EFFECTS OF PREPARTUM WHOLE COTTONSEED OR WHOLE RAW SOYBEAN SUPPLEMENTATION ON RESPONSE TO TIMED ARTIFICIAL INSEMINATION IN SUCKLED MATURE BEEF COWS FOLLOWING OVULATION SYNCHRONIZATION

by

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ABSTRACT

Prepartum fat supplementation has been associated with improved reproductive performance by cows managed for AI. Our objective was to evaluate the effects of prepartum supplementation with whole cottonseed or whole raw soybeans on response to ovulation synchronization and timed artificial insemination in mature beef cows. Cows ($n = 188$; average initial BW = 579 ± 54 kg) were stratified by BCS and BW and assigned to 3 supplementation treatments: whole raw soybeans (21.6 % fat, 38.6% CP), whole fuzzy cottonseed (21.7% fat, 21.1% CP), or a 50:50 mixture of ground corn and soybean meal (2.6% fat, 30.6% CP). Supplements were fed at 1.8 kg per animal daily for 45 d before the first projected calving date (April 1). Supplementation was continued until each cow calved; thereafter, all cows received the control supplement until May 1. Ovulation was synchronized using the CoSynch + CIDR protocol and cows were bred via AI on June 21. Eleven d after AI, cows were exposed for natural service breeding for 50 d. Conception to AI was assessed 33 d after AI. Overall conception was assessed and conception to AI reaffirmed 126 d after AI. Body weight of cows fed control or oilseed supplements was similar ($P > 0.3$) at calving, initiation of ovulation synchronization, and at the end of the breeding season. Cottonseed-supplemented cows lost more BW and more BCS ($P < 0.03$) from the beginning of the trial to calving than those fed soybeans. Proportion of cycling cows was similar ($P = 0.57$) between treatments. Pregnancy to timed AI and final pregnancy rates were similar ($P \geq 0.75$) between control and oilseed-supplemented cows. Conversely, supplementation with cottonseed was associated with increased AI conception ($P = 0.08$; 54 and 39%, for cottonseed and soybeans, respectively) and greater final pregnancy rate compared to soybean-fed cows ($P = 0.03$; 100 and 93% for cottonseed and soybeans, respectively). Calf birth weights and calf weights at the end of the breeding season were similar ($P \geq 0.24$) between treatments. Effects of

cottonseed and soybean supplementation on response to ovulation synchronization and timed AI by beef cows warrant further study.

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DEDICATION

I dedicate this work to all of my family. The pride you have shown in my accomplishments through the years has given me the drive and determination to complete this goal. The support I always know I can find in all of you gives me the confidence to reach for my dreams.

Chapter 1

General Literature Review

Introduction

Lack of timely rebreeding by cows is a problem in the beef cattle industry. North American production systems are usually predicated on a 12-mo calving interval; however, a 12-mo calving interval is not always easy to achieve. Loss of income due to reproductive complications in the U.S. exceeded $14 per cow (Bellows, 2002).

Timely rebreeding is related to pre- and postpartum energy intake. Prepartum energy intake is of equal or greater importance than postpartum energy intake to ensure cows return to a functional estrous cycle in a timely manner (Randel, 1990). Owing to the critical role of energy intake for rebreeding success, there has been a significant amount of research examining fat supplementation for pre- and postpartum beef cows and pre-pubertal heifers. This research has evaluated effects of fat source, timing of supplementation, supplementation amount, and duration of supplementation period. No consensus on the value of fat supplementation for enhancing reproductive performance has been reached. This leads to confusion about the mechanisms through which fat supplementation may influence reproductive performance and the conditions under which fat supplementation may be effective.

Body Weight and Body Condition Score

Body weight (BW) and body condition score (BCS) immediately before calving and immediately before breeding strongly influence the likelihood of timely rebreeding of beef cows. Effects of pre- and postpartum fat supplementation on cow performance have been variable. Multiparous beef cows were fed isonitrogenous diets for 76 d after calving. Diets were based either on soybean meal (4 g/d total supplemental lipids), soybean hulls (38 g/d total supplemental lipids), or high linoleic acid sunflower seeds (405 g/d total supplemental lipids). The soybean hull-fed cattle gained more BW and BCS than the other treatments during the supplementation period. Conversely, the cows fed the sunflower seed-based diet lost less weight than the soybean hull-fed cows from the end of supplementation to breeding. There were no differences in BW or BCS between treatments at weaning time during the subsequent fall (Banta et al., 2006).

