be directly through its own receptors or indirectly by modulating IGF-I production. Similarly, Strauch et al. (2001) reported primiparous heifers supplemented with UIP before calving had increased concentrations of IGF-I, and this response was unrelated to changes in BW or BCS. Therefore, we hypothesized that feeding heifers diets during late gestation containing DDGS, as a source of added fat and UIP to meet or exceed MP requirements, would result in improved subsequent reproduction compared with heifers fed SBH diets with similar energy content and adequate rumen degradable intake protein (DIP).

Our objective was to evaluate effects of feeding DDGS compared with soybean hulls (SBH) in late gestation on heifer performance, calf performance, proportion of primiparous cows that had initiated estrous cycles, pregnancy distribution, final pregnancy rates, and parturient plasma concentrations of GH, IGF-I, and NEFA.

**MATERIALS AND METHODS**

**Year 1 and 2**

**Experimental Design.** This research was conducted in accordance with procedures approved by the South Dakota State University Institutional Animal Care and Use Committee during the winters of 2004 to 2005 and 2005 to 2006 at the South Dakota State University Cottonwood Research Station.

Pregnant crossbred heifers (n = 96 Angus × Hereford × Simmental, yr 1; and n = 105 predominantly Angus, yr 2) approximately 22 mo of age were used to evaluate DDGS compared with SBH on animal and reproductive performance. Before the current experiment, heifers were part of a winter development experiment and were developed in a drylot or on pasture (at 2 locations in yr 1 and 1 location in yr 2). During a 60-d breeding season, the heifers were bred as one group on pasture to Angus sires. For the current study, the heifers were blocked by previous development (yr 1, drylot-location 1, drylot-location 2, or pasture-location 1; and yr 2, drylot or pasture) and stratified within block by initial BW (505 ± 0.55 kg, yr 1; and 466 ± 0.33 kg, yr 2), initial BCS (5.90 ± 0.04, yr 1; and 5.5 ± 0.05, yr 2), and expected calving date (calculated by fetal age, as determined by previous transrectal ultrasonography; April 5 ± 1.29 d and April 14 ± 1.29 d, yr 1 and 2, respectively). Blocks were randomly allotted to 1 of 12 drylot pens. Pens were randomly allotted to 1 of 2 late-gestation dietary treatments (DDGS, n = 48 and n = 53; or SBH, n = 48 and n = 52, yr 1 and 2, respectively) with 6 pens/treatment, 4 pens/development (yr 1 and 2, respectively), and 7 to 10 animals/pen. Heifers were removed from treatment within 24 h after calving.

Diets were fed at a rate of 4.04 and 3.94 kg-heifer⁻¹·d⁻¹ of ground grass hay [predominantly crested wheatgrass, western wheat grass, and alfalfa; 88% DM; 9.1% CP (18.0% UIP); 37.0% ADF; 3.2% ether extract (EE); 57% TDN and 93% DM; 12% CP (18% UIP); 37% ADF; 3% EE; 51% TDN; all on a DM basis]. In addition, in yr 1 and 2, respectively, the heifers received 3.08 and 2.80 kg-heifer⁻¹·d⁻¹ of DDGS [90% DM; 29% CP (50% UIP); 10.6% EE; 91% DM; 25% CP (50% UIP); 13% ADF; 9% EE; all on a DM basis] or 3.45 and 3.17 kg-heifer⁻¹·d⁻¹ SBH [87% DM; 12% CP (25% UIP); 47% ADF; 3% EE and 88% DM; 13% CP (25% UIP); 44% ADF; 4% EE; all on a DM basis], and 0.31 kg-heifer⁻¹·d⁻¹ of a supplement formulated specifically for each diet each year [92% DM; 7% CP (36% UIP); 2% EE and 92% DM; 50% CP (10% UIP); 3% EE; DM basis, for DDGS and SBH, respectively, yr 1; and 92% DM; 14% CP (36% UIP); 9% ADF; 4% EE and 91% DM; 48% CP (10% UIP); 14% ADF; 3% EE; DM basis, for DDGS and SBH supplements, respectively, yr 2].

The DDGS diet was composed of 3.6 and 4.6% (yr 1) and 2.1 and 3.7% (yr 2) greater EE (DM basis) and UIP (tabular value), respectively, than the SBH control diet (Table 1). Diets were limited fed once daily in concrete bunks (34.7 m of bunk space/pen) at a constant rate from mean gestation d 190 (yr 1) or 194 (yr 2) through parturition [mean days on feed; 95.6 ± 2.5 and 97.8 ± 2.5 d (P = 0.55), yr 1; and 90.6 ± 2.1 and 92.8 ± 2.1 d (P = 0.49), yr 2; for DDGS and SBH, respectively]. Dietary treatments were formulated using the 1996 NRC computer model and were designed to be similar in energy, adequate in DIP (Table 1), and to meet or exceed the daily mineral requirements for a 508 and 466 kg of BW heifer (yr 1 and 2, respectively) at 240 d of gestation in thermoneutral conditions.

