2005

Effects of supplementation of whole corn germ on reproductive performance, calf performance, and leptin concentration in primiparous and mature beef cows

J. L. Martin
University of Nebraska-Lincoln

Richard J. Rasby
University of Nebraska - Lincoln, rrasby1@unl.edu

Dennis R. Brink
University of Nebraska - Lincoln, dbrink1@unl.edu

R. U. Lindquist
Archer Daniels Midland Company

D. H. Keisler
University of Missouri

See next page for additional authors

Authors
J. L. Martin, Richard J. Rasby, Dennis R. Brink, R. U. Lindquist, D. H. Keisler, and Stephen D. Kachman

Effects of supplementation of whole corn germ on reproductive performance, calf performance, and leptin concentration in primiparous and mature beef cows[1]

J. L. Martin*, R. J. Rasby*[2], D. R. Brink*, R. U. Lindquist†, D. H. Keisler‡, and S. D. Kachman†

*Department of Animal Science and †Department of Biometry, University of Nebraska-Lincoln, Lincoln 68583; †Archer Daniels Midland Company, Columbus, NE 68601; and ‡Department of Animal Science, University of Missouri-Columbia, Columbia 65211

ABSTRACT: A 2-yr study using primiparous and multiparous, spring-calving, crossbred beef cows was conducted to evaluate the effects of supplemental whole corn germ on reproductive performance, calf performance, and serum leptin concentrations. Each year, cows were blocked by age and BCS and assigned randomly to one of three treatments: PRE (n = 115) cows received 1.14 kg/d (DM basis) of whole corn germ for approximately 45 d before calving; POST (n = 109) cows were fed 1.14 kg/d of whole corn germ for approximately 45 d after calving; and control cows (n = 118) were fed similar energy and protein from dry-rolled corn (1.82 kg of DM/d) for 45 d before and after calving. Additionally, PRE cows were grouped with controls after calving, and POST cows were grouped with control cows before calving, so that corn germ-supplemented cows received the control supplement in the alternate feeding period. Cow BW (538 ± 13 kg) and BCS (5.4 ± 0.13) did not differ among treatments at any time during the experiment. Calf birth weight (39 ± 2 kg), weaning weight (225 ± 7 kg), and age-adjusted weaning weight (234 ± 8 kg) did not differ because of dam supplementation regimen. Treatment did not affect the proportion of cows exhibiting ovarian luteal activity before the start of the breeding season (67%) or pregnancy rate (91%). The interval from exposure to bulls until subsequent calving did not differ ($P = 0.16$) among PRE (298 ± 2.3 d), POST (303 ± 2.6 d), and control (304 ± 2.3 d) cows. Leptin concentrations did not differ among treatments and were 2.15 ± 0.75, 1.88 ± 0.76, and 1.91 ± 0.75 ng/mL for control, POST, and PRE cows, respectively. Age and week relative to calving influenced leptin concentration. Primiparous cows had similar leptin concentrations to 3-yr-old and mature cows for wk –7 and –6 relative to calving, but lower ($P < 0.10$) concentrations than mature cows for wk –5, and lower ($P < 0.05$) concentrations than either 3-yr-old or mature cows for wk –4 to +7 relative to calving. Serum leptin was correlated with BCS ($P < 0.0001$; r = 0.35) at initiation of the feeding period and was correlated with BCS ($P = 0.02$; r = 0.12) and weight ($P < 0.01$; r = 0.14) at the completion of the supplement period, but it was not correlated with initial BW or interim BCS. Calving interval was not correlated ($P > 0.12$) with weekly measures of serum leptin concentration. Supplementing beef cows with whole corn germ had no effect on cow performance, calf performance, or serum leptin concentrations of cows.

Key Words: Beef Cows, Fat, Leptin, Postpartum Interval, Whole Corn Germ

 J. Anim. Sci. 2005. 83:2663–2670

Introduction

Supplementation with lipid during the prepartum period increased pregnancy rate in beef cows (Bellows et al., 1999) and primiparous heifers (Lammoglia et al., 1997) and increased first-service conception rate in cows (Graham et al., 2001). Fat supplementation during the postpartum period improved first-service conception rate (Bader et al., 2000), pregnancy rate (De Fries et al., 1998), and number of cows exhibiting estrus within 60 d after calving (Webb et al., 2001).

The mechanism by which fat improves reproductive performance in some situations is unclear, but it may involve the hormone leptin. Beef heifers fed a diet supplemented with 4% corn oil had greater adipose tissue leptin concentrations than heifers fed a basal diet (Gillis et al., 2004). Increasing leptin production may affect

[1]Published with approval of the director as Paper No. 14781, Journal Series, Nebraska Agric. Res. Div.

[2]Correspondence: C204 Animal Science Bldg. (phone: 402-472-6477; fax: 402-472-6362; e-mail: rrasby1@unl.edu).

Received November 2, 2004.

Accepted July 26, 2005.

reproductive performance. Exogenous leptin increased circulating LH (Zieba et al., 2003) according to dosage and increased mean LH concentration in feed-deprived cows (Zieba et al., 2004). Similarly, leptin increased basal LH release in adenohypophyseal explants from nutrient-restricted cows and stimulated greater GnRH-induced LH release in explants from cows that were not restricted (Amstalden et al., 2003).