Two trials compared dietary fat levels in which ewes were fed isocaloric and isonitrogenous diets for 55 d prepartum. Dietary fat levels were 2.8 vs. 5.7% of diet DM in trial 1 and 1.9 vs. 4.9% of diet DM in trial 2; dietary fat was varied using cracked safflower seeds. These researchers reported that BW and BCS at parturition were similar between treatments (Enchinas et al., 2004).

Body weight and BCS of heifers at calving were similar after they were fed either a control diet with 2.2% crude fat (CF) or a safflower seed-based diet containing 5.1% CF for 55 d prepartum (Lammoglia et al., 1999b). Conversely, subsequent research reported that heifers fed a diet based on safflower seeds (4.7% dietary CF) for 53 d prepartum were heavier at calving than heifers fed a control diet (1.7% dietary CF; Lammoglia et al., 1999a).

Primiparous or multiparous cows were fed a control diet, a fat-rich diet, or a fat-rich diet with soybean soapstock added in two trials (Alexander et al., 2002). Diets were neither isocaloric nor isonitrogenous and were fed for approximately 60 d before calving. Calving BW and BCS of heifers were not affected by treatment. Body weight of mature cows at calving was also similar between treatments; however, cows fed the control diet had greater BCS at calving than cows fed the fat-rich diets. By 90 d postpartum, cows fed control and fat-rich diets had similar BCS.

A control diet (2.4% CF), a safflower seed-based diet (4.7% CF), a soybean-based diet (3.8% CF), or a sunflower seed-based diet (5.1% fat) were fed to cows. All diets were isocaloric and isonitrogenous and were supplemented for 65 d prepartum. All fat-rich diets resulted in greater prebreeding BCS than the control diet. In contrast, a control diet (2.2% CF) produced changes in prebreeding BCS and BW that were similar to those produced by a fat-rich diet (6.3% CF, sunflower seed-based diet) in a companion trial (Bellows et al., 2001).

Postpartum fat supplementation has also yielded inconsistent effects on cow and heifer performance. Postpartum fat supplementation had no effect BW or BW change in the majority of studies reviewed (Williams, 1989; De Fries et al., 1998; Tjardes et al., 1998; Graham et al., 2001; Bottger et al., 2002; Lloyd et al., 2002; Lake et al., 2005; Murietta et al., 2006). Although most types of fat supplementation did not affect weight change of primiparous cows, supplementation with oleic acid-rich safflower seeds (29.3% dietary total fatty acids) was associated with a lesser BCS than heifers fed supplements rich in linoleic acid (31.4% dietary total fatty acids) or control supplements (3.8% dietary total fatty acids; Bottger et al., 2002). Similarly, heifers fed a sunflower seed-based supplement (6.7% CF) for 60 d postpartum had lesser ADG than heifers fed a control supplement (3.2% CF). Body weight of heifers fed for a shorter time interval (i.e., 30 d) did not respond to fat supplementation (Funston et al., 2002). Fat-supplemented ewes also lost more weight than control ewes (Appendu et al., 2004).

Cows fed a diet rich in linoleic-acid postpartum gained more weight than cows fed a low-fat diet (Grant et al., 2003). Likewise, fat-supplemented cows (5.2% dietary ether extract; EE) gained more BCS postpartum than control cows (3.7% dietary EE; De Fries et al., 1998).

Fat supplementation of prepubertal heifers also has been investigated. Prepubertal heifers supplemented with microencapsulated tallow deposited more intramuscular and subcutaneous fat and had greater BCS than unsupplemented heifers; moreover, feed efficiency of supplemented heifers was improved over that of unsupplemented heifers (Rhodes et al., 1978). Total gain, ADG, and BCS were not different in prepubertal heifers fed either a fat-poor (1.9% CF) or a fat-rich (4.4% CF) diet for 162 d before breeding; however, heifers fed the fat-rich diet tended to have more 12th-rib back fat than heifers fed the fat-poor diet (Lammoglia et al., 2000).