At the beginning of the feeding period, initial heifer BW was determined from an average of BW taken on 2 consecutive days (d –1 and 0). The final prepartum BW was determined from an average of BW taken on 2 consecutive days (d 71 and 72, yr 1; and d 68 and 69, yr 2) during the feeding period. Prepartum BW were measured after removal from feed and water for 12 h. Initial postpartum cow BW was measured within 24 h after parturition, and calving ease (1 = no assistance, 5 = malpresentation; Bellows et al., 1996) and calf vigor
scores (1 = nursing without assistance, 5 = calf dead at birth; Tubman et al., 2004) were assigned. Additional postpartum BW were determined before breeding and at weaning without prior removal from feed and water. The BCS were determined by 2 trained technicians, based on visual observation and palpation of the ribs and vertebrae (1 = thin, 9 = obese; Richards et al., 1986) in conjunction with the BW measurements. After parturition, primiparous cows had unlimited access to grass hay and access to a limited-intake vitamin and mineral supplement until adequate green grass was available in April. Primiparous cows were managed as a single group for an average of 97 and 70 d (yr 1 and 2, respectively).

Primiparous cows were exposed to fertile bulls (20 and 22 cows/bull; yr 1 and 2, respectively) for a 64- and 63-d breeding season beginning June 9 [yr 1; mean postpartum interval, 65.4 ± 2.6 and 63.2 ± 2.6 d; for DDGS and SBH, respectively; P = 0.56] and June 16 (yr 2; mean postpartum interval, 71.4 ± 2.1 d and 69.2 ± 2.1 d; for DDGS and SBH, respectively; P = 0.49). On d 5 of the breeding season, all primiparous cows received an injection of prostaglandin F2α (25 mg as 5 mL of ProstaMate i.m., IVX Animal Health, St. Joseph, MO, yr 1; or 500 μg as 2 mL of estroPLAN, Pfizer Animal Health, New York, NY, yr 2). In yr 1, on d 32 of the breeding season, cows were stratified by block and dietary treatment into 4 breeding groups and rotationally grazed on pastures of similar quality and quantity for the remainder of the breeding season. In yr 2, primiparous cows were stratified by development and dietary treatment and split among 2 similar pastures at the beginning of the breeding season. Pregnancy and fetal age were determined by transrectal ultrasonography 86 and 117 d and 52 and 108 d after the beginning of the breeding season, yr 1 and 2, respectively.

When heifers were removed from the experiment and from the subsequent data analysis, it was for reasons unrelated to dietary treatments. In yr 1, one heifer from the SBH treatment had to be euthanized due to complications resulting from calving. Data from heifers that failed to calve (n = 1, DDGS, yr 1; and n = 3 and 1, DDGS and SBH, respectively, yr 2) were removed from all performance and pregnancy analyses. Additionally, heifers that lost calves (due to dystocia or enterotoxemia) were removed from the postpartum animal and reproductive performance analyses (n = 9 and 3, yr 1; and n = 5 and 7, yr 2; for DDGS and SBH, respectively).

**Calves.** Calf BW was recorded within 24 h after parturition and monthly until weaning (168 ± 2 and 177 ± 2 d of age; yr 1 and 2, respectively). Calves were sorted from cows just before weighing on each weigh day.

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**Table 1.** Ingredient composition, chemical composition, and daily intakes for dried distillers grains plus solubles (DDGS) and soybean hull (SBH) diets consumed by gestating beef heifers

<table>
<thead>
<tr>
<th>Item</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 1</th>
<th>Year 2</th>
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<tr>
<td></td>
<td>DDGS</td>
<td>SBH</td>
<td>DDGS</td>
<td>SBH</td>
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<tr>
<td>Diet composition, % of DM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass hay</td>
<td>54.4</td>
<td>51.8</td>
<td>55.8</td>
<td>53.1</td>
</tr>
<tr>
<td>Dry distillers grains + solubles</td>
<td>41.4</td>
<td>—</td>
<td>39.8</td>
<td>—</td>
</tr>
<tr>
<td>Soybean hulls</td>
<td>—</td>
<td>44.2</td>
<td>—</td>
<td>42.7</td>
</tr>
<tr>
<td>Supplement</td>
<td>4.2</td>
<td>4.0</td>
<td>4.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Diet nutrient composition, % of DM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP4</td>
<td>17.2</td>
<td>12.0</td>
<td>17.2</td>
<td>13.6</td>
</tr>
<tr>
<td>DIP5, % of CP</td>
<td>59.5</td>
<td>80.2</td>
<td>62.5</td>
<td>80.3</td>
</tr>
<tr>
<td>UIP5, % of CP</td>
<td>40.5</td>
<td>19.8</td>
<td>37.5</td>
<td>19.7</td>
</tr>
<tr>
<td>Ether extract4</td>
<td>6.7</td>
<td>3.1</td>
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<td>40.0</td>
<td>26.3</td>
<td>39.1</td>
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<td>68.0</td>
<td>65.0</td>
<td>65.5</td>
<td>63.2</td>
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<tr>
<td>Daily intake</td>
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<tr>
<td>DMI, kg/d</td>
<td>7.4</td>
<td>7.8</td>
<td>7.1</td>
<td>7.4</td>
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<tr>
<td>NEmet6, Mcal/d</td>
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<td>10.3</td>
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<td>Ether extract,4 g/d</td>
<td>496</td>
<td>242</td>
<td>412</td>
<td>270</td>
</tr>
<tr>
<td>MP4, g/d</td>
<td>834</td>
<td>570</td>
<td>749</td>
<td>550</td>
</tr>
<tr>
<td>Rumen degradable intake protein4, g/d</td>
<td>761</td>
<td>748</td>
<td>758</td>
<td>814</td>
</tr>
<tr>
<td>Rumen undegradable intake protein4, g/d</td>
<td>511</td>
<td>187</td>
<td>455</td>
<td>200</td>
</tr>
</tbody>
</table>