The effects of feeding lipid from whole corn germ on reproductive performance and circulating leptin concentration of beef cows have not been reported. The role of leptin in gonadotropin secretion and the effects of lipid on leptin production warrant investigation of leptin as a link between dietary fat and reproduction. The objectives of this study were to determine whether feeding whole corn germ to beef cows pre- or postpartum affects the proportion of cows cyclic at initiation of the breeding season, pregnancy rate, and subsequent calving interval and to evaluate whether circulating leptin concentration is affected by whole corn germ supplementation.

Materials and Methods

Animals and Treatments

The University of Nebraska-Lincoln Animal Care and Use Committee (IACUC No. 01-06-039) approved the procedures and facilities used in this experiment. Primiparous and multiparous composite MARC II (one-quarter each Hereford, Angus, Simmental, and Gelbvieh) beef cows and cows sired by Hereford × Angus bulls from MARC II dams were used in a 2-yr experiment conducted at the University of Nebraska-Lincoln, Dalbey-Halleck Experiment Station. In each year, cows (n = 172 in yr 1, n = 170 in yr 2) were blocked by age and BCS (1 = emaciated to 9 = obese; Wagner et al., 1988) and assigned randomly to one of three treatments: 1) supplemented before and after calving with dry rolled corn (control; n = 118), 2) supplemented with whole corn germ before calving (**PRE**; n = 115), or 3) supplemented with whole corn germ after calving (**POST**; n = 109). Initial number of cows was similar for each treatment, but cows were removed from the experiment for reasons unrelated to treatment. Reasons for removal included death, calving difficulty, calf death, treatment for mastitis, and culling from the herd for reasons of udder quality, age, or behavior. Within each group, the numbers of 2-yr-old (n = 18, 17, and 19 for PRE, POST, and control, respectively), 3-yr-old (n = 15, 11, and 17 for PRE, POST, and control, respectively), and ≥4-yr-old (n = 82, 81, and 82 for PRE, POST, and control, respectively) cows were initially similar, but final numbers varied because of removal of cows for the reasons stated previously.

Supplements were equal in CP and TDN but differed in lipid content (Table 1) and consisted of 1.82 kg of DM of dry-rolled corn or 1.14 kg of DM of whole corn germ supplemented daily. Five percent dry molasses, on an equal DM basis (wt/wt), was added to the whole corn germ to ensure complete supplement intake. Supplements were group-fed daily at approximately 0830, with at least 1 m of bunk space per cow. The base diet consisted of baled smooth bromegrass (*Bromus inermis* Leyss; 9.0% CP, 54% TDN; DM basis) and alfalfa hay (19.0% CP, 57% TDN; DM basis). Cows were fed a mixture of approximately one-third alfalfa hay and two-thirds bromegrass hay (as-fed basis) and were allowed ad libitum intake, such that minimal hay remained before the subsequent daily feeding. For the total diet, the NRC model (NRC, 1996) predicted adequate DIP, MP, and ME during late gestation and adequate DIP and MP, but deficient ME, during early lactation.

Table 1. Supplement and nutrient intake for cows fed corn or whole corn germ

Item	Corn	Whole corn germ
Supplement intake, kg of DM/d	1.82	1.14
CP, kg/d[a]	0.16	0.14
Ether extract, kg/d[a]	0.07	0.40
TDN, kg/d[b]	1.63	1.60

[a]Laboratory-analyzed values.
[b]Calculated using the NRC (1996) value for dry-rolled corn and commercial laboratory analysis for whole corn germ.

Supplementation periods averaged approximately 45 d and began January 29, 2002, in yr 1 and January 20, 2003, in yr 2. Corn germ was fed to PRE cows for 42 d from January 29 to March 11, 2002, and for 52 d from January 20 to March 12, 2003. During the period when PRE cows were supplemented with whole corn germ, control and POST cows were managed as a single group and supplemented with dry-rolled corn. Whole corn germ was fed to POST cows for 42 d from March 12 to April 23, 2002, and for 50 d from March 12 to April 30, 2003. Average calving date in yr 1 and yr 2 was March 12 ± 1.4 d and March 20 ± 1.5 d, respectively. During the period when POST cows were supplemented with whole corn germ, control and PRE cows were fed the control supplement as a single group. From the end of the postcalving supplementation period to the beginning of the subsequent precalving supplementation period, cows and calves were managed as a single group on pasture.

Body weight change and BCS change were used as predictors of nutritional status. Cows were weighed once, without restriction of feed or water, in January (initiation of supplementation), in April (after the supplementation period), immediately before the breeding season, and at weaning. Weaning dates were September 24, 2002, and October 7, 2003, for yr 1 and 2, respectively. Body condition scores were assigned independently by two technicians each time the cows were weighed, and on March 5 of each year. Calf birth weights were recorded within 24 h of parturition. Calf weaning weights were evaluated on an actual and 205-d adjusted basis. Beef Improvement Federation (BIF, 2002) formulas were used to calculate adjusted 205-d weights, except that weights were not adjusted to account for age of dam. Cows were exposed to fertile bulls for a 62-d breeding season beginning May 23 of each year. Pregnancy was diagnosed via rectal palpation approximately 90 d after the end of the breeding season. The interval from the beginning of the breeding season until subsequent calving date was used to evaluate the effects of supplementation on the ability of cows to become pregnant early in the breeding season. Calving interval was not used in this analysis because calving dates tended ($P = 0.12$) to be different between groups. Calving interval was used in correlation analyses to relate serum leptin concentration to reproductive performance. Calving interval was calculated as the number of days between subsequent calving dates, using the 2002 and 2003 calving dates for yr 1 and the 2003 and 2004 calving dates for yr 2. Data for calving interval and the interval from exposure to bulls until subsequent calving include only cows that became pregnant in the subsequent breeding season (control, n = 98; PRE, n = 99; POST, n = 96).