Milk and Milk Components

Production and composition of milk were occasionally influenced by pre- or postpartum fat supplementation in the studies reviewed. Ewes supplemented with calcium salts of palm-oil fatty acids (7.1% CF) had milk production similar to that of unsupplemented ewes; however, fat-supplemented ewes had greater milk fat percentage, lesser milk lactose, and lesser milk protein than unsupplemented ewes (Appendu et al., 2004). Soybean meal- (4 g/d lipids), soybean hull- (38 g/d lipids), or sunflower seed-based (405 g/d lipids) diets fed to beef cows had similar effects on milk production and milk composition (Banta et al., 2006). In primiparous cows fed a cracked-corn diet or a cracked-corn-plus-yellow-grease diet, milk production was similar between treatments 52 d after calving; however, it was greater in heifers supplemented with yellow grease 91 d after calving. In addition, the percentage of non-fat milk solids from cows fed fat-rich diets was decreased compared with control cows (Tjardes et al., 1998).

Differences in milk composition were also reported when cows were either fed a low-fat control diet (2.2% dietary CF), a high-linoleate safflower seed-based diet (5.0% dietary CF), or a high-oleate safflower seed-based diet (5.0% dietary CF). Although no differences were detected in milk fat percentage, total milk fat output, milk lactose, or milk energy, cattle fed the low-fat control diet tended to have greater milk protein percentage and total milk protein than cattle fed either of the fat-rich diets (Lake et al., 2005).

Calf Performance

Calf and lamb performance was occasionally affected when supplemental fat was supplied to the dam. No differences in birth weight or weaning weight of calves were reported when dams were fed either fat-rich or fat-poor supplements prepartum (Banta et al., 2006). These researchers also reported that no treatment differences occurred in feedlot performance or carcass characteristics of calves.

No differences were detected in calf birth weight, calf vigor, calf shivering score, dystocia, time to stand, or time to nurse in calves born to fat-supplemented (5.0% dietary CF) or control cows (2.0% dietary CF). In contrast, body temperatures of control calves 180 min after birth were lesser than that of calves born to fat-supplemented dams (Deitz et al., 2003). Lambs born to fat-supplemented (5.7% dietary CF) ewes had a greater mortality rate than lambs born to control (2.8% dietary CF) ewes. Birth weights, weaning weights, and brown fat stores of lambs were not different between treatments (Encinias et al., 2004).

Several studies investigated the interactive effects of cold stress and maternal fat supplementation on well-being of neonatal calves. Birth weights were similar among calves when dams were fed either a fat-rich (5.1% CF) or a fat-poor (2.2% CF) diet. Conversely, rectal temperatures and blood glucose at birth were greater in calves born to fat-supplemented cows than in calves born to control cows. Body temperature and blood glucose of calves born to fat-supplemented cows were greater than those of calves born to control cows throughout a 140-min, cold-exposure period (Lammoglia et al., 1999b). These researchers also reported that calves of fat-supplemented cows (4.7% CF) were heavier at birth than calves of control cows (1.7% CF). In contrast to earlier results, calves from control cows had greater rectal temperatures during an 80-min cold-exposure period than did calves from fat-supplemented cows; however, the cold-induced increase in body temperature was greater in calves born to fat-supplemented cows and was maintained for a longer period of time than in calves born to control cows. Postpartum blood-glucose concentration was greater in calves born to fat-supplemented dams than in calves born to control dams (Lammoglia et al., 1999a).

Postpartum fat supplementation of cows had no effect on ADG or weaning weight of calves in two recent studies (Bottger et al., 2002; Lake et al., 2005). Other researchers reported greater ADG by calves (De Fries et al., 1998) and lambs (Appendu et al., 2004) of dams fed supplemental fat postpartum compared to those of dams receiving no supplemental fat. Conversely, calves of dams fed low-fat supplements postpartum had greater antibody response to immune challenge than calves of dams fed fat-rich supplements in 2 trials (Lake et al., 2006).

Blood Metabolites

Blood metabolites are often used as an indicator for various metabolic effects of fat supplementation. Serum concentrations of cholesterol were greater in cows supplemented with fat in the form of whole cottonseed postpartum (8% EE) than in control cows (2.8% EE) after 28 d of supplementation (Williams et al., 1989). Greater serum cholesterol levels were reported in heifers supplemented with calcium salts of long-chain fatty acids compared with control heifers (Lloyd et al., 2002). In addition, serum cholesterol was greater in heifer calves supplemented with fat in the form of whole sunflower seeds (7.4% dietary EE) compared to control heifers (2.9% dietary EE; Garcia et al., 2003). Similar results were reported for serum cholesterol concentration in prepubertal heifers (Lammoglia et al., 2000).