1Diets were formulated to be similar in energy and to meet or exceed the rumen degradable intake protein requirement (assuming 13% microbial efficiency) for a 508 and 466 kg of BW (yr 1 and 2, respectively) heifer at 240 d of gestation under thermoneutral conditions, using the 1996 NRC computer model.

2Values listed on a DM basis.

3The DDGS and SBH diet supplements were formulated specifically for each diet.

4Calculated values based on laboratory analysis of feed ingredients.

5Calculated values based on tabular values of feed ingredients.

6Calculated values based on TDN values used for feed ingredients.
Table 2. Nutrient balance of gestating beef heifers consuming limit-fed, grass hay diets with dried distillers grains plus solubles (DDGS) or soybean hulls (SBH) before calving

<table>
<thead>
<tr>
<th>Item</th>
<th>January¹</th>
<th>February²</th>
<th>March³</th>
<th>April⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DDGS</td>
<td>SBH</td>
<td>DDGS</td>
<td>SBH</td>
</tr>
<tr>
<td>NEm balance⁶</td>
<td>0.5</td>
<td>0.6</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>MP⁷</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplied</td>
<td>834</td>
<td>570</td>
<td>834</td>
<td>570</td>
</tr>
<tr>
<td>Required</td>
<td>510</td>
<td>508</td>
<td>515</td>
<td>513</td>
</tr>
<tr>
<td>Balance</td>
<td>324</td>
<td>62</td>
<td>319</td>
<td>57</td>
</tr>
<tr>
<td>DIP⁸</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplied</td>
<td>761</td>
<td>748</td>
<td>761</td>
<td>748</td>
</tr>
<tr>
<td>Required</td>
<td>654</td>
<td>660</td>
<td>654</td>
<td>660</td>
</tr>
<tr>
<td>Balance</td>
<td>107</td>
<td>88</td>
<td>107</td>
<td>88</td>
</tr>
</tbody>
</table>

¹21 mo of age and 184 d of gestation; 13% microbial efficiency.
²22 mo of age and 214 d of gestation; 13% microbial efficiency.
³23 mo of age and 240 d of gestation; 13% microbial efficiency.
⁴24 mo of age and 274 d of gestation; 13% microbial efficiency.
⁵Calculated energy and protein balance for a 508-kg BW (yr 1) and 466-kg BW (yr 2) heifer consuming DDGS or SBH during late gestation (NRC, 1996).
⁶Net energy for maintenance (Mcal/d), calculated using the NRC based on TDN values for feedstuffs.
⁷Metabolizable protein (g/d), calculated from tabular and analyzed CP values.
⁸Degradable intake protein (g/d), calculated from tabular and analyzed CP values.

Calves were not offered any creep feed or additional supplementation while nursing the primiparous cows.

Analytical Procedures. Individual dietary feed ingredients were sampled weekly and composited over the feeding period for each year. Composite samples were thoroughly mixed, subsampled, and ground to pass a 1-mm screen in a Wiley Mill. Ingredient subsamples were assayed for CP (Kjeldahl method 954.01, AOAC, 1995), ADF (Goering and Van Soest, 1970), and EE (Soxhlet fat extraction method AOAC, 1995). The IVDMD was determined for the grass hay using a modified Tilley and Terry (1963) procedure, with the addition of 1 g of urea to the buffer (Weiss, 1994). The IVDMD (57.1 and 51.0% of DM; yr 1 and 2, respectively) was assumed to be equal to TDN for the grass hay used in both treatment diets. Tabular values of 88.0 and 80.0% TDN and values of 50.0 and 75.0% DIP were assumed for DDGS and SBH feedstuffs, respectively (NRC, 1996; Spiehs et al., 2002). Mineral analysis was conducted on a composite sample of the complete diet; all assayed minerals met or exceeded the animal requirements for both dietary treatments (Servi-Tech Labs, Hastings, NE; data not shown). For the heifers in this experiment, nutrient balances during the prepartum feeding period were evaluated using the NRC (1996) model (Table 2). Values used in the model included predicted feed intakes (kg of feed delivered to the pen – animal units/pen; at each feeding, all feed was consumed), along with analyzed, tabular, and assumed nutrient values for the feedstuffs used in the experiment. Data were modeled assuming thermoneutral conditions and 13% microbial efficiency.

