INFLUENCE OF NUTRITION AND BODY CONDITION ON PITUITARY, OVARIAN, AND THYROID FUNCTION OF NONLACTATING BEEF COWS1,2


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ABSTRACT

Nonpregnant Hereford cows (n = 70) were used to determine the effect of nutrient intake and body condition on reproductive and thyroid function. Body condition scores (BCS; 1 = emaciated, 9 = obese) of cows averaged 5.0 ± 0.2 on July 1, and cows were fed for 4 mo either to lose weight and BCS (thin; n = 22), to maintain weight and BCS (moderate; n = 24), or to gain weight and BCS (fat; n = 24). After November 1, cows received a complete ration to maintain weight and BCS. Cows were slaughtered in December (six thin, eight moderate, and eight fat cows) or the subsequent March (16 cows per group). Before slaughter, cows were given two injections of prostaglandin F2α (PGF) 11 d apart. Six days after the second PGF injection, cows were simultaneously treated with 100 μg of gonadotropin releasing hormone (GnRH, i.m) and 100 μg of thyrotropin releasing hormone (TRH; i.v.) and serum samples were obtained. The BCS of cows at slaughter (8 d after PGF) averaged 3.4, 5.3, and 7.1 (P < .01) and carcass energy content averaged 243,432, and 714 Mcal (P < .01) for thin, moderate, and fat cows, respectively. Wet ovarian (P < .001) and corpora lutea (P < .01) weights were heavier for fat cows. Content of LH in the pituitary gland and concentrations of thyroxine (T4) in serum after GnRH/TRH were not influenced by nutrient intake or BCS. However, thin cows had greater concentrations (P < .05) of LH in serum after GnRH/TRH than did moderate or fat cows. We conclude that nutrient intake and body energy reserves of beef cows influenced ovarian function and LH in serum after treatment with GnRH.

Key Words: Beef Cows, Nutrition, Body Condition, Anestrus, LH, Thyroxine


Introduction

The interval from parturition to first estrus is influenced by age of cow (Wiltbank, 1970; Bellows and Short, 1978), suckling frequency by calves (Wettemann et al., 1978; Carruthers and Hafs, 1980), nutrient intake of cows before and after calving (Wiltbank et al., 1962; Dunn et al., 1969; Corah et al., 1975), and body condition of the cow (Lishman et al., 1979; Dunn and Kaltenbach, 1980; Selk et al., 1988). The mechanisms by which these factors independently or collectively affect the length of anestrus in beef cows is unclear.

Cattle fed less than maintenance amounts of energy had greater (Gombe and Hansel, 1973),
similar (Hill et al., 1970; Dunn et al., 1974; Spitzer et al., 1978), or decreased (Appar et al., 1975) concentrations of LH in serum compared with cows fed adequate amounts of energy. Restricting energy intake resulted in greater concentrations of LH in serum after GnRH in heifers (Beal et al., 1978) and cows (Whisnant et al., 1985). Inconsistencies among experiments suggest that energy reserves of cows may influence pituitary function. Hypophyseal LH was correlated with body condition score (BCS) in cows at parturition and at 30 d postpartum (Connor et al., 1990). In addition, the onset of nutritionally induced anestrus in beef cows is associated with decreases in body energy reserves and the frequency of LH pulses (Richards et al., 1989). Increased pulsatile release of LH is a prerequisite for initiating estrous cycles in postpartum beef cows (Rawlings et al., 1990; Wettemann, 1980; Lanning et al., 1981; Riley et al., 1981; Humphrey et al., 1983).

Content of thyroid stimulating hormone (TSH) in the pituitaries of ewes is inversely related to LH content (Louw et al., 1964) and may account for the anestrus exhibited in cows (Hallford et al., 1979). Intra- and interassay CV were 6.0 and 7.2%, respectively.