In young heifers, serum growth hormone (GH) concentration was greater in fat-supplemented heifers (7.4% EE) than in controls (2.9% EE; Garcia et al., 2003). Conversely, no differences were found in GH concentrations for either control or fat-supplemented cows (3.74% and 1.9% CF, respectively) and control or fat-supplemented heifers (5.2% and 4.4% CF, respectively; Lammoglia et al., 1997; Lammoglia et al., 2000). Serum leptin in young or preputertal heifers also did not seem to be affected by fat supplementation (Lloyd et al., 2002; Garcia et al., 2003).

Serum insulin of prepubertal heifers was not affected by fat supplementation (Lammoglia et al., 2000). Similar results were reported when primiparous cows were supplemented with fat postpartum; moreover, serum glucose was unaffected by treatment (Bottger et al., 2002). Conversely, mature cows supplemented with rice bran (5.2% CF) during the postpartum period had greater serum insulin after 16 d of supplementation than heifers supplemented with a coastal bermudagrass hay-based control (3.74% CF; Lammoglia et al., 1997).

Serum triglycerides were not affected when mature cows were supplemented with rice bran or bermudagrass hay during the postpartum period. In contrast, serum estradiol was greater in rice bran-supplemented cows than control-supplemented cows during the first estrous cycle postpartum but not during the second (Lammoglia et al., 1997). Luteinizing hormone and FSH were similar in control and fat-supplemented cows before and after a GnRH challenge (Grant et al., 2003).

Serum prostaglandin $F2_{\alpha}$ metabolite (PGFM) concentrations tended to be greater in cows fed a fat-rich supplement (5.2% CF) than in cows fed a control diet (3.74% CF; Lammoglia et al., 1996). Serum PGFM was greater in cows supplemented with linoleic acid-rich safflower seeds (31.36% CF) than in cows fed oleic acid-rich safflower seeds (29.32% CF), a beet pulp-soybean meal supplement (0.55% CF), or a corn-soybean meal supplement (3.8% CF; Grant et al., 2005).

Prepubertal heifers supplemented with a safflower seed-based supplement (4.4% CF) had greater serum progesterone (P4) than heifers fed a control supplement (1.9% CF; Lammoglia et al., 2000). Cows supplemented with rice bran (5.2% CF) had greater serum P4 concentrations by d 5 of the second estrous cycle postpartum than cows supplemented with a bermudagrass hay-based control (3.7% CF; Lammoglia et al., 1997). Williams et al. (1989) and De Fries et al. (1998) found no dietary effects on serum P4 concentrations of cows.

Cows were fed isonitrogenous and isocaloric diets consisting of a corn-soybean meal control, a high-linoleate diet or a high-oleate diet. The high-linoleate diet resulted in greater relative plasma concentrations of both linoleic acid and arachidonic acid. The high-oleate diet resulted in greater plasma concentrations of oleic acid (Grant et al., 2005).

Follicular Inventory

Follicular dynamics of cows were consistently altered by fat supplementation. Cows supplemented with rice bran postpartum (5.2% EE) had more total follicles than cows fed an isonitrogenous, isocaloric control supplement (3.7% EE); moreover, the largest follicle in fat-supplemented cows was of greater size than that in control cows between d 15 and d 24 postpartum, 3 wk postpartum, and 1 wk before initial estrous behavior was detected (DeFries et al., 1998). Similarly, fat-supplemented cows (5.2% dietary fat) had greater numbers of small, medium, and total follicles compared with control cows (3.74% dietary fat). The size of the largest follicle was greater also in fat-supplemented cows compared with cows fed the control supplement (Lammoglia et al., 1996). Conversely, increased numbers of follicles were reported among cows fed a control diet (3.74% CF) compared with those fed a rice bran-based diet (5.2% CF) even though diets were isonitrogenous and isocaloric. There were no treatment effects on ovarian weight, ovarian area, corpus luteum weight, or corpus luteum area (Lammoglia et al., 1997).