For yr 1 and 2, respectively, blood samples were collected by jugular venipuncture into 10-mL Vacutainer tubes containing EDTA (Fischer Scientific, Pittsburgh, PA) from all prepartum heifers on d 71 and 69 of the feeding period (15.3 ± 0.65 and 17.7 ± 1.05 d before parturition) and weekly from all postpartum heifers after calving for 4 and 6 (to further characterize changes in concentrations of hormones) consecutive weeks (d 84 to 105 and 76 to 111, relative to the beginning of dietary treatment). Blood was immediately placed on ice and shipped to the laboratory. Within 24 h, plasma was harvested after centrifugation (1,200 × g for 25 min at 4°C) and stored at −20°C until analyzed for GH and IGF-I. Blood samples also were collected 7 and 10 d before the beginning of the breeding season and 11 (yr 1) and 14 (yr 2) d later to determine the percentage of animals that had initiated estrous cycles at the beginning of the breeding season. Primiparous cows with plasma concentrations of progesterone ≥1 ng/mL in one of the 2 samples were considered to be cycling. Primiparous cows were determined to be anestrus if the concentrations of progesterone were <1 ng/mL in both samples.
Plasma concentrations of GH were determined in duplicate by RIA. Plasma samples and standards (0.13, 0.25, 0.50, 1.25, 2.50, 3.75, 5.00, and 10.00 ng/tube) were incubated with 200 μL of GH antiserum (National Hormone and Peptide Program, Torrance, CA; 1:30,000, vol/vol, dilution) at 4°C for 24 h. After incubation, 100 μL of [¹²⁵I] GH (adjusted to 20,000 cpm/100 μL) was added to each tube and incubated at 4°C for 24 h. Separation of bound and free GH was performed by the addition of 100 μL of preprecipitated sheep anti-rabbit antibody (15 min incubation at room temperature) followed by centrifugation at 1,200 × g for 30 min. The supernatant was removed, and the precipitate was counted in a gamma counter for 1 min. Increasing volumes of bovine serum (0, 200, and 300 μL) produced a displacement curve that was parallel \( (P = 0.43) \) to the standard curve (slope = 2.80 ± 0.66 for the standard curve; slope = 2.53 ± 0.71 for bovine serum). Addition of known amounts of GH (0, 1, and 5 ng/mL) to cow serum were accurately recovered (95%; \( r = 0.99 \)). Intra- and interassay CV were 4.0 and 6.3% (yr 1) and 4.5 and 18.5% (yr 2), respectively. Assay sensitivity was 0.65 ng/mL.

Plasma concentrations of IGF-I were determined in duplicate by RIA using a method described previously by Funston et al. (1995). Increasing volumes of bovine serum (0, 200, and 300 μL) produced a displacement curve that was parallel \( (P = 0.35) \) to the standard curve (slope = 2.34 ± 0.06 for the standard curve; slope = 2.24 ± 0.15 for bovine serum). Addition of known amounts of IGF-I (0, 1, 4, and 5 ng/mL) to cow serum were accurately recovered (109%; \( r = 0.96 \)). Intra- and interassay CV were 3.5 and 12.8% (yr 1) and 3.8 and 14.0% (yr 2), respectively. Assay sensitivity was 4.0 ng/mL.

Plasma concentrations of progesterone were analyzed by RIA. Duplicate samples (50 μL) with 350 μL of assay buffer (0.1% gelatin, 0.05% sodium azide, 0.09% NaH₂PO₄, 0.05% Na₂HPO₄, and 0.9% NaCl, pH 7.0) and progesterone standards (0.02, 0.04, 0.10, 0.20, 0.50, 1.0, 1.5, and 2.0 ng/tube) were incubated with 200 μL of progesterone antiserum (Assay Designs, Ann Arbor, MI; 1:550,000 vol/vol dilution) at 4°C for 20 h. After incubation, 100 μL of [¹²⁵I] progesterone (adjusted to 20,000 cpm) were added to each tube and incubated at 4°C for 20 h. Bound and free progesterone were separated by addition of 100 μL of preprecipitated goat anti-mouse secondary antibody (15 min incubation) followed by centrifugation at 1,200 × g for 30 min. Supernatants were aspirated, and the precipitates were counted in a gamma counter for 1 min/tube. Cross reactivities of the antibody, as determined by the manufacturer, were 100% for progesterone, 3.46% for 17-hydroxyprogesterone, 0.77% for corticosterone, 0.056% for deoxycorticosterone, and <0.001% for estradiol-17β, estrone, estriol, testosterone, hydrocortisone, 5α-pregnane-3α, 20α-diol, and danazol. Increasing volumes of bovine serum (2, 4, 10, 20, 50, 70, 100, and 150 μL) produced a displacement curve that was parallel \( (P = 0.51) \) to the standard curve (slope = 2.17 ± 0.31 for the standard curve; slope = 2.52 ± 0.66 for bovine serum). Addition of known amounts of progesterone (0, 1, 3, and 5 ng/mL) to cow serum were accurately recovered (94.3%; \( r = 0.98 \)). Concentrations were determined in all samples in one assay, with an intraassay CV of 6.8 and 3.5%, yr 1 and 2, respectively. Assay sensitivity was 0.4 ng/mL.

Plasma concentrations of NEFA (yr 2 only) were quantified in duplicate with an enzymatic colorimetric assay kit (NEFA-C Wako Chemicals USA, Richmond, VA) with intra- and interassay CV of 4.3 and 9.0%, respectively.

**Year 1 and Year 2 Statistical Analysis**

All BW and BCS data were analyzed by ANOVA using the GLM procedure (SAS Inst. Inc., Cary, NC) for a fixed model with year, development (year), treatment, treatment × year, and treatment × development (year) as independent variables. Pen was the experimental unit, and the residual experimental error was the error term. Heifer BW and BCS data collected at the beginning of the feeding period were analyzed to determine if both treatments had similar \( (P = 0.85 \) and \( P = 0.83 \), for yr 1 and 2, respectively) initial BW and BCS, and therefore no covariate adjustment was required. Actual calving date was included in the initial analysis; however, calving date was not significant \( (P > 0.05) \) as a covariate for any of the BW and BCS dependent variables and was therefore removed from the model. When a significant \( (P ≤ 0.05) \) effect of treatment or treatment × year was detected, least squares means were separated by the PDIFF option of SAS. No significant \( (P > 0.05) \) treatment × year interactions were detected; thus, year was removed from the model, and the data are presented as the main effect of treatment least squares means ± SE of the mean.

Plasma concentrations of GH, IGF-I, and NEFA data were analyzed by repeated measures using the MIXED procedure of SAS, as described by Littell et al. (1998) for yr 1 and yr 2 independently. All covariance structures were modeled in the initial analysis. The indicated best fit covariance structure, compound symmetry, was used for the final analysis. The model included the independent variables of treatment, time, and treatment × time. In both years, samples were blocked by time relative to calving. All prepartum blood samples were blocked as prepartum. The subsequent postpartum blood samples were blocked by a 2-d intervals relative to parturition \( (yr \ 1, n = 54, 32, 10, 16, 15, 17, 10, 17, 18, 8, 12, 8, \) and 6 for prepartum \( (15.3 ± 0.65 \) d, before parturition), \( d 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, \) and 24 postpartum, respectively; \( yr \ 2, n = 75, 20, 21, 29, 21, 16, 17, 19, 16, 13, 20, 15, 19, 16, 15, 12, 7 \) and 6 for prepartum \( (17.7 ± 1.05 \) d, before parturition), \( d 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, \) and 34 postpartum, respectively).

Cyclicity and pregnancy data were analyzed using the CATMOD procedure of SAS, with pen as the experi-
mental unit. The model included the independent variables of treatment, year, and treatment × year. No significant \((P > 0.05)\) treatment × year interaction was detected; thus, the data were presented as the main effect of treatment.

Pregnancy distribution was analyzed by repeated measures for categorical data, using SAS as described by Koch et al. (1977). All covariance structures were modeled initially. The indicated best fit model of compound symmetry was used as the covariance structure. Pen was used as the experimental unit. The statistical model included the independent variables of treatment, year, time, treatment × year, treatment × time, and treatment × year × time.

**RESULTS**

**Animal Performance**

Both DDGS- and SBH-supplemented heifers had a positive BW change (58 ± 1.4 and 49 ± 1.4 kg, respectively) over the feeding period, but the BW change in DDGS-supplemented heifers was greater \((P < 0.01)\) compared with SBH supplemented heifers. Consequently, DDGS-supplemented heifers had a heavier final BW \((P = 0.01)\) just before parturition (Table 3). There were no differences between DDGS- and SBH-supplemented heifers for final \((P = 0.47)\) or change \((0.01 \pm 0.04, \text{respectively}; P = 0.97)\) in BCS during the feeding period (Table 3).

Cow BW, taken within 24 h after parturition, at the beginning of the breeding season, and at weaning were similar \((P \geq 0.09)\) for DDGS and SBH treatments (Table 3). There was no effect of treatment on BW change from calving to breeding \((15.1 \pm 1.9 \text{ kg}; \text{DDGS and SBH, respectively}; P = 0.69)\) or from calving to weaning \((-5.5 \pm 0.6 \pm 4.9 \text{ kg}; \text{DDGS and SBH, respectively}; P = 0.39)\). Subsequently, BCS changes from just before calving until breeding \((-0.27 \pm 0.05; P = 0.98)\) and calving until weaning \((-0.35 \pm 0.05; P = 0.12)\) were similar for DDGS and SBH supplemented primiparous cows, respectively. Although SBH supplemented cows had a lower \((P = 0.03)\) BCS at weaning compared with DDGS supplemented cows, both treatments maintained a BCS >5.0 from calving through weaning (Table 3).

Both calving ease \((1.37 \pm 0.11; P = 0.41)\) and calf vigor scores \((1.35 \pm 0.12; P = 0.72)\) were similar for DDGS and SBH treatments, respectively. Average calving date \((April 4 \pm April 7 \pm 1.6 \text{ d}; P = 0.17)\) and age at weaning \((174 \pm 171 \pm 1.6 \text{ d}; P = 0.17)\) were similar for DDGS and SBH treatments, respectively. Actual calf birth weights \((38 \pm 38 \pm 0.62 \text{ kg}; P = 0.73)\), weaning weights \((191 \pm 190 \pm 2.9 \text{ kg}; P = 0.74)\), and ADG \((0.88 \pm 0.88 \pm 0.01 \text{ kg}; P = 0.79)\) from birth to weaning did not differ between DDGS and SBH treatments, respectively.