Blood Sampling and Hormone Assays

Blood samples were drawn weekly via coccygeal venipuncture from all cows during the treatment periods to determine leptin concentrations. Weekly samples were collected before feeding, and collection time ranged from approximately 0800 to 1400 during each collection period. Samples were cooled immediately, and serum was harvested and frozen at −20°C until analysis. Two additional samples were collected 10 d apart immediately before the breeding season to determine serum progesterone concentrations to assess ovarian luteal activity. Serum progesterone concentrations were determined by direct solid-phase RIA (Coat-A-Count; Diagnostics Products Corp., Los Angeles, CA), with modifications described by Schneider and Hallford (1996). Inter- and intra-assay CV (n = 5 assays) were 4 and 12%, respectively. Serum progesterone concentrations ≥1 ng/mL were interpreted to indicate that a cow had resumed ovarian luteal activity. Leptin concentrations were assayed using an ovine-specific double-antibody RIA (Delavaud et al., 2000) validated for use in bovine serum (Delavaud et al., 2002). Intra- and interassay CV were <10%.

Statistical Analyses

Data for yr 2 were analyzed using yr 1 treatment as a covariate to test for residual effects. No residual effects were found for any variable; therefore, yr 1 treatment was removed from the model. The model for all analyses included treatment, age, and treatment × age interaction. Age was included in the model to allow comparison of response variables between cows of different ages, despite inclusion of age as a blocking factor. Cows were classified as 2-yr-old, 3-yr-old, or mature for all analyses, where cows ≥4 yr old were considered mature cows. Random effects for all analyses included year, year × treatment × age, block nested within year, and cow. Calving date was included as a covariate in analyses of cow BW, cow BCS, and the interval from initiation of the breeding season to subsequent calving date. Pregnancy and ovarian luteal activity data were analyzed using logit transformation as described by Cox (1988).

Effects of treatment on cow BCS relative to calving date also were tested to ensure that differences in BCS at calving did not influence subsequent reproductive performance. The BCS measurement taken closest to calving was used to determine group means. Leptin concentrations and BCS are presented for 7 wk relative to calving, which is approximately equal to the length of the supplementation period.

Leptin data were analyzed as a split-plot in time; fixed effects included treatment, age, week relative to calving, and the second-order interactions of these three main effects. Body condition score and initial leptin concentration were included as covariates. The repeated statement included measurements for cow nested within year over week nested within year. A first-order autoregressive covariance structure was deemed appropriate based on comparison of covariance structures with Akaike's information criterion. Correlations between traits were evaluated using the CORR procedure of SAS (SAS Inst., Inc., Cary, NC).

Results

Treatment did not influence BCS at any sampling time, nor was there an effect of treatment × age interaction on BCS (Table 2). In January, 2-yr-old cows were in greater body condition than 3-yr-old or mature cows, and mature cows were in greater condition than 3-yr-old cows ($P < 0.01$; Table 2). There were neither age nor treatment effects on BCS at calving. Primiparous cows had the least amount of body condition at initiation of the breeding season (May; $P < 0.01$) and at weaning ($P < 0.01$), 3-yr-olds were intermediate, and mature cows were in the greatest body condition.

Similar to BCS, BW was not influenced by treatment at any time measured (Table 3). Age affected BW for all time points. Two year olds were the lightest, and 3 yr olds were intermediate; mature cows were the heaviest ($P < 0.01$). Changes in BW and BCS throughout the supplementation period and the summer grazing season were not affected by supplementation (Table 4). All cows gained body condition between late April, when cows began grazing cool-season pasture, and late May, the beginning of the breeding season.

Calf growth and cow reproductive data are shown in Table 5. Control cows tended ($P = 0.12$) to calve earlier than either corn germ-supplemented group; therefore, control calves tended ($P = 0.13$) to be older at weaning (control = 199 ± 1.9 d, POST = 194 ± 2.3 d, PRE = 192 ± 2.0 d). Birth weight, actual weaning weight, and weaning weight adjusted for calf age were similar among treatments. There was no difference among

Table 2. Effects of pre- or postpartum whole corn germ supplementation and age on cow BCS from late gestation until weaning

	Treatment[a]			Age			
Date	Control	PRE	POST	2 yr	3 yr	≥4 yr	SE[b]
January	5.39	5.40	5.30	5.68[e]	5.11[f]	5.30[g]	0.13
March	5.36	5.21	5.29	5.27	5.23	5.35	0.14
April	5.10	5.02	4.91	4.98	4.92	5.12	0.12
May	5.38	5.28	5.32	5.03[e]	5.27[f]	5.67[g]	0.08
Calving[c]	5.36	5.21	5.24	5.30	5.17	5.35	0.16
Weaning[d]	5.25	5.31	5.27	4.95[e]	5.38[f]	5.49[f]	0.09

[a]Control = supplemented with dry-rolled corn pre- and postpartum, PRE = supplemented with whole corn germ prepartum, and POST = supplemented with whole corn germ postpartum.
[b]Most conservative SE. Control (n = 118), PRE (n = 115), POST (n = 109), 2 yr (n = 54), 3 yr (n = 43), and ≥4 yr (n = 245).
[c]BCS measurement recorded closest to calving date.
[d]Weaning measurements recorded September 24, 2002, and October 7, 2003.
[e,f,g]Within a row, means without common superscripts differ, $P < 0.01$.

treatment means for the proportion of cows exhibiting ovarian luteal activity at initiation of the breeding season or for pregnancy rate. The interval from bull exposure to subsequent calving date did not differ ($P = 0.16$) among treatments (control = 304 ± 2.3 d, POST = 303 ± 2.6 d, PRE = 298 ± 2.3 d).