Cyclicity and Pregnancy Rates

Most researchers reported that fat supplementation did not influence postpartum cyclicity by mature cows. There was no effect of diet on days to first estrus or number of cows cycling when cows were fed either a fat-rich range supplement or a low-fat range supplement prepartum (Alexander et al., 2002). Proportion of cows displaying estrous behaviors at the beginning of the breeding season was similar when they received either a control supplement (2.2% CF) or a sunflower seed-based supplement (6.3% CF) prepartum (Bellows et al., 2001). Moreover, postpartum fat supplementation had no influence on cyclicity or the time to first estrus (Lammoglia et al., 1996; De Fries et al., 1998; Grant et al., 2003). In contrast, a greater proportion of fat-supplemented cows (8% dietary EE) had evidence of luteal tissue before a GnRH injection than their control counterparts (2.8% dietary EE). On d 5 to 7 after ovulation, fewer fat-supplemented cows had corpora lutea that had undergone premature regression than control cows. In addition, control cows had a luteal phase approximately half the duration of the fat-supplemented cows (Williams, 1989).

Several researchers noted positive effects on pregnancy when supplemental dietary fat was offered. In multiparous cows supplemented prepartum, AI conception rate was greater in cows supplemented with soybean hulls (38 g/d lipids) than in cows fed a control supplement (4 g/d lipids). In addition, cows fed supplemental sunflower seeds (405 g/d lipids) tended to have greater AI conception rate than cows fed the control supplement (4 g/d lipids). Final pregnancy rates were not different between treatments (Banta et al., 2006).

The pregnancy rate of cows supplemented with rice bran (5.2% EE) was increased compared with cows fed a control supplement (3.7% EE; De Fries et al., 1998). Similarly, prepartum supplementation of cows with whole, raw soybeans resulted in increased first-service conception compared with an isonitrogenous, isocaloric control supplement in two separate studies (Graham et al., 2001).

Other researchers reported that fat supplementation had negative or no effects on pregnancy. A standard heifer-development diet (2.4% CF) was compared with diets supplemented with various fat sources, including safflower seeds (4.7% CF), soybeans (3.8% CF), and sunflower seeds (5.1% CF; Bellows et al., 2001). The proportion of heifers displaying estrous behavior at breeding and final pregnancy rates were similar between treatments.

Cows supplemented postpartum with linoleic acid-rich safflower seeds tended to have lesser AI conception rates than cows fed a control supplement. Final pregnancy rates were not different between treatments (Grant et al., 2003). Conception to AI and final pregnancy rates were similar when prepartum cows were fed either a control diet (1.9% CF) or a safflower-seed based diet (4.4% CF; Lammoglia et al., 2000). Similarly, conception to AI and final pregnancy rates were not affected when prepartum cows received a control supplement, a manufactured high-fat range supplement, or a manufactured high-fat range supplement with added soybean soapstock (Alexander et al., 2002).

Pregnancy rate of cows supplemented with fat postpartum was not different from cows receiving no supplemental fat (Bottger et al., 2002; Funston et al., 2002; Lake et al., 2005). Similarly, heifers fed fat-rich or fat-poor supplements postpartum showed no pregnancy differences (Rhodes et al., 1978; Lammoglia et al., 2000; Lloyd et al., 2002).

A safflower-seed supplement (4.4% fat) had no effect on age at puberty compared with a control supplement (1.9% fat) when fed to heifers for 162 d before first breeding (Lammoglia et al., 2000). Conversely, heifers fed a control diet reached puberty earlier than heifers fed the control diet plus microencapsulated tallow (Rhodes et al., 1978).

Conclusions

Fat supplementation has varying effects on reproductive performance of beef heifers and cows. There does not seem to be a consistent response to type of fat supplementation or the timing of fat supplementation (i.e. pre- or postpartum). More research is needed to fully evaluate how the provision of supplemental fat interacts with BCS, BW, and age of cows. In addition, the influence of supplemental fat composition on reproductive efficiency has yet to be studied in detail. Certain long-chain fatty acids may modify the effects of prostaglandins and certain hormones. Further study in this field seems warranted.