Five days after the second PGF injection, a cannula (polyvynyl; 2.08-mm o.d.) was inserted into an external jugular vein of each cow, and cows were confined to individual stalls (1.2 m x 2.1 m) at 20 ± 3°C. The next day, cows were simultaneously treated with GnRH (100 µg i.m.; chloride form, batch #2, NIDDK) and thyrotropin releasing hormone³ (TRH; 100 µg, i.v.). Commencing at 0600, serum samples (20 ml) were obtained every 15 min for 30 min before treatment. After treatment, samples were obtained every 15 min for the first 2 h, every 30 min for the next 4 h, and then every 2 h until 12 h after treatment. Samples were allowed to clot (24 h), and serum was separated by centrifugation (4,000 x g) and stored at −20°C until LH and thyroxine (T₄) were quantified.

Concentrations of LH (Hallford et al., 1979) were assayed in pretreatment samples and samples obtained every 15 min for the first 6 h after treatment with GnRH. Antisera (B225) against bovine LH was used at a dilution of 1:100,000. Bovine LH (NIH-LH-B9) was used as the standard. Radiolabeled ligand was prepared using LER-1374A-ovine LH and ¹²⁵I. Intra- and interassay CV (n = 16 assays) for the LH assay were 4.7 and 12.2%, respectively.

Materials and Methods

Multiparous, nonpregnant Hereford cows (n = 72), previously described by Wagner et al. (1988), were randomly assigned to one of three feeding regimens to alter weight and body condition. Two cows eventually were removed from the study because of sickness. Thirty-five cows were slaughtered in each of 2 yr. Twenty-seven cows were fed to lose weight and body condition (thin; n = 11/yr), to maintain weight and body condition (moderate; n = 12/yr), or to gain weight and body condition (fat; n = 12/yr). It was anticipated that, by November 1, BCS (Wagner et al., 1988) would be 6 or greater, 5, and 4 or less for fat, moderate, and thin cows, respectively. After November 1, cows were weighed and BCS was determined weekly. Each cow was individually fed a complete ration to maintain weight and BCS. Cows were slaughtered in December (a total of six thin, eight moderate, and eight fat cows, respectively) or the subsequent March (16 cows per group) each year. This allowed evaluation of cows after they had been maintained at a BCS for 1 or 4 mo.

Before slaughter, two i.m. injections of 25 mg of prostaglandin F₂α (PGF)⁷ were given 11 d apart to all cows to synchronize estrus. Blood samples were collected by venipuncture on the days of the first and second PGF injection and 6 d after the second injection of PGF. Blood samples (20 ml) were mixed in tubes containing 12.5 mg of oxalic acid, immediately cooled on ice to 4°C, and centrifuged (5,000 x g for 15 min). Plasma was decanted and stored at −20°C until it was assayed for concentration of progesterone (Lusby et al., 1981). Intra- and interassay CV were 6.0 and 7.2%, respectively.

²Ludens, The UpJohn Co., Kalamazoo, MI.
³Sigma Chemical Co., St. Louis, MO.
⁴²⁵⁵I.
Concentrations of T4 (Pratt et al., 1986) were quantified in samples obtained every 30 min for the first 6 h and at 8, 10, and 12 h after treatment. Intra- and interassay CV (n = 11 assays) for the T4 assays were 5.4 and 6.8%, respectively.

Pituitary glands were removed and weighed within 45 min of exsanguination. The posterior lobe was dissected from the anterior lobe, and weight of the anterior lobe of the pituitary was determined. Anterior pituitaries were immediately frozen on dry ice and stored at -20°C until assayed for LH content by RIA. The anterior pituitary was prepared for assay of LH as described by Rasby et al. (1990). Pituitary LH content was quantified in a single RIA in which the intra-assay CV was 2.5%.

Corpora lutea (CL) were removed from ovaries and total wet ovarian and CL weights were determined. In addition, the ovaries were minced, blotted on paper, and weighed to determine follicular fluid weights. Dry ovarian weights were determined after desiccation at 90°C for 54 h.

One-half of the carcass was obtained at slaughter. Soft carcass tissues were separated from the bone, and energy content and percentage of fat of the soft tissues were determined (Wagner et al., 1988).