Circulating leptin concentration was not influenced by supplementation regimen and averaged 1.91 ± 0.75, 1.88 ± 0.76, and 2.15 ± 0.75 ng/mL for PRE, POST, and control groups, respectively. There was an age × week relative to calving effect on leptin concentration (Table 6). Primiparous females had similar circulating leptin concentrations as 3-yr-old and mature cows 7 and 6 wk before calving; however, 3-yr-old and mature cows tended ($P < 0.10$) to have greater leptin concentrations than primiparous females 5 wk before calving. From 4 wk before calving through 7 wk after calving, both 3-yr-old and mature cows had greater ($P < 0.05$) concentrations of leptin than primiparous heifers.

Serum leptin was correlated to initial BCS ($P < 0.0001$; r = 0.35) but not to initial BW ($P = 0.70$). Leptin concentration was not correlated ($P = 0.18$) to BCS between feeding periods in March. In April, at completion of the supplement periods, serum leptin was positively correlated to BCS ($P = 0.02$; r = 0.12) and BW ($P < 0.01$; r = 0.14). Calving interval was not correlated ($P > 0.12$) to any of the weekly serum leptin concentrations measured from 7 wk before to 7 wk after calving (data not shown).

Discussion

Whole corn germ is a coproduct of corn grain fermentation and contains the oil fraction of the grain. The whole corn germ used in this experiment contained 35 to 38% ether extract and 12.5 to 13% CP, with slight variation across years. Typically, commercial laboratory analysis of whole corn germ indicates 40 to 45% crude fat, 12.5 to 14% CP, and approximately 140% TDN. The difference between our analyzed value for ether extract and typical analyses of this product may represent sampling error because it was not possible to capture all of the oil fraction from the whole corn germ when ground to pass a 1-mm screen. Of the lipid contained in whole corn germ, approximately 56% is linoleic acid.

Supplementation with dietary lipid from whole corn germ for approximately 45 d either pre- or postpartum

Table 3. Effects of pre- or postpartum whole corn germ supplementation and age on cow BW (kg) from late gestation until weaning

	Treatment[a]			Age			
Date	Control	PRE	POST	2 yr	3 yr	≥4 yr	SE[b]
January	540	535	540	485[d]	532[e]	598[f]	13
April	469	465	461	405[d]	462[e]	528[f]	9
May	503	497	499	435[d]	501[e]	563[f]	8
Weaning[c]	522	518	519	464[d]	523[e]	572[f]	9

[a]Control = supplemented with dry-rolled corn pre- and postpartum, PRE = supplemented with whole corn germ prepartum, and POST = supplemented with whole corn germ postpartum.
[b]Most conservative SE. Control (n = 118), PRE (n = 115), POST (n = 109), 2 yr (n = 54), 3 yr (n = 43), and ≥4-yr (n = 245).
[c]Weaning measurements were taken September 24, 2002, and October 7, 2003.
[d,e,f]Within a row, means without common superscripts differ, $P < 0.01$.

Table 4. Effects of pre- or postpartum whole corn germ supplementation on cow BCS and BW

Item	Treatment[a]			SE[b]
	Control	PRE	POST	
BCS change				
January to March	–0.03	–0.19	–0.01	0.09
March to April	–0.24	–0.19	–0.41	0.09
January to April	–0.28	–0.39	–0.41	0.11
April to May	0.29	0.28	0.41	0.13
May to weaning	–0.13	0.02	–0.04	0.09
BW change, kg				
January to May	–37	–38	–40	6
May to weaning	20	25	23	3

[a]Control = supplemented with dry-rolled corn pre- and postpartum, PRE = supplemented with whole corn germ prepartum, and POST = supplemented with whole corn germ postpartum.
[b]Most conservative SE. Control (n = 118), PRE (n = 115), and POST (n = 109).

Table 6. Effects of cow age on leptin concentration (ng/mL) from 7 wk before until 7 wk after calving

Week relative to calving[a]	Age			SE[b]
	2 yr	3 yr	≥4 yr	
–7	3.48	3.40	3.22	0.78
–6	2.79	3.06	3.19	0.78
–5	1.99[c]	2.83[d]	3.00[d]	0.78
–4	1.36[e]	2.64[f]	2.99[f]	0.78
–3	1.03[e]	2.51[f]	2.78[f]	0.77
–2	0.86[e]	2.33[f]	2.63[f]	0.77
–1	0.77[e]	2.46[f]	2.49[f]	0.77
0	0.78[e]	2.52[f]	2.63[f]	0.77
1	0.54[e]	2.37[f]	2.43[f]	0.77
2	0.39[e]	2.05[f]	2.02[f]	0.77
3	0.13[e]	1.88[f]	2.11[f]	0.77
4	0.08[e]	1.98[f]	2.10[f]	0.77
5	0.01[e]	1.88[f]	2.17[f]	0.77
6	0.28[e]	1.90[f]	2.30[f]	0.78
7	0.36[e]	2.01[f]	2.45[f]	0.78