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Chapter 2

Effects of Prepartum Whole Cottonseed or Whole Raw Soybean Supplementation on Response to Timed Artificial Insemination in Suckled Mature Beef Cows Following Ovulation Synchronization

ABSTRACT

Prepartum fat supplementation has been associated with improved reproductive performance by cows managed for AI. Our objective was to evaluate the effects of prepartum supplementation with whole cottonseed or whole raw soybeans on response to ovulation synchronization and timed artificial insemination in mature beef cows. Cows (n = 188; average initial BW = 579 ± 54 kg) were stratified by BCS and BW and assigned to 3 supplementation treatments: whole raw soybeans (21.6 % fat, 38.6% CP), whole fuzzy cottonseed (21.7% fat, 21.1% CP), or a 50:50 mixture of ground corn and soybean meal (2.6% fat, 30.6% CP). Supplements were fed at 1.8 kg per animal daily for 45 d before the first projected calving date (April 1). Supplementation was continued until each cow calved; thereafter, all cows received the control supplement until May 1. Ovulation was synchronized using the CoSynch + CIDR protocol and cows were bred via AI on June 21. Eleven d after AI, cows were exposed for natural service breeding for 50 d. Conception to AI was assessed 33 d after AI. Overall conception was assessed and conception to AI reaffirmed 126 d after AI. Body weight of cows fed control or oilseed supplements was similar ($P > 0.3$) at calving, initiation of ovulation synchronization, and at the end of the breeding season. Cottonseed-supplemented cows lost more BW and more BCS ($P < 0.03$) from the beginning of the trial to calving than those fed soybeans. Proportion of cycling cows was similar ($P = 0.57$) between treatments. Pregnancy to timed AI and final pregnancy rates were similar ($P \geq 0.75$) between control and oilseed-supplemented cows. Conversely, supplementation with cottonseed was associated with increased AI conception ($P = 0.08$; 54 and 39%, for cottonseed and soybeans, respectively) and greater final pregnancy rate compared to soybean-fed cows ($P = 0.03$; 100 and 93% for cottonseed and soybeans, respectively). Calf birth weights and calf weights at the end of the breeding season were similar ($P \geq 0.24$) between treatments. Effects of cottonseed and soybean supplementation on response to ovulation synchronization and timed AI by beef cows warrant further study.

Key words: Conception rate, beef cows, fat supplementation

INTRODUCTION

Fat supplementation of beef cattle, pre- and postpartum, has been evaluated as a means to improve reproductive performance. Some studies reported improvements in BCS and BW as a result of supplementation (De Fries et al., 1998; Bellows et al., 2001; Grant et al., 2003), whereas others reported no difference in BCS and BW (Williams, 1989; Tjardes et al., 1998; Lammoglia et al., 1999b; Murietta et al., 2006). Most studies reported that calf performance was not affected by fat supplementation of the cow (Deitz et al., 2003; Banta et al., 2006); although there was some evidence that calves of fat-supplemented cows may be larger at birth and more capable of surviving cold stress than those of cows fed carbohydrate based-supplements (Lammoglia et al., 1999a; Lammoglia et al., 1999b).

Follicular inventory was improved in response to fat supplementation (Lammoglia et al., 1996; DeFries et al., 1998). Moreover, pregnancy rates were improved by fat supplementation in some cases (DeFries et al., 1998; Graham et al., 2001; Banta et al., 2006) but not in others (Bellows, 2001; Grant et al., 2003; and Lake et al., 2005).

The objective of this trial was to evaluate the effects of prepartum fat supplementation using either whole, raw soybeans or whole, fuzzy cottonseed on cow BW, cow BCS, calf BW, cow response to ovulation synchronization, and cow response to timed AI. We hypothesized that oilseed-supplemented cows would have greater pregnancy rates after timed AI.

MATERIALS AND METHODS

Spring calving, multiparous cows (n = 188; average initial BW = 579 ± 54 kg) grazing native tallgrass range were stratified by BCS (1 to 9 scale; 1 = emaciated, 9 = obese) and BW and assigned randomly to 1 of 3 treatments: a control supplement consisting of a 1:1 ratio of dry-rolled corn and soybean meal (2.6% fat; n = 65), a supplement of whole raw soybeans (21.6% fat; n = 64), or a supplement of whole fuzzy cottonseed (21.7% fat; n = 59). Chemical composition of supplements is displayed in Table 1. Long-chain fatty acid composition of supplements is displayed in Table 2. Within treatment, cows were assigned randomly to four native tallgrass pastures such that each treatment was equally represented in each pasture. Chemical composition of pastures grazed during supplementation and calving was reported in Table 3. Pastures were stocked at approximately 2 hectares per cow from January 15 to May 15.