**Growth Hormone**

In yr 1 and 2, there was no effect of treatment \((P \geq 0.30)\) or treatment × time \((P \geq 0.87)\), but there was an effect of time \((P < 0.05)\) on plasma concentrations of GH (Figure 1). In yr 1, plasma concentrations of GH were similar \((P = 0.68)\) prepartum \((15.3 \pm 0.65 \text{ d before parturition})\) and on d 2 postpartum. In yr 2, concentrations of GH were increased \((P = 0.03)\) on d 2 postpartum compared with prepartum concentrations \((17.7 \pm 1.05 \text{ d before parturition})\). In both years, plasma concentrations of GH decreased \((P < 0.04)\) from d 2 to 4 after calving. Throughout the remainder of the yr 1 sampling period, plasma concentrations of GH remained at concentrations similar to d 4 \((P \geq 0.54)\). In yr 2, plasma concentrations of GH remained similar \((P \geq 0.12)\) from d 4 through 32, with the exception of d 26 \((P = 0.02)\). Beginning on d 20, plasma concentrations of GH had increased to concentrations similar \((P < 0.12)\) to those observed d 2 after calving (Figure 1).

**Insulin-like Growth Factor-I**

In both yr 1 and 2, there were no effects of treatment \((P \geq 0.17)\) or treatment × time \((P = 0.52)\), but there was an effect of time \((P < 0.001)\) on plasma concentrations of IGF-I (Figure 2). Plasma concentrations of IGF-I in yr 1 were increased \((P < 0.01)\) at d 2 after calving, compared with prepartum \((15.3 \pm 0.65 \text{ d before parturition})\), and decreased \((P < 0.05)\) through d 8. From d 8 through 24 postpartum, with the exceptions of d 12 and 20 \((P < 0.04)\), plasma IGF-I concentrations were similar \((P \geq 0.19)\). In yr 2, plasma concentrations of IGF-I decreased from before calving to d 6 after calving and remained at similar concentrations \((P > 0.10)\) through d 34 after calving (Figure 2).

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**Table 3. Performance of gestating and lactating beef females that consumed limit-fed, grass hay diets with dried distillers grains plus solubles (DDGS) or soybean hulls (SBH) before calving**

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DDGS</td>
<td>SBH</td>
<td></td>
</tr>
<tr>
<td>Prepartum BW, kg</td>
<td>486</td>
<td>487</td>
<td>1.4</td>
</tr>
<tr>
<td>Initial</td>
<td>543</td>
<td>536</td>
<td>1.8</td>
</tr>
<tr>
<td>Prepartum BCS</td>
<td>5.75</td>
<td>5.70</td>
<td>0.03</td>
</tr>
<tr>
<td>Initial</td>
<td>5.76</td>
<td>5.71</td>
<td>0.04</td>
</tr>
<tr>
<td>Postpartum BW, kg</td>
<td>497</td>
<td>492</td>
<td>1.8</td>
</tr>
<tr>
<td>Calving</td>
<td>512</td>
<td>510</td>
<td>5.7</td>
</tr>
<tr>
<td>Breeding</td>
<td>491</td>
<td>493</td>
<td>5.6</td>
</tr>
<tr>
<td>Weaning</td>
<td>5.75</td>
<td>5.70</td>
<td>0.05</td>
</tr>
<tr>
<td>Postpartum BCS</td>
<td>5.49</td>
<td>5.43</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>5.40</td>
<td>5.24</td>
<td>0.05</td>
</tr>
</tbody>
</table>

1Main effect of treatment.
NEFA

There was no effect of treatment \((P = 0.68)\) or treatment × time \((P = 0.86)\) on plasma concentrations of NEFA in yr 2; however, there was an effect of time \((P < 0.001; \text{Figure 3})\). Concentrations of NEFA were increased from prepartum \((17.7 ± 1.05 \text{ d before parturition}; 0.6 ± 0.04 \text{ mEq/L})\) concentrations through d 4 to 8 postpartum \((1.04 ± 0.07 \text{ mEq/L})\), then gradually declined through d 20 to concentrations similar \((P > 0.44)\) to those observed prepartum (Figure 3).

Reproductive Performance

The proportions of primiparous cows that had initiated estrous cycles at the beginning of the breeding season were similar \([67 and 72 ± 3\%; P = 0.46]\) between DDGS- and SBH-supplemented, and there was no effect of year \((P = 0.58)\) or treatment × year \((P = 0.23)\). There were no effects of year \((P = 0.08)\), treatment \((P = 0.56)\), year × treatment \((P = 0.20)\), or treatment × year × time \((P = 0.40)\) for pregnancy distribution (Figure 4). As would be expected, the percentage of animals that be-
came pregnant increased \( (P < 0.001) \) as the breeding season progressed, and there was a treatment \( \times \) time interaction \( (P = 0.05; \text{Figure 4}) \). There were no effects of year \( (P = 0.25) \) or treatment \( \times \) year \( (P = 0.68) \) on overall pregnancy rates. There was an effect of treatment \( (P = 0.058) \), with DDGS-supplemented primiparous cows having a greater final pregnancy rate compared with SBH-supplemented cows [94 and 84 \( \pm \) 2\%, respectively].