[a]Week 0 is week of calving.
[b]Most conservative SE. 2 yr (n = 54), 3 yr (n = 43), ≥4 yr (n = 245).
[c,d]Within a row, means without common superscripts differ, $P < 0.10$.
[e,f]Within a row, means without common superscripts differ, $P < 0.05$.

did not affect cow BCS or BW change during late gestation, early lactation, or the subsequent grazing season compared with pre- and postpartum supplementation with isoenergetic amounts of dry-rolled corn. Before the experiment, primiparous heifers were managed separately from the 3-yr-old and older cows. The 2-yr-old cows were fed to be in greater condition (BCS 5.5 to 6.0) than older cows at initiation of the experiment. The observation that they were in the lowest condition at the end of the supplementation period is likely a result of the concomitant requirement for tissue growth and lactation in primiparous heifers that are not compounded in mature cows (NRC, 1996).

In the present study, calf birth and weaning weights did not differ as a result of dam treatment. This finding agrees with the observations of Bottger et al. (2002), who reported that milk production, calf gain, and adjusted weaning weight were similar between cows supplemented postpartum with 5% dietary fat and cows receiving isocaloric, isonitrogenous control diets. Additionally, Alexander et al. (2001) found that fat supplementation during the prepartum period did not influence calf weight gains, despite increased milk production from fat-supplemented cows. Other reports support

Table 5. Effects of pre- or postpartum whole corn germ supplementation on calf growth and cow reproductive performance

Item	Treatment[a]			SE[b]
	Control	PRE	POST	
Calf performance				
Calving date, d of year	73[g]	79[h]	78[gh]	2
Birth weight, kg	40	40	38	2
Actual weaning weight, kg[c]	228	222	225	7
Adjusted weaning weight, kg[d]	234	234	234	8
Weaning age, d	199[i]	193[j]	194[ij]	2
Cow performance				
Cyclic at initiation of breeding, %[e]	72.3	65.0	63.1	
Pregnant, %[f]	90.7	91.6	91.6	
Interval from bull exposure until subsequent calving	304[k]	298[l]	303[k]	3

[a]Control = supplemented with dry-rolled corn pre- and postpartum, PRE = supplemented with whole corn germ prepartum, and POST = supplemented with whole corn germ postpartum.
[b]Most conservative SE. Control (n = 98), PRE (n = 99), and POST (n = 96).
[c]Unadjusted weaning weight.
[d]Weaning weight adjusted for calf age.
[e,f]Ovarian luteal activity and pregnancy data analyzed using a logit transformation; therefore, SE are not available.
[g,h]Within a row, means without common superscripts differ, $P = 0.12$.
[i,j]Within a row, means without common superscripts differ, $P = 0.13$.
[k,l]Within a row, means without common superscripts differ, $P = 0.16$.

the absence of an effect of fat supplementation on milk production (Lake et al., 2003) or weaning weight (Geary et al., 2002). Cow and calf weight gain during the supplementation period were increased by rice bran supplementation compared with control supplementation (5.2 vs. 3.7% dietary fat) postpartum, but weaning weight was similar to that of control-fed cows (De Fries et al., 1998). Furthermore, calves nursing primiparous dams supplemented for 65 d prepartum with fat from safflower seeds, whole soybeans, or sunflower seeds were heavier at weaning than calves nursing cows fed an isocaloric, isonitrogenous control supplement (Bellows et al., 1999). In the present study, failure of fat supplementation to elicit a response in calf weight gain reflects similar protein and energy intake between fat-supplemented and control cows; however, we did not measure calf weight gain during the supplementation period.

Proportion of cows exhibiting ovarian luteal activity before the breeding season, pregnancy rate, and subsequent calving interval did not differ as a result of fat supplementation postpartum. In contrast, Webb et al. (2001) reported greater cumulative numbers of cows returning to estrus within 60 d of calving when supplemented postpartum with 5.2% dietary fat from rice bran. Previous research noted that cows supplemented with fat postpartum did not have decreased postpartum intervals (Carr et al., 1994; Filley et al., 2000; Johnson et al., 2001a; Bottger et al., 2002) or increased pregnancy rate (Filley et al., 2000). These findings agree with our conclusion that supplementation with whole corn germ postpartum does not influence pregnancy rate or calving interval compared with cows supplemented with dry-rolled corn. Nonetheless, postpartum fat supplementation improved estrus response and first-service conception rate in primiparous heifers and cows, respectively (Bader et al., 2000). Brahman cows supplemented postpartum with fat from rice bran also failed to differ from controls in terms of postpartum interval, but supplemented cows had greater pregnancy rates following a 60-d breeding season (94 vs. 71%; De Fries et al., 1998). Although postpartum fat supplementation has elicited positive reproductive responses in other studies, an isoenergetic control supplement produced similar pregnancy rates and calving intervals in the current study.

Supplementation with 1.14 kg of whole corn germ/d for approximately 45 d during late gestation did not increase the percentage of cows exhibiting ovarian luteal activity before the breeding season, pregnancy rate, or the interval from bull exposure until subsequent calving date. This is counter to the increased pregnancy rates (19%) in response to dietary fat reported by Lammoglia et al. (1997) when primiparous heifers were supplemented from d 230 of gestation through calving with approximately 4.7% dietary fat. Bellows et al. (1999) supplemented primiparous cows with 4.2, 3.3, or 4.5% fat from oilseeds for 65 d before calving and achieved pregnancy rates of 94, 90, and 91%, respectively, compared with 79% for control-supplemented cows; however, the proportion of cows cyclic at initiation of the breeding season did not differ among treatments. Supplementation prepartum with 1.6 kg of whole soybeans/d for 45 d improved first-service conception rate in a natural service breeding season, and 30-d supplementation prepartum increased first-service pregnancy rates to synchronized AI (Graham et al., 2001). In other studies, prepartum supplementation with fat did not affect postpartum interval (Alexander et al., 2001; Geary et al., 2002) or pregnancy rate (Alexander et al., 2001; Burns et al., 2002; Geary et al., 2002). Grings et al. (2001) reported an improvement in pregnancy rates in 3-yr-old cows calving in February and 5-yr-old cows calving in April when fed supplements containing 14.8% ether extract from safflower seeds compared with control cows fed a 2.6% fat supplement. However, April-calving, 3-yr-old cows fed the 14.8% fat supplement had lower pregnancy rates than cows of the same age and calving season fed the 2.6% fat supplement. Bellows et al. (2000) also observed increased pregnancy rates in response to fat supplementation when mature cows calved in February but not in April-calving cows. The primary difference between the two calving seasons was forage availability during the postpartum period, indicating that plane of nutrition may mediate the responsiveness of cows to fat supplementation. Cows in our study lost similar weight and condition during the supplementation period and did not differ in pregnancy rate or interval from the beginning of the breeding season until subsequent calving.

Circulating leptin concentration was positively correlated to BCS in cows fed at 62% ($r = 0.65$) or 128% ($r = 0.57$) of their maintenance requirement for ME (Delavaud et al., 2002). Leon et al. (2004) also reported a positive correlation between plasma leptin and BCS in Zebu-Brown Swiss crossbred heifers when heifers were restricted to 60% of maintenance ME intake ($r = 0.47$) and during realimentation when the same heifers were fed to gain 1 kg/d ($r = 0.83$). Initial BCS ($r = 0.35$) and BCS following the supplementation period ($r = 0.12$) were weakly correlated to serum leptin in the present study; however, BCS in March, between supplementation periods, was not correlated to serum leptin concentration. Differences in leptin concentration during the periparturient period were noted in Holstein cows (Kadokawa et al., 2000) and likely explain the lack of correlation between leptin and BCS recorded during the early part of the calving season in the present study. It also is important to consider that the present study was not designed to produce large differences in BCS.

Initial BW, recorded in January, was not correlated with serum leptin concentration. This was expected because cows in the present study were in late gestation in January; therefore, BW was influenced by conceptus weight in addition to body composition. At the end of the supplementation period, following the calving season, BW was correlated ($r = 0.14$) to serum leptin. The latter data agree with observations in heifers, where

BW and plasma leptin were correlated during nutrient restriction (r = 0.40) and weight gain (r = 0.78; Leon et al., 2004).

Supplemental lipid elicits varied effects on leptin production and secretion. Supplementing Holstein heifers with rumen bypass fatty acids or CLA from 3 to 5 mo of age until the third postpubertal estrus had no effect on plasma leptin (Block et al., 2003). Similarly, feeding sunflower oil to heifers beginning at 4 mo of age did not change leptin concentration (Garcia et al., 2003). Leptin also was unchanged by addition of 6% sunflower oil to the finishing diet of Wagyu or Limousin steers (Johnson et al., 2001b). Similarly, neither 4% corn oil nor 2% rumen-protected CLA had an effect on circulating leptin in feedlot heifers (Gillis et al., 2004). Despite the failure to stimulate circulating leptin, dietary corn oil increased adipose tissue leptin concentration by 68% compared with control heifers or those supplemented with CLA. Jugular infusion of lipid rapidly increased circulating leptin in late lactation cows, but it did not affect leptin concentrations in early lactation cows (Chelikani et al., 2003). Supplementing primiparous heifers that had an average BCS of 5.8 at calving with a high-fat diet rich in linoleic acid for 56 d before calving did not alter leptin concentration (Geary et al., 2002). Similarly, our data indicate that supplementation of cows with 0.40 kg/d of lipid from whole corn germ either pre- or postpartum did not influence leptin concentrations compared with control cows with similar BCS.

Leptin concentrations were monitored in 20 Holstein cows before parturition through the first postpartum ovulation, and postpartum time to first ovulation was unrelated to precalving, postcalving, or postovulatory leptin levels (Kadokawa et al., 2000). This observation agrees with our findings that calving interval was unrelated to serum leptin concentrations measured between 7 wk before and 7 wk after calving. Nonetheless, in the study conducted by Kadokawa et al. (2000), leptin concentrations decreased as calving approached and reached a nadir shortly after parturition. The group least squares means from our trial also displayed a postpartum nadir in leptin concentration in the early postpartum period. Time to first ovulation was correlated (r = 0.83) to the length of time between parturition and the postpartum nadir in leptin concentration (Kadokawa et al., 2000). Because of longer sampling intervals, we were unable to test this effect in the present study. The relative timing of the postpartum leptin nadir is longer in our work than reported by Kadokawa et al. (2000). This may reflect the difference in postpartum interval between beef and dairy cows (Yavas and Walton, 2000). Strauch et al. (2003) noted a negative correlation (r = –0.29) between leptin at calving and postpartum interval in Brahman cows that was not substantiated in *Bos taurus* cows in our study.

It is possible that a threshold leptin requirement for cyclicity and pregnancy dictates the ability of a cow to reproduce. In mice, a threshold leptin requirement must be met for ovulation and pregnancy to be achieved (Malik et al., 2001). Further investigation into the roles of leptin and dietary lipid in reproduction in beef cows is needed. In our study, supplementing cows with 0.40 kg of fat from whole corn germ/d for approximately 45 d during late gestation or postpartum did not influence pregnancy rates, number of cows exhibiting ovarian luteal activity before the breeding season, interval between bull exposure and subsequent calving date, BCS, or serum leptin concentration.

Literature Cited

Alexander, B. M., D. L. Hixon, B. W. Hess, B. L. Garrett, J. D. Bottger, D. D. Simms, and G. E. Moss. 2001. Influence of fat-supplementation on beef cow reproduction and calf performance. Proc. West. Sect. Am. Soc. Anim. Sci. 52:186–188.

Amstalden, M., D. A. Zieba, P. G. Harms, T. H. Welsh, R. L. Stanko, and G. L. Williams. 2003. Leptin acts at the bovine adenohypophysis to enhance basal and gonadotropin-releasing hormone-mediated release of luteinizing hormone: Differential effects are dependent upon nutritional history. Biol. Reprod. 69:1539–1544.

Bader, J. F., E. E. D. Felton, M. S. Kerley, D. D. Simms, and D. J. Patterson. 2000. Effects of postpartum fat supplementation on reproduction in primiparous 2-year-old and mature cows. J. Anim. Sci. 78(Suppl. 1):224. (Abstr.)

Bellows, R. A., E. E. Grings, D. A. Phelps, S. E. Bellows, T. W. Geary, and D. D. Simms. 2000. Feeding supplemental fat to mature cows. J. Anim. Sci. 78(Suppl. 1):228. (Abstr.)

Bellows, R. A., D. D. Simms, E. E. Grings, D. A. Phelps, S. E. Bellows, N. R. Bellows, R. E. Short, R. N. Funston, and T. W. Geary. 1999. Effects of feeding supplemental fat during gestation on reproduction in primiparous beef heifers. J. Anim. Sci. 77(Suppl. 1):236. (Abstr.)

BIF. 2002. Guidelines for Uniform Beef Improvement Programs. 8th ed. Beef Improvement Federation, Athens, GA.

Block, S. S., J. M. Smith, R. A. Ehrhardt, M. C. Diaz, R. P. Rhoads, M. E. VanAmburgh, and Y. R. Boisclair. 2003. Nutritional and developmental regulation of plasma leptin in dairy cattle. J. Dairy Sci. 86:3206–3214.

Bottger, J. D., B. W. Hess, B. M. Alexander, D. L. Hixon, L. F. Woodard, R. N. Funston, D. M. Hallford, and G. E. Moss. 2002. Effects of supplementation with high linoleic or oleic cracked safflower seeds on postpartum reproduction and calf performance of primiparous beef heifers. J. Anim. Sci. 80:2023–2030.

Burns, P. D., E. R. Downing, T. E. Engle, J. C. Whittier, and R. M. Enns. 2002. Effect of fishmeal supplementation on fertility in young beef cows grazing pasture. Proc. West. Sect. Am. Soc. Anim. Sci. 53:392–395.

Carr, D. L., J. C. Spitzer, T. C. Jenkins, G. L. Burns, and B. B. Plyler. 1994. Effect of dietary lipid supplementation on progesterone concentration and reproductive performance in suckled beef cows. Theriogenology 41:423–435.

Chelikani, P. K., D. H. Keisler, and J. J. Kenelly. 2003. Response of plasma leptin concentration to jugular infusion of glucose or lipid is dependent on the stage of lactation of Holstein cows. J. Nutr. 133:4163–4171.

Cox, C. 1988. Multinomial regression models based on continuation ratios. Stat. Med. 7:435–441.

De Fries, C. A., D. A. Neuendorff, and R. D. Randel. 1998. Fat supplementation influences postpartum reproductive performance in Brahman cows. J. Anim. Sci. 76:864–870.

Delavaud, C., F. Bocquier, Y. Chilliard, D. H. Keisler, A. Gertler and G. Kahn. 2000. Plasma leptin determination in ruminants: Effect of nutritional status and body fatness on plasma leptin concentration assessed by a specific RIA in sheep. J. Endocrinol. 165:519–526.

Delavaud, C., A. Ferlay, Y. Faulconnier, F. Bocquier, G. Kann, and Y. Chilliard. 2002. Plasma leptin concentration in adult cattle:

Effects of breed, adiposity, feeding level, and meal intake. J. Anim. Sci. 80:1317–1328.

Filley, S. J., H. A. Turner, and F. Stormshak. 2000. Plasma fatty acids, prostaglandin F2α, metabolite, and reproductive response in postpartum heifers fed rumen bypass fat. J. Anim. Sci. 78:139–144.