Supplementation was initiated on January 30. Cows were gathered from pastures at 0700 daily and they were sorted into their respective treatment groups. Within treatments, cows were group-fed supplements in bunks. Approximately 75 cm of bunk space was provided for each cow. Cows were allowed 1 h to consume their allotment of supplement. Thereafter, treatments were commingled and returned to their assigned pastures. All cows were fed the control supplement from January 30 to February 15 in order to acclimate them to the sorting process. Treatment supplements were introduced on February 15, 45 d before the first projected calving date (April 1). Supplements were fed at 1.8 kg per cow daily and were approximately isocaloric. Supplement consumption was complete each day.

All cows were weighed and assigned a BCS at parturition. Calf birth weights also were recorded. All cows were fed the control supplement from the day they calved until May 1.

Cows were stratified by treatment and assigned randomly to four adjacent native tall grass pastures for the summer grazing period. Cow-calf pairs were moved approximately 38 km to these summer pastures on May 15. Pastures were stocked at approximately 1.9 ha per cow-calf pair. Chemical composition of pastures grazed during this period as presented in Table 4.

Forage and supplement samples were dried in a forced-air oven (96 h; 50 °C), weighed, and ground (No. 4 Wiley mill, Thomas Scientific, Swedesboro, NJ) to pass a 1-mm screen. A portion of the ground samples were dried in a forced air oven at 105° C overnight, and combusted at 450° C for 8 h to determine laboratory DM and OM, respectively (Undersander et al., 1993). Forage and supplement NDF, with amylase, with sulfite, and without correction for residual ash, and ADF were analyzed using an ANKOM fiber analyzer (ANKOM technology Corp., Fairport, NY) using standard procedures provided by the manufacturer. Forage and supplement N was measured by using a LECO FP–2000 nitrogen analyzer (LECO Corp., St Joseph, MI; AOAC, 1995).

Ether extract of supplements was analyzed according to the AOAC (1995). Calcium concentration of supplements was measured using methods described by Bowers and Rains (1988). Phosphorus concentration of supplements was analyzed as described by Fiske and Subarrow (1925). Fatty acids in supplements were derivatized to fatty acid methyl esters as described by Sukhija and Palmquist (1988) and measured using a HP 5890 GC with a SP-2560 capillary column (100m x .25mm x .2µ film; Supelco, Inc., Bellefonte, PA). Injection port and detector temperatures were 250°C with a flow rate of 1 ml/min helium and a split ratio of 100:1.

Blood samples were collected from all cows on May 1; BW and BCS were measured at that time. A second blood sample was collected on June 11, at which time ovulation synchronization was initiated using the Co-Synch + CIDR protocol (Figure 1). A CIDR (controlled internal drug-releasing device, Pfizer Animal Health, New York, NY) was inserted into the vagina and 100 µg of GnRH (2 mL Ovacyst, IVY Animal Health, St. Joseph, MO) was injected intramuscularly. The CIDR was removed on June 18 and cows were injected intramuscularly with 25 mg of $PGF_{2\alpha}$ (Prostamate, IVY Animal Health, St. Joseph, MO). Timed AI (TAI) was initiated 60 to 64 hours after the $PGF_{2\alpha}$ injection on June 21. Four technicians performed the AI procedures using semen from 1 of 6 AI sires. All AI sires were equally represented in each of our treatment groups.

Blood samples were collected from a coccygeal vessel into evacuated tubes and immediately placed on ice. Samples were stored overnight at 5 ^{0}C and subsequently centrifuged at (1,500 x g). Serum was decanted into12 x 75-mm plastic tubes and immediately frozen (-20 ^{0}C). Content of progesterone (P4) in serum was ascertained using radioimmunoassay (Skaggs et al., 1986). Inter- and intra-assay coefficients of variation were 6.4 and 6.7%, respectively. Cows were classified as cycling if either or both serum samples (collected 21 d and 10 d before TAI) contained P4 levels $\geq$ 1.0 ng/mg. Cows were classified as non-cycling if both serum samples contained P4 levels < 1.0 ng/mg.

Two bulls were released into each pasture 11 d after TAI (July 2) and were removed 50 d later. Pregnancy diagnosis was made using transrectal ultrasonography 33 d after TAI. Cows and calves were weighed and cows were assigned a BCS 67 d after TAI. Final pregnