ABSTRACT: Effects of body condition score (BCS) at parturition and postpartum weight gain on luteal activity and concentrations of glucose, insulin, and NEFA in plasma were evaluated during the breeding season in 242 primiparous beef cows over 3 yr (Y) at three locations (L). At approximately 90 d prepartum, cows were blocked by breed, expected calving date, and BCS and randomly assigned to diets so that cows would calve in BCS of 4, 5, or 6. At calving, cows were blocked by breed, calving date, and BCS and randomly allotted to gain .45 (M) or .90 (H) kg/d, from parturition to the start of breeding (postpartum nutrition; PPN). During the 60-d breeding season, weekly blood samples were obtained from cows, and progesterone, insulin, glucose, and NEFA were quantified. Progesterone concentrations greater than 1 ng/mL for more than 1 wk indicated luteal activity. To determine the possible value of blood constituents as predictors of luteal activity, categorical data analyses were performed. Cows with greater BCS at parturition had greater concentrations of glucose during breeding (P < .07). Similarly, PPN influenced glucose at the beginning of breeding, but the differences were minimal after d 28 (PPN × day; P < .001). Cows with greater BCS at parturition and M-PPN had greater concentrations of insulin during the breeding season (BCS × PPN; P < .02). Cows with a BCS of 6 at parturition had the lowest concentrations of NEFA; however, cows on H-PPN had greater concentrations of NEFA (BCS × PPN; P < .03). Location, BCS, PPN, and day affected luteal activity (P < .002). Location differences in luteal activity were associated with the interval from calving to the start of breeding. In general, a greater percentage of cows with BCS of 5 or 6 at calving had luteal activity by the end of the breeding season. Concentrations of metabolites in blood during breeding were not predictive of luteal activity. We conclude that BCS at parturition and postpartum nutrition influence concentrations of glucose, insulin, and NEFA in blood and the onset of luteal activity in primiparous beef cows.

Key Words: Nutrition, Body Composition, Reproduction, Glucose, Insulin, Cows

Introduction

Nutritional management is a major factor controlling reproduction in beef cows. Reduced nutrient intake is associated with loss of body weight, which in turn is manifested in changes in body condition score (BCS), decreased luteal activity, and cessation of estrous cycles (Richards et al., 1989a; Bishop and Wettemann, 1993; Vizcarra et al., 1997). The mechanism by which nutrition influences reproduction in cattle remains unclear, although it is established that body energy reserves control reproductive performance in cows (Richards et al., 1986; Selk et al., 1988; Spitzer et al., 1995). The use of BCS is an accurate and repeatable method to estimate body energy or fat reserves of beef cows (Wagner et al., 1988; Vizcarra and Wettemann, 1996).

Concentrations of glucose in plasma are affected by BCS (Adams et al., 1987) and may influence reproductive performance in cattle. Energy restriction decreased insulin concentrations in heifers (Harrison and Randel, 1986; McCann and Hansel, 1986; Yelich...
Animals and Treatments

Detailed descriptions of the animals, locations, and treatments for this experiment have been reported (Spitzer et al., 1995). Briefly, 242 primiparous beef cows calving at 21 to 23 mo of age were used in an experiment replicated over 3 yr in three locations. Louisiana (LA) used a total of 74 cows (Angus × Hereford and Simmental × Angus-Hereford) in yr 1 and 3, Oklahoma (OK) used 66 Hereford or Angus × Hereford cows during yr 1 and 2, and South Carolina (SC) used 102 Angus cows during yr 1, 2, and 3. At approximately 90 d prepartum, cows were blocked by breed, expected calving date, and BCS (1 = emaciated, 9 = obese; Wagner et al., 1988) and randomly assigned to diets so that cows would calve in BCS of 4, 5, or 6. All cows calved in a 60-d period at a location each year. At calving, cows were blocked by breed, calving date, and BCS within each location and randomly allotted to gain .45 (moderate) or .90 (high) kg/d, from parturition to the start of breeding (postpartum nutrition; PPN). A 60-d breeding season began no later than 105 d after the first cow had calved at each location each year.

Blood Analyses

Blood samples were obtained weekly from d 0 to d 60 of breeding in LA and OK. In SC blood samples were obtained during the first 5 wk and at wk 8 of breeding. Samples were collected in 10-mL tubes that contained EDTA or oxalic acid to prevent clotting. Samples were maintained at 4°C and centrifuged (1,800 × g for 20 min) within 4 h and plasma was decanted and stored at −20°C.

Progesterone was quantified with RIA (OK: Lusby et al., 1981; LA: Thompson et al., 1983; SC: Plata et al., 1990). Concentrations of progesterone in plasma greater than 1 ng/mL for more than 1 wk indicated luteal activity. Concentrations of insulin were quantified with RIA (SC: Gettys et al., 1988; LA and OK: Richards et al., 1989b). Glucose was quantified with a colorimetric procedure (no. 510, Sigma Chemical, St. Louis, MO). Concentration of NEFA were quantified with a colorimetric procedure (Patterson, 1963) and are expressed as microequivalents of palmitate per liter.

Statistical Analyses

Variables were analyzed by split-plot analyses of variance for effects of location, BCS, PPN, and their interactions. The model used to determine the effect of treatment on luteal activity, insulin, glucose, and NEFA concentrations included the interval (days) from calving to initiation of breeding as a covariable. Year within location was the error term to test location (L) effects. Cow within (L × BCS × PPN) was the error term to test treatment effects (BCS, PPN, and BCS × PPN), and the treatment × location interaction. The residual mean square error (MSE) was used to test repeated measurements during the breeding period and the interaction of day with treatment and location. If interactions with day of breeding were significant, polynomial response curves were calculated and significant differences were computed by using dummy variables (Steel and Torrie, 1980). Orthogonal contrasts were used to determine linear or quadratic components by fitting a second-order polynomial when there was a significant BCS effect. Separation of means for main effects were performed by Duncan analyses (Steel and Torrie, 1980). To determine the possible value of glucose, insulin, or NEFA as predictors of luteal activity, the effect of the presence or absence of luteal activity was added to the ANOVA described above. If concentrations of glucose, insulin, or NEFA were significantly influenced by luteal activity, and there was no luteal activity × day of breeding interaction, a categorical data analysis was performed (Agresti, 1990). The true portion of positive results obtained by a blood constituent (glucose, insulin, or NEFA) when performed on cows known to have luteal activity was called sensitivity. The true portion of negative results obtained by a blood constituent when performed on cows known to lack luteal activity was called specificity. Analyses of false positive and false negative rates of luteal activity associated with a blood constituent were performed as described by Fleiss (1981).

Results

Pre- and postpartum management was successful in achieving a range of BCS between 4 and 6 at calving, and postpartum weight gains to the start of the breeding season averaged .44 and .85 kg/d (for more details see Spitzer et al., 1995).

Glucose

There were no interactions between the main effects for concentrations of glucose in plasma. A location × day interaction (P < .05) for glucose concentrations was best described by linear regression equations (Figure 1). Concentrations of glucose at the
initiation of the breeding season (linear intercept) were influenced by location (77 ± 2, 73 ± 1, and 64 ± 1 mg/dL; LA, SC, and OK respectively; P < .0001). Concentrations of glucose in cows at all locations decreased as the breeding season progressed. However, concentrations of glucose in cows in SC decreased more rapidly than those in cows in LA and OK (P < .05).

Linear regression equations best described the day of breeding × PPN interaction (P < .001) for glucose concentrations (Figure 2). Glucose concentrations at the initiation of the breeding season were greater in cows on high PPN (74 ± 1 mg/dL) than in cows on moderate PPN (70 ± 1 mg/dL). Concentrations of glucose decreased more rapidly (P < .003) during the breeding season in cows on high PPN (−.16 mg/dL/wk) than in cows on moderate PPN (−.07 mg/dL/wk).

Concentrations of glucose during the breeding season were affected by BCS at calving (67.1 ± 4, 68.5 ± .5, and 70.7 ± .5 mg/dL for BCS 4, 5, and 6, respectively). Orthogonal comparisons revealed a linear effect (P < .08) of BCS on glucose concentrations.

Glucose concentrations were greater during the breeding season in cows that had luteal activity compared with cows without luteal activity (69.9 ± .3 and 64.2 ± .5 mg/dL, respectively; P < .003; Table 1). A glucose concentration of 66.5 mg/dL was selected as the discriminating value, because sensitivity and specificity were similar (63%) at this concentration. Analyses of false negative and false positive rates were performed assuming that 70% of the cows had luteal activity. The proportion of cows, among those having glucose concentrations less than 66.5 mg/dL, that had luteal activity (false negative rate) was 54%.

**Insulin**

There was a location × day effect (P < .004) on insulin concentrations. When polynomial response curves up to the seventh order were calculated, less than 4% of the variation in insulin was explained by day of breeding for all locations. Therefore, results from this interaction are not interpretable.

There were no interactions between location or day with BCS or PPN on concentrations of insulin, but there was a BCS × PPN interaction for insulin concentrations (P < .02). Cows on moderate PPN had a linear increase (P < .0001) in insulin concentrations with increasing BCS at calving (.38 ± .01, .44 ± .01, and .49 ± .02 ng/mL for BCS 4, 5, and 6, respectively). However, BCS at calving did not influence insulin concentrations in cows on high PPN (.47 ± .02, .47 ± .01, and .48 ± .02 ng/mL for BCS 4, 5, and 6, respectively; Figure 3). There was an interaction (P < .02) between day of breeding and the presence or absence of luteal activity on concentrations of insulin in serum (Table 1). Concentrations of insulin were not significantly different between cows with or without luteal activity, and analyses of sensitivity and specificity were not performed.

**Nonesterified Fatty Acids**

There were no interactions between location or day with BCS or PPN on concentrations of NEFA. A BCS × PPN effect (P < .03) on NEFA concentrations was due to the magnitude of the responses and not to changes...
Figure 3. Least squares mean concentrations of insulin (mean square error = .13) in primiparous beef cows that calved at three body condition scores (BCS) and were fed high or moderate postpartum nutrition. Postpartum nutrition × BCS interaction (P < .02).

Figure 4. Least squares mean concentrations of NEFA (mean square error = 128,891) in primiparous beef cows that calved at three body condition scores (BCS) and were fed high or moderate postpartum nutrition. Postpartum nutrition × BCS interaction (P < .003).

in rank order (Figure 4). There was a quadratic effect (P < .0001) of BCS at calving on NEFA concentrations in cows on the high and moderate PPN. Cows on high PPN had increased concentrations of NEFA compared with cows on low PPN, and concentrations of NEFA were maximal in cows with a BCS of 5.

Concentrations of NEFA were greater (P < .0001) in cows in OK (1,292 ± 17 μEq/L) than in cows in LA (267 ± 13 μEq/L) and SC (492 ± 12 μEq/L). Concentrations of NEFA were influenced (P < .04) by the presence or absence of luteal activity in cows. However, there was an interaction (P < .0001) of day of breeding and the presence or absence of luteal activity on concentrations of NEFA in plasma (Table 1). Concentrations of NEFA varied in magnitude and direction among days, and analyses of sensitivity and specificity were not performed.

Luteal Activity

There was a location × BCS × PPN × day effect (P < .002) on the cumulative percentage of cows exhibiting luteal activity during the breeding season. This high-order interaction was analyzed by location and is depicted in Figures 5, 6, and 7.

At the initiation of the breeding season, 84% of the cows in SC had luteal activity, but only 12 and 5% of the cows had luteal activity in LA and OK, respectively (P < .05). The interval from the average calving date to initiation of the breeding season in SC was greater than in LA and OK (92, 64, and 53 d, respectively). By the end of the breeding season, a greater percentage (P < .05) of cows in SC and LA (98 and 83%, respectively) had luteal activity than did cows in OK (65%).

Within LA, there were significant BCS (P < .007) and PPN × day (P < .05) effects on luteal activity (Figure 5). By the end of the breeding season, only 58% of the cows that calved with a BCS of 4 had luteal activity compared with 89% of cows that calved with a BCS of 5 or 6. At the initiation of the breeding season, 5 and 20% of the cows on moderate or high PPN (respectively) had luteal activity. By the end of the breeding season, only 71% of the cows on moderate PPN had luteal activity, but 97% of the cows on high PPN had luteal activity.

Within SC, there was a significant PPN × day (P < .06) interaction for luteal activity, but BCS did not affect luteal activity (Figure 6). At the initiation of the breeding season, 78 and 90% of the cows on moderate or high PPN, respectively, had luteal activity. By the end of the breeding season, 100 and 96% of the cows on moderate or high PPN, respectively, had luteal activity.

Within OK, there was a significant BCS × PPN × day (P < .0003) effect on luteal activity (Figure 7). Regardless of the BCS at calving, cows on a moderate PPN did not have luteal activity at the onset of the breeding season. Of the cows on a high PPN and with a BCS of 4 or 5 at calving, 0 and 5%, respectively, had luteal activity at the initiation of the breeding season, and 33% of the cows on high PPN with a BCS of 6 had luteal activity. By the end of the breeding season, 25, 80, and 100%, respectively, of the cows that calved with a BCS of 4, 5, or 6 and with a moderate PPN had luteal activity. Of the cows with a high PPN, 55, 74, and 100% had luteal activity (BCS 4, 5, and 6, respectively).

Discussion

Most of the glucose that is available to tissues in ruminants is supplied by gluconeogenesis, because
less than 10% of the total glucose utilized by ruminants is absorbed as glucose from the gut (Otchere et al., 1974; Young, 1977). Dietary carbohydrates are fermented to VFA in the rumen, and propionate is the major contributor in gluconeogenesis (Young, 1977). Glucose can be conserved by recycling glucose carbons as lactate, pyruvate, and alanine, which can be reconverted to glucose by gluconeogenesis (Baird et al., 1983). We found that glucose concentrations in plasma during the breeding season were influenced by location, BCS at calving, and PPN. Differences in glucose concentrations in plasma might be related to differences in energy intake. Increased energy intake in cattle is associated with increased glucose entry rates and blood glucose concentrations (Herbein et al., 1978; Schmidt and Keith, 1983). However, there is controversy about whether increased dietary intake or diet composition affect glucose concentrations in plasma (Herbein et al., 1978; Huntington and Prior, 1983; Wieghart et al., 1986). Glucose is the main precursor of lactose in cows. Therefore, glucose demand is normally greatest during early lactation, and it is during this period that cows are susceptible to hypoglycemia (Bickerstaffe and Annison, 1974). Cows in OK started the breeding season an average of 53 d postpartum and presumably just preceding maximal milk production (Jenkins and Ferrell, 1992; Marston et al., 1992). Cows in LA and SC had greater postpartum intervals to the start of breeding and had significantly greater glucose concentrations than cows in OK. These differences might reflect less glucose demand in cows after the peak of lactation compared with cows in OK. In addition, the quality and(or) quantity of the diet could be related to the differences in glucose concentrations among locations. Rusche et al. (1993) found that plasma glucose concentrations were reduced when beef cows were fed high-escape protein, which probably is due to increased lactose concentrations in milk.

During the summer, as forages mature, DM intake, DM digestibility, and VFA concentrations in the rumen usually decrease (McCollum et al., 1985; Funk et al., 1987; Gunter et al., 1995). We found a significant decrease in glucose concentrations in cows at all locations during the breeding season. Decreased glucose concentrations were probably caused by reduced DM intake, resulting in decreased propionate production.

Body condition scoring is a precise system that can be used to estimate body energy reserves of beef cattle (Wagner et al., 1988; Vizcarra and Wetttemann, 1996). During nutritional restriction, losses in weight and(or) BCS are associated with decreased glucose concentrations (Richards et al., 1989b; Rutter and Manns, 1991; Grimard et al., 1995). Energy requirements for maintenance are associated with BCS, and cows with a BCS of 4 to 5 had greater requirements for maintenance (Mcal/kg BW .75) compared with cows in a BCS of 6 or more (Thompson et al., 1983; Wagner et al., 1988). We found that cows that had a BCS of 6 at calving had significantly greater glucose concentrations during the subsequent breeding season than cows that calved with a BCS of 4 or 5. Adams et al. (1987) suggested that cows in moderate to thin condition had greater requirements for glucose than cows in a good condition due to increased maintenance requirements, and therefore increased glucose utilization and reduced serum glucose concentrations. However, it is also possible that cows with a BCS of 6 had increased energy intake that was reflected in greater concentrations of glucose compared with cows with BCS of 4 or 5. In contrast to our results, glucose concentrations were not affected when primiparous cows

### Table 1. Concentrations of glucose and NEFA in plasma and insulin in serum of primiparous cows with or without luteal activity during the breeding season

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<tr>
<th>Item</th>
<th>No luteal activity</th>
<th>Luteal activity</th>
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<td>Day 0</td>
<td>64.1 (.3)d</td>
<td>72.9 (.8)</td>
<td>.40 (.03)</td>
<td>.40 (.02)</td>
<td>1,043 (101)</td>
<td>682 (42)</td>
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<td>Day 7</td>
<td>63.4 (1.2)</td>
<td>73.4 (.8)</td>
<td>.63 (.09)</td>
<td>.49 (.03)</td>
<td>804 (73)</td>
<td>596 (36)</td>
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<td>Day 14</td>
<td>64.8 (1.3)</td>
<td>71.2 (.8)</td>
<td>.46 (.04)</td>
<td>.41 (.02)</td>
<td>896 (99)</td>
<td>698 (42)</td>
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<tr>
<td>Day 21</td>
<td>64.4 (1.3)</td>
<td>67.9 (.8)</td>
<td>.54 (.09)</td>
<td>.48 (.02)</td>
<td>892 (101)</td>
<td>679 (49)</td>
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<td>Day 28</td>
<td>65.4 (1.2)</td>
<td>69.7 (.9)</td>
<td>.39 (.03)</td>
<td>.47 (.02)</td>
<td>1,022 (116)</td>
<td>860 (66)</td>
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<td>Day 35</td>
<td>66.5 (2.0)</td>
<td>68.4 (1.6)</td>
<td>.58 (.06)</td>
<td>.47 (.03)</td>
<td>845 (69)</td>
<td>938 (58)</td>
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<td>Day 42</td>
<td>64.6 (1.6)</td>
<td>69.2 (1.2)</td>
<td>.43 (.03)</td>
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<td>1,094 (105)</td>
<td>1,073 (76)</td>
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<td>Day 49</td>
<td>61.5 (1.2)</td>
<td>66.8 (1.1)</td>
<td>.51 (.04)</td>
<td>.48 (.03)</td>
<td>797 (60)</td>
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<td>Day 56</td>
<td>63.4 (1.8)</td>
<td>66.0 (.8)</td>
<td>.49 (.04)</td>
<td>.41 (.01)</td>
<td>978 (102)</td>
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<td>Mean</td>
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<td>69.9 (.3)</td>
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<td>929 (31)</td>
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*Day of breeding × presence or absence of luteal activity interaction (P > .3).
*Day of breeding × presence or absence of luteal activity interaction (P < .02).
*Day of breeding × presence or absence of luteal activity interaction (P < .0001).
*Standard error in parentheses.
*Number of observations during the breeding season.
cows were fed different pre- and/or postpartum diets to achieve different BCS at parturition (Wiley et al., 1991; Pedron et al., 1993; Grummer et al., 1995). In these studies, cows differed in BCS at parturition by less than one unit, which might explain the nonsignificant effect of BCS on glucose concentrations. Hypoglycemia is associated with infertility in lactating cows (Oxenreider and Wagner, 1971; Patil and
Deshpande, 1979). The day of the estrous cycle influences the metabolism of glucose by bovine corpora lutea in vitro (Chase et al., 1992), and inhibition of glycolysis is associated with the lack of estrus and failure of formation of functional corpora lutea in cattle (McClure et al., 1978). Infusion of propionate into heifers resulted in increased concentrations of glucose in blood and enhanced the GnRH-stimulated LH secretion (Rutter et al., 1983). In the present experiment, cows that had luteal activity during the breeding season had 5.7 mg/dL more glucose than cows without luteal activity. Despite the significant difference, categorical data analysis indicated that individual glucose values were not determinants of luteal activity. The false positive rate of 18% indicates that of every 100 cows that have concentrations of glucose greater than 66.5 mg/dL, and thus presumably have luteal activity, 18 will actually be anestrous. This indicates that even though glucose concentrations were influenced by BCS and PPN, glucose concentrations are not predictive of luteal activity in beef cows.

Insulin secretion is stimulated by VFA in ruminants (Harmon, 1992). Most diets that increase the production of propionate are associated with increased concentrations of insulin. Similarly, energy restriction decreases insulin concentrations in heifers (Harrison and Randel, 1986; Wiley et al., 1991; Grimard et al., 1995) and cows (Richards et al., 1989b; Schrick et al., 1990), and obese heifers can be hyperinsulinemic (McCann and Reimers, 1986). Isocaloric diets with different protein contents had no effect on serum concentrations of insulin in primiparous cows (Rusche et al., 1993), but concentrations of insulin in serum were increased when additional protein was fed to mature cows after calving (Marston et al., 1995).

We found that BCS at calving did not affect subsequent insulin concentrations in cows that received high PPN. Glucose is the main physiological regulator of insulin in mammals (Philippe, 1991). In the present experiment, increased glucose concentrations in cows that gained .9 kg/d from parturition to the start of the breeding season was associated with increased serum concentrations of insulin. Probably cows on a greater PPN had increased energy intake and increased propionate production, which increased insulin concentrations during the breeding season. Cows on moderate PPN had a differential response to insulin depending on the BCS at calving. Increased concentrations of glucose in cows with BCS of 6 were associated with increased insulin secretion, and cows that calved with a moderate to thin BCS had minimal concentrations of glucose and insulin.

The mechanism by which insulin influences reproduction has not been determined. Exogenous administration of insulin increased ovulation rate in heifers on energy-restricted diets (Harrison and Randel, 1986). In the present experiment, cows with or without luteal activity had extremely variable concentrations of insulin in serum during the breeding season. Therefore, insulin concentrations are not predictive of luteal activity.
Plasma concentrations of NEFA are negatively correlated with energy balance in cows (Lucy et al., 1991), and the loss of body weight in cows is associated with increased concentrations of NEFA (McCann and Hansel, 1986; Richards et al., 1989b). It is well recognized that during the first weeks of lactation the lipolytic pathways increase in activity and lipolysis is positively correlated with milk energy secretion (McNamara, 1991). In the present experiment, cows on high PPN had increased concentrations of NEFA during breeding compared with cows on moderate PPN. The increased concentrations of NEFA might be related to increased milk production, because cows on a high PPN diet had heavier calves at weaning (Spitzer et al., 1995). Concentrations of NEFA during the breeding season were affected by BCS at calving. However, BCS did not affect weaning weight of calves, suggesting that body energy reserves at calving are not related to total milk production during a lactation. Similarly, body condition at calving did not affect milk production in beef (Wiley et al., 1991) and dairy cattle (Pedron et al., 1993). Moreover, milk production of mature cows was not influenced by feeding additional energy during gestation, but it was increased when cows received additional energy during early lactation (Marston et al., 1995).

Cows in SC started the breeding season with a 28- and 39-d longer postpartum interval than cows in LA and OK, respectively. Postpartum interval has long been recognized as an important factor that can influence breeding efficiency (VanDemark and Salisbury, 1950; Perkins and Kidder, 1963); thus, cows in SC had an advantage over cows at the other locations that was reflected in a greater percentage of cows with luteal activity at the onset of breeding.

Body condition score at calving influenced the percentage of cows with luteal activity in LA but not in SC. In OK, the effect of BCS on luteal activity depended on the PPN and day of the breeding season. On d 28 of the breeding season, more cows that calved with BCS of 5 and 6 had luteal activity compared with cows that calved with a BCS of 4. Similarly, Corah et al. (1975) found that feeding greater amounts of energy prepartum increased the percentage of heifers that exhibited estrus by 40 d postpartum. Reduced energy intake prepartum delays the onset of estrus in beef cattle (Wiltbank et al., 1962; Dunn et al., 1969), and BCS at calving influenced pregnancy rates and postpartum interval to estrus in cows (Richards et al., 1986; Selk et al., 1988).

More cows in LA and SC on high PPN (.85 kg/d) had luteal activity during breeding compared with cows on low PPN (.44 kg/d). The effect of PPN in OK depended on the BCS at calving and day of breeding. Even though the percentage of cows that calved with a BCS of 4 that had luteal activity at d 56 of breeding in OK was increased by greater gains after calving, these cows did not perform as well as cows that calved with BCS of 5 or 6 and had moderate gains after calving. Perry et al. (1991) found that increased postpartum energy intake increased the number of cows that ovulated by 150 d postpartum, and this was associated with an increase in LH pulse frequency. Similarly, increased postpartum feed intake increased pregnancy rates of mature cows that calved with a BCS of 5 (Wettemann et al., 1987).

**Implications**

Body condition score at parturition and postpartum nutrition influence the occurrence of luteal activity and concentrations of glucose, insulin, and nonesterified fatty acids in plasma of primiparous cows. Concentrations of glucose, insulin, or nonesterified fatty acids in blood during the breeding season are not predictive of luteal activity.

**Literature Cited**