Garcia, M. R., M. Amstalden, C. D. Morrison, D. H. Keisler, and G. L. Williams. 2003. Age at puberty, total fat and conjugated linoleic acid content of carcass, and circulating metabolic hormones in beef heifers fed a diet high in linoleic acid beginning at four months of age. J. Anim. Sci. 81:261–268.

Geary, T. W., E. E. Grings, M. D. MacNeil, and D. H. Keisler. 2002. Effects of feeding high linoleate safflower seeds prepartum on leptin concentration, weaning, and rebreeding performance of beef heifers. J. Anim. Sci. 80(Suppl. 2):131. (Abstr.)

Gillis, M. H., S. K. Duckett, J. R. Sackman, C. E. Realini, D. H. Keisler, and T. D. Pringle. 2004. Effects of supplemental rumen-protected conjugated linoleic acid or linoleic acid on feedlot performance, carcass quality, and leptin concentrations in beef cattle. J. Anim. Sci. 82:851–859.

Graham, K. K., J. F. Bader, D. J. Patterson, M. S. Kerley, and C. N. Zumbrunnen. 2001. Supplementing whole soybeans prepartum increases first service conception rate in postpartum suckled beef cows. J. Anim. Sci. 79(Suppl. 2):106. (Abstr.)

Grings, E. E., R. E. Short, M. Blummel, M. D. MacNeil, and R. A. Bellows. 2001. Prepartum supplementation with protein or fat and protein for grazing cows in three seasons of calving. Proc. West. Sect. Am. Soc. Anim. Sci. 52:501–504.

Johnson, K. A., P. S. Mir, P. S. Kuber, Z. Mir, D. H. Keisler, C. T. Gaskins, J. J. Michal, J. R. Busboom, and J. R. Reeves. 2001b. An evaluation of breed and diet on plasma leptin concentration in beef steers. J. Anim. Sci. 79(Suppl. 1):357. (Abstr.)

Johnson, S. K., J. S. Stevenson, K. R. Harmoney, and J. R. Brethour. 2001a. Effects of pre and/or postpartum fat supplementation on reproduction in mature beef cows. J. Anim. Sci. 79(Suppl. 2):275. (Abstr.)

Kadokawa, H., D. Blache, Y. Yamada, and G. B. Martin. 2000. Relationships between changes in plasma concentrations of leptin before and after parturition and the timing of first post-partum ovulation in high-producing Holstein dairy cows. Reprod. Fertil. Dev. 12:405–411.

Lake, S. C., B. W. Hess, D. C. Rule, C. M. Murrieta, E. J. Scholljegerdes, V. Nayigihugu, and R. L. Atkinson. 2003. Effects of supplemental high-linoleate or high-oleate safflower seeds on production and lipogenesis by adipose tissue of mature cows. J. Anim. Sci. 81(Suppl. 1):36. (Abstr.)

Lammoglia, M. A., R. A. Bellows, E. E. Grings, J. W. Bergman, R. E. Short, and M. D. MacNeil. 1997. Effects of dietary fat composition and content, breed and calf sex on birth weight, dystocia, calf vigor and postpartum reproduction of first calf beef heifers. Proc. West. Sect. Am. Soc. Anim. Sci. 48:81–84.

Leon, H. V., J. Hernandez-Ceron, D. H. Keisler, and C. C. Gutierrez. 2004. Plasma concentrations of leptin, insulin-like growth factor-I, and insulin in relation to changes in body condition score in heifers. J. Anim. Sci. 82:445–451.

Malik, N. M., N. D. Carter, J. F. Murray, R. J. Scaramauzzi, C. A. Wilson, and M. J. Stock. 2001. Leptin requirement for conception, implantation, and gestation in the mouse. Endocrinology 142:5198–5202.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th ed. Natl. Acad. Press, Washington, DC.

Schneider, F. A., and D. M. Hallford. 1996. Use of a rapid progesterone radioimmunoassay to predict pregnancy and fetal numbers in ewes. Sheep Goat Res. 12:33–42.

Strauch, T. A., D. A. Neuendorff, C. G. Brown, M. L. Wade, A. W. Lewis, D. H. Keisler, and R. D. Randel. 2003. Effects of lasalocid on circulating concentrations of leptin and insulin-like growth factor-I and reproductive performance of postpartum Brahman cows. J. Anim. Sci. 81:1363–1370.

Wagner, J. J., K. S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Wettemann, and L. E. Walters. 1988. Carcass composition in mature Hereford cows: Estimation and effect on daily metabolizable energy requirement during winter. J. Anim. Sci. 66:603–612.

Webb, S. M., A. W. Lewis, D. A. Neuendorff, and R. D. Randel. 2001. Effects of dietary rice bran, lasalocid, and sex of calf on postpartum reproduction in Brahman cows. J. Anim. Sci. 79:2986–2974.

Yavas, Y., and J. S. Walton. 2000. Postpartum acyclicity in suckled beef cows: A review. Theriogenology 54:24–55.

Zieba, D. A., M. Amstalden, M. N. Maciel, D. H. Keisler, N. Raver, A. Gertler, and G. L. Williams. 2003. Divergent effects of leptin on luteinizing hormone and insulin secretion are dose dependent. Exp. Biol. Med. 228(3):325–330.

Zieba, D. A., M. Amstalden, S. Morton, M. N. Maciel, D. H. Keisler, and G. L. Williams. 2004. Regulatory roles of leptin at the hypothalamic-hypophyseal axis before and after sexual maturation in cattle. Biol. Reprod. 71:804–812.