**DISCUSSION**

Gestating beef heifers that consumed limit-fed grass hay-DDGS diets gained more BW than heifers consuming limit-fed grass hay-SBH diets. Although diets were formulated according to NRC (1996) to be similar in energy, the weight advantage of the DDGS heifers over SBH heifers suggests that we may have slightly underestimated the energy value of the DDGS or overesti-
imated the energy value of the SBH feedstuffs used in these experiments. Current NRC (1996) recommendations and data from Spieths et al. (2002) suggest that dried distillers grains plus solubles have at least the energy of corn. Work from Nebraska showed that when DDGS was compared with dry rolled corn in high forage diets, forage intake was similar but ADG was greater for the DDGS-supplemented heifers (Loy et al., 2003).

The BW advantage observed for the DDGS heifers was only 9 kg and not significant enough to affect prepartum BCS, indicating that heifers performed well on both diets. Previously, researchers have reported no effect on BCS or BW change relative to control cattle in response to late gestation supplementation with UIP (Sletmoen-Olson et al., 2000; Patterson et al., 2003) or fat (Alexander et al., 2001; Bellows et al., 2001). The beef NRC (1996) was used to evaluate and model energy and protein status for heifers in the present study. The model revealed that DDGS and SBH heifers were slightly deficient in NE\textsubscript{m} beginning at 240 d of gestation in yr 1 and protein status for heifers in the present study was only 9 kg and not significant enough to affect prepartum BCS, indicating that heifers performed well on both diets. Previously, researchers have reported no effect on BCS or BW change relative to control cattle in response to late gestation supplementation with UIP (Sletmoen-Olson et al., 2000; Patterson et al., 2003) or fat (Alexander et al., 2001; Bellows et al., 2001). The beef NRC (1996) was used to evaluate and model energy and protein status for heifers in the present study. The model revealed that DDGS and SBH heifers were slightly deficient in NE\textsubscript{m} beginning at 240 d of gestation in yr 1 and at 214 d of gestation in yr 2. Estimated DIP was more than adequate over the entire feeding period for both diets; however, MP appeared to be deficient for the SBH-supplemented heifers just before calving in both years. Late gestation dietary treatments did not cause subsequent effects on postpartum BW or changes in BW or BCS from calving to weaning. In agreement, Small et al. (2004) showed no associated effects from limit-fed, high-fat diets offered for 61 d precalving on postpartum BW and BCS through breeding compared with isoenergetic, isonitrogenous control diets. Other reports support the absence of an effect of prepartum supplemental lipids on BW and BCS change during the postpartum period (Alexander et al., 2001; Martin et al., 2005).

Supplementation with DDGS during late gestation did not influence the proportion of primiparous cows initiating estrous cycles by the beginning of the breeding season or the distribution of pregnancies throughout the breeding season. After approximately a 60-d natural service breeding season, DDGS-supplemented primiparous cows had a greater pregnancy rate compared with SBH-supplemented cows. The MP deficiency of the SBH treatment diet, during the last 30 d before calving, may be an important aspect limiting maximum conception rates. However, supplementing cows with additional UIP, with or without propionate, beyond MP requirements resulted in decreased postpartum interval but did not influence overall pregnancy rates (Waterman et al., 2006). Sletmoen-Olson et al. (2000) reported no improvement in pregnancy rates when isocaloric and iso-DIP diets were fed with increasing amounts of UIP for the last 3 mo of gestation and the first 3 mo of lactation. However, Patterson et al. (2003) found 2-yr-old pregnancy rates were improved when supplemental UIP was provided to meet the MP requirements during the prepartum period. Similarly, supplemental dietary fat from a variety of oilseed sources provided to beef heifers between 55 and 65 d before calving has been reported to increase subsequent overall pregnancy rates compared with low dietary fat levels (Lammoglia et al., 1997; Bellows et al., 2001). Therefore, additional fat supplied in the DDGS diet also may have been a significant factor contributing to the difference in pregnancy response. Graham et al. (2001) reported supplementing multiparous cows with whole soybeans for approximately 40 d before calving did not affect luteal activity or final pregnancy rates. However, for natural service and AI breeding programs, first service conception rates and AI pregnancy rates were greater among fat-supplemented compared with control cows (Graham et al., 2001). In contrast, Small et al. (2004) reported that the number of multiparous cows cycling by 60 d postpartum, first service conception rates, and overall conception rates were similar for cows receiving limit-fed diets containing between 4.6 and 2.7% dietary fat for 61 d before calving. Other researchers also have reported no influence of prepartum dietary lipids in beef cow diets on postpartum interval (Geary et al., 2002), ovarian activity at the beginning of the breeding season (Martin et al., 2005), pregnancy distribution (Geary et al., 2002; Martin et al., 2005), first service conception rates (Alexander et al., 2001), or overall pregnancy rates (Alexander et al., 2001; Geary et al., 2002; Martin et al., 2005) compared with low dietary lipid controls. Thus, effects of prepartum fat and UIP supplementation on subsequent reproductive parameters and overall pregnancy have been mixed. Among these studies animal type (heifers, primiparous or multiparous cows) and animal numbers can potentially limit the ability to detect differences. In a review, Hess et al. (2002) explored this potential by combining the similar data sets of Bellows et al. (2001) and Alexander et al. (2001) to conduct a chi-square analysis. The resulting analysis revealed an improvement in pregnancy rates for beef heifers when supplemental fat was provided prepartum. Hess et al. (2002) suggested a 10.5% improvement in pregnancy rates might be reasonable for heifers supplemented with dietary fat for the last 65 d before calving. Although none of the other reproductive parameters measured differed between dietary treatment in the present study, primiparous cows supplemented prepartum with lipids and UIP from DDGS had an improvement in final pregnancy rates, similar to that predicted by the analysis of Hess et al. (2005).