Analyses of variance were used to analyze cow, carcass, pituitary, and ovarian characteristics. Analyses of variance of endocrine responses were split-plot designs in which cows were nested within treatment, year, and season slaughtered (Gill and Hafs, 1971). Repeated measurements over time were taken on cows, and time sampled was the subplot. The effect of year and interactions with year were not significant for any traits and were omitted from the model. Full-model analyses of LH and T4 after GnRH and TRH treatments indicated nonsignificant season slaughtered × treatment, season slaughtered × time sample, and season slaughtered × treatment × time sampled interactions. Therefore, the reduced model included season slaughtered, treatment, cow (season slaughtered × treatment), and time sampled. If a significant treatment × time sampled interaction existed, response curves for hormone concentrations were characterized by time trends that were analyzed by regression (SAS, 1988). Tests of homogeneity of regressions were used to determine differences in time trends for endocrine responses among cows with thin, moderate, or fat body condition (Snedecor and Cochran, 1968).

Results and Discussion

From July 1 to November 1, thin cows lost approximately 60 kg and 2 BCS units, moderate cows maintained weight and BCS, and fat cows gained about 80 kg and 2 BCS units. Between November 1 and slaughter, cows on all treatments maintained BCS (Table 1). Body condition score at slaughter for thin cows (3.4) was less (P < .001) than that for moderate (5.3) and fat (7.1) cows. Cows in all groups maintained weight (Table 1) from November 1 until slaughter; at slaughter, thin, moderate, and fat cows weighed 341, 394, and 483 kg (P < .001), respectively. Energy content and percentage of fat in soft tissue of carcasses were greatest (P < .001) for fat cows and less for moderate and thin cows (Table 1).

Analyses of LH response to GnRH included only cows that exhibited luteal activity as indicated by the presence of a CL at slaughter or plasma progesterone equal to or greater than 1 ng/ml at the time of the first or second PGF injection or at the time or treatment with

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**TABLE 1. LEAST SQUARES MEANS FOR BODY CONDITION, WEIGHT, AND CARCASS ENERGY CONTENT OF COWS WITH THIN, MODERATE, OR FAT BODY CONDITIONS**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Thin</th>
<th>Moderate</th>
<th>Fat</th>
<th>Pooled SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition score on November 1</td>
<td>3.2b</td>
<td>5.3c</td>
<td>6.9d</td>
<td>.1</td>
</tr>
<tr>
<td>Condition score at slaughter</td>
<td>3.4b</td>
<td>5.3c</td>
<td>7.1d</td>
<td>.1</td>
</tr>
<tr>
<td>Weight on November 1, kg</td>
<td>339b</td>
<td>394c</td>
<td>480d</td>
<td>8</td>
</tr>
<tr>
<td>Weight at slaughter, kg</td>
<td>341b</td>
<td>394c</td>
<td>483d</td>
<td>8</td>
</tr>
<tr>
<td>Carcass energy content, Mcal</td>
<td>243b</td>
<td>432c</td>
<td>714d</td>
<td>6</td>
</tr>
<tr>
<td>Fat, %</td>
<td>7.0b</td>
<td>12.7c</td>
<td>21.6d</td>
<td>.7</td>
</tr>
</tbody>
</table>

*These data were derived from another study (Wagner et al., 1988). b,c,d Means not having a common superscript letter differ (P < .001).
pituitary weights were similar to those ob-
Present experiment maintained weight for
4
heats were
losing weight and body condition
f .l, thin, experiment was similar to that in pituitaries of
LH content were similar (P
ncmlactating, cyclic beef cows averaged
influenced pituitary LH content.
GnRH and TRH. Eighteen (81.8%) thin, 24
(100%) moderate, and 23 (95.8%) fat cows (P
< .025) had luteal activity, and data from these
cows were used in the analyses. Percentage of
fat in the carcasses of the four thin cows that
did not exhibit luteal activity averaged 4.1%,
compared with 7.4% (P < .05) for thin cows
with luteal activity. In an experiment with
similar cows, anestrus occurred when BCS of
nonlactating, cyclic beef cows averaged 3.5
(Richards et al., 1989).

Total pituitary gland and anterior pituitary
weights did not differ among treatments (Table
2). Likewise, concentrations and total pituitary
LH content were similar (P > .10) for thin,
moderate, and fat cows. Pituitary and anterior
pituitary weights were similar to those ob-
served in cyclic beef cows and heifers (Beal et
al., 1978) and dairy cows (Carruthers et al.,
1980). Pituitary LH content of cows in this
experiment was similar to that in pituitaries of
cows slaughtered when BCS (1 = extremely
thin; 5 = extremely fat) averaged 4.4 ± .2, 3.1
± .1, and 1.6 ± .3 (Moss et al., 1982).

Our results suggest that nutrition and BCS
do not influence pituitary weights in nonlactat-
ing cows and they agree with previous results
(Beal et al., 1978). However, it has been
demonstrated that energy intake (Beal et al.,
1978) and BCS (Moss et al., 1982) of beef
cows can affect pituitary LH content. In these
studies cows in poor body condition with
restricted energy intake had reduced pituitary
LH. Cows in the previous experiments were
losing weight and body condition until the
time the pituitary was removed. Cows in the
present experiment maintained weight for 1 to
4 mo before slaughter, which may have
influenced pituitary LH content.

Season that the cows were slaughtered
(March vs December) influenced pituitary
weights and pituitary LH content. Regardless
of nutrient intake and BCS, cows slaughtered
in March had heavier (P < .02) total pituitaries
and anterior pituitaries and had more (P < .02)
LH in the pituitary than did cows slaughtered
in December (Table 3). It has been demon-
strated that there is a seasonal influence on LH
secretion in ovariectomized cows, and serum
LH concentrations in those cows are greater in
spring than in fall (Day et al., 1986). In
addition, cows in this experiment that were
slaughtered in December maintained weight
and body condition for about 1 mo before
slaughter, whereas, cows slaughtered in March
maintained weight and BCS for about 4 mo
before slaughter. The length of time that a cow
maintains weight and BCS may influence
pituitary characteristics. Cows maintaining
weight and BCS had greater basal LH and
greater GnRH-induced LH release than cows
losing weight and BCS (Rutter and Randel,
1984). Reducing energy substrate at the cellular
level does result in decreased pituitary
function. Rat pituitaries in medium treated
with metabolic inhibitors that alter glycolysis
and oxidative phosphorylation released less
LH than control pituitaries when stimulated
with GnRH (Sen et al., 1979).

Fat cows had heavier (P < .001) wet
ovarian weights than did moderate or thin
cows (Table 2). Dry ovarian weights for fat
cows tended to be heavier (P < .10) than those
for thin cows (Table 2). Corpora lutea weights
were less for thin cows than for moderate and
fat cows.

In agreement with previous studies, cows
that were fed limited amounts of energy had

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Body condition</th>
<th></th>
<th>Pooled SE</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Thin</td>
<td>Moderate</td>
<td>Fat</td>
</tr>
<tr>
<td>Wet ovarian wt, g</td>
<td>12.1ab</td>
<td>14.7a</td>
<td>20.6b</td>
</tr>
<tr>
<td>Dry ovarian wt, g</td>
<td>1.80c</td>
<td>2.07cd</td>
<td>2.43d</td>
</tr>
<tr>
<td>Corpus luteum wt, g</td>
<td>1.01c</td>
<td>2.00d</td>
<td>1.93d</td>
</tr>
<tr>
<td>Pituitary wt, g</td>
<td>2.33</td>
<td>2.40</td>
<td>2.54</td>
</tr>
<tr>
<td>Anterior pituitary wt, g</td>
<td>1.96</td>
<td>1.92</td>
<td>2.03</td>
</tr>
<tr>
<td>Concentration of pituitary LH, µg/mg</td>
<td>1.59</td>
<td>1.44</td>
<td>1.79</td>
</tr>
<tr>
<td>Total pituitary LH, g</td>
<td>3.05</td>
<td>2.78</td>
<td>3.66</td>
</tr>
</tbody>
</table>

* Means not having a common superscript letter differ (P < .001).
* Means not having a common superscript letter differ (P < .10).
reduced ovarian weights (Gombe and Hansel, 1973; Beal et al., 1978). Thin cows had lighter wet and dry ovarian and CL weights, suggesting that nutrients available to maintain ovarian cell structure and integrity may differ in thin cows. When cows were fed diets that contained less than the required amounts of protein and energy to maintain BW, concentrations of glucose in plasma were decreased (Rasby et al., 1982) and concentrations of nonesterified fatty acids in plasma were increased (Garmendia et al., 1984). Blood glucose is the primary energy substrate used at the cellular level and reduced concentrations may influence ovarian and CL weights.

Secretion of pituitary gonadotropins necessary to maintain ovarian and CL function may be reduced in thin cows. Although, total pituitary LH content of thin, moderate, and fat cows in our experiment were similar, secretion of GnRH may have been reduced, which could result in reduced secretion of LH. The amount of GnRH in the infundibular stalk-media eminence of beef cows is negatively correlated with BCS (Wettemann et al., 1989).

Regardless of nutrient intake and BCS, CL from cows slaughtered in March were heavier (2.03 g; \( P < .01 \)) than CL from cows slaughtered in December (1.26 g). Pituitary LH content was greater (\( P < .02 \)) in cows slaughtered in March than in cows slaughtered in December and may influence ovarian luteal cell function in cows slaughtered in March, causing heavier CL.

Analysis of follicular fluid weight indicated a treatment \( \times \) season slaughtered interaction. Thin cows had the least and fat cows had the greatest amount of follicular fluid (\( P < .01 \); Table 4) in December. Follicular fluid weights of moderate cows were intermediate and did not differ from those for thin and fat cows. However, in March, follicular fluid weight did not differ among treatment group.

Thin cows slaughtered in December lost weight and body condition from July 1 to November 1, then maintained weight and BCS for about 1 mo before slaughter. Thin cows slaughtered in March maintained weight and BCS for about 4 mo before slaughter. Losses of weight and BCS followed by a short period of maintaining weight and BCS may alter the hypothalamic-pituitary-ovarian axis. Thin cows slaughtered in March may have adjusted to a lighter BW and less body energy stores, resulting in increased hypothalamic and pituitary gonadotropin secretion and increased follicular development.

Concentrations of \( T_4 \) in serum before TRH treatment tended to be reduced (\( P < .12 \)) in thin cows (64 ng/ml) compared with moderate (72 ng/ml) and fat (73 ng/ml) cows. Reduced thyroid activity decreases ruminal motility and rate of passage but increases digestibility (Kennedy et al., 1977). Thin cows may use feed more efficiently, minimizing the effect of nutrient intake on pituitary and ovarian characteristics. This supports the conclusion that less feed was required for maintenance of cows in thin vs moderate body condition (Wagner et al., 1988).

Concentrations of \( T_4 \) in serum of cows in thin, moderate, or fat body condition were best described by a third-order polynomial regression equation. Time trends for concentrations of \( T_4 \) were similar (\( P > .10 \)) for thin, moderate, and fat cows. At the time of TRH treatment, concentrations of \( T_4 \) averaged 69.4 \( \pm \) 9 ng/ml for all cows (Figure 1). Concentrations of \( T_4 \) in serum increased to 91.7 \( \pm \) 1.3 ng/ml by 5 h.

### Table 3. Least Squares Means for Pituitary Characteristics for Cows With Thin, Moderate, or Fat Body Condition in December and March

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Month slaughtered</th>
<th>Pooled MEAN</th>
<th>Pooled SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>December</td>
<td>March</td>
<td></td>
</tr>
<tr>
<td>Pituitary wt, g</td>
<td>2.32( ^a )</td>
<td>2.53( ^b )</td>
<td>.06</td>
</tr>
<tr>
<td>Anterior pituitary wt, g</td>
<td>1.88( ^a )</td>
<td>2.06( ^b )</td>
<td>.06</td>
</tr>
<tr>
<td>Concentration of pituitary LH, ( \mu g/) mg</td>
<td>1.49</td>
<td>1.72</td>
<td>.14</td>
</tr>
<tr>
<td>Total pituitary LH, mg</td>
<td>2.72( ^a )</td>
<td>3.61( ^b )</td>
<td>.28</td>
</tr>
</tbody>
</table>

\( ^{a,b} \)Means not having a common superscript letter differ (\( P < .02 \)).

### Table 4. Least Squares Means for Follicular Fluid Weight (g) for Cows With Thin, Moderate, or Fat Body Condition in December and March

<table>
<thead>
<tr>
<th>Body condition</th>
<th>Month slaughtered</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>December</td>
<td>March</td>
</tr>
<tr>
<td>Thin</td>
<td>1.83( ^a )</td>
<td>2.42</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.66( ^b )</td>
<td>1.84</td>
</tr>
<tr>
<td>Fat</td>
<td>3.63( ^c )</td>
<td>2.51</td>
</tr>
<tr>
<td>Pooled SE</td>
<td>.28</td>
<td>.38</td>
</tr>
</tbody>
</table>

\( ^{a,b,c} \)Means in columns not having a common superscript letter differ (\( P < .01 \)).
after TRH and were similar to those observed after TRH treatment of steers (Pratt et al., 1986) and cows (Vanjonack et al., 1974).

Our results suggest that thyroid function, as indicated by T4 release after TRH, is similar in thin, moderate, and fat cows. Even though BCS among groups differed, environmental conditions in this experiment were not adverse. Cows were allowed a 1-d adaptation period in stalls in a temperature-controlled room before TRH treatment. This adjustment period may have minimized any differences in thyroid response to TRH treatment.

Concentrations of LH in serum of cows in thin, moderate, and fat body condition after GnRH were best described by a fourth-order polynomial regression equation. Time trends for LH concentrations in serum of thin, moderate, and fat cows were not parallel (P < .025). Before GnRH treatment, concentrations of LH in serum were similar for all treatments and averaged 2.2 ± .6 ng/ml (Figure 2). At 105 min after treatment, concentrations of LH in serum averaged 41 ± 3, 32 ± 4, and 34 ± 4 ng/ml for thin, moderate, and fat cows, respectively. By 360 min after GnRH treatment, concentrations of LH in serum averaged 4 ± 1 ng/ml for all groups. Our results are similar to those of Whisman et al. (1985) and Killen et al. (1989) and indicate greater release of LH after treatment with GnRH in cows or heifers fed restricted amounts of energy.

Thin cows release more LH when treated with GnRH than do cows in a moderate or fat body condition; therefore, pituitary stores of releasable LH in thin cows may be greater than those in moderate and fat cows. The releasable pool of LH in the rat changes during the estrous cycle, but total pituitary LH does not change (Pickering and Fink, 1979). Our results indicate that pituitary LH content is similar among cows in different body conditions. We suggest that greater concentrations of LH after treatment with GnRH in thin cows is a result of a greater releasable LH pool.

We conclude that nutrient intake and BCS do not influence total pituitary weight, anterior pituitary weight, pituitary LH content, or thyroxine after TRH treatment. However, nutrition and BCS influence ovarian and CL weights and the release of LH from the pituitary gland. Therefore, effects of BCS on reproductive efficiency seem to be mediated through secretion of LH.

Implications

Thin body condition of beef cows is associated with reduced secretion of luteinizing hormone, reduced ovarian and corpora lutea weights, and the cessation or lack of initiation of estrous cycles. Reproductive failure is a major cost to cattle producers. Body condition of cows should be monitored to evaluate feeding programs and to reduce reproductive inefficiencies.

Literature Cited