Young, primiparous cows are typically the most difficult class of females to manage nutritionally and often have extended postpartum intervals compared with mature, multiparous cows (Lalman et al., 2000; Meikle et al., 2004). Body condition scores at calving have a significant impact on subsequent reproductive performance in both multiparous and primiparous beef cows and may be the most important factor influencing early postpartum return to estrus (Richards et al., 1986). Several researchers have suggested that managing cows to calve in a BCS 5 to 6 will ensure adequate...
reproductive performance (Spitzer et al., 1995; Vizcarra et al., 1998; Lake et al., 2005). The young cows in the present study were in adequate body condition from late gestation through weaning, and changes in BCS were similar between dietary treatments. In agreement with our hypothesis, differences observed in final pregnancy rates were independent of effects on BCS. Although target BCS are beneficial to ascertain sufficient body energy reserves, results from this study demonstrate other factors exist that affect reproductive performance.

The exact mechanisms by which supplemental lipids, UIP, or both enhance subsequent reproductive performance in beef cattle have not been fully elucidated. Dietary fat supplementation has been reported to cause changes in several metabolic hormones (Williams and Stanko, 2000). More specifically dietary fats have increased insulin (Ryan et al., 1995; Thomas and Williams, 1996) and GH (Ryan et al., 1995; Thomas and Williams, 1996; Thomas et al., 1997). Strauch et al. (2001) reported primiparous heifers supplemented with UIP beginning 64 d before calving had increased concentrations of IGF-I, and this response was unrelated to changes in BW or BCS. The role of the GH-IGF-I pathway on reproduction has had tremendous investigation (Lucy, 2000). Sustained postpartum increases in GH and depressed IGF-I are observed in relation to reduced body condition (Meikle et al., 2004; Lake et al., 2005) in beef and dairy cows and negative energy balance in dairy cows (Vandehaar et al., 1995; Meikle et al., 2004). Increased postpartum IGF-I concentrations have been associated with improved reproductive function (Roberts et al., 1997; Zulu et al., 2002). Normal follicular development may depend largely on concentrations of IGF-I (Zulu et al., 2002), whether systemic or ovarian derived (Stewart et al., 1995). In the present study, prepartum dietary treatment had no apparent effect on plasma concentrations of GH or IGF-I. Concentrations of GH and IGF-I were increased around the time of parturition and decreased within a few days. Similarly, Alexander et al. (2001) found no effect of prepartum fat supplementation on systemic concentrations of IGF-I before or during the postpartum interval. The observed response in the GH-IGF-I axis is consistent with other published data for cows in excellent to moderate nutritional status at parturition (Schams et al., 1991; Lulman et al., 2000; Lake et al., 2006).

The extent of negative energy balance and adaptation to energy balance can have a profound effect on metabolic changes around the time of calving and early lactation (Jorritsma et al., 2003). Plasma concentrations of NEFA are typically increased during periods of negative energy balance, common to early lactation. In the present study, plasma concentrations of NEFA were increased during early lactation, peaked early, and subsequently declined. In addition NEFA concentrations were not differentially influenced by prepartum diet.

In the present study, neither calving difficulty nor calf vigor differed as a result of dietary treatment. Similar results have been published for beef dams that received supplemental lipids (Bellows et al., 2001; Dietz et al., 2003; Small et al., 2004) or protein (Bolze et al., 1985) prepartum. In contrast, Lammoglia et al. (1997) observed reduced incidence of calving difficulty and improved calf vigor and cold tolerance (Lammoglia et al., 1999) in calves from fat-supplemented dams. Calves from DDGS-supplemented heifers had similar birth weights, weaning weights, and ADG compared with calves from SBH-supplemented heifers in the present study. Similarly, Martin et al. (2005) reported corn germ supplementation during the prepartum period did not influence calf birth or weaning weights, and Small et al. (2004) reported similar calf birth weights, weaning weights and ADG for limit-fed gestation diets with or without fat. Miner et al. (1990) reported calf birth weights to be similar between dams fed soybean meal diets with or without additional UIP or fat.

In conclusion, DDGS and SBH diets caused similar effects on heifer BW and BCS change, calving ease, calf performance, and blood metabolites. Both feedstuffs can be fed during the last trimester of gestation to replace hay in limit-fed heifer diets. Heifers supplemented with DDGS had a greater overall pregnancy rate than SBH-supplemented heifers. The observed pregnancy response could have been due to DDGS supplying supplemental UIP to meet late gestation MP requirements or supplemental fat or may have involved a combined response due to fat and UIP. The mechanisms by which fat or UIP or the combination of fat and UIP work to affect reproductive function remain unclear.

**LITERATURE CITED**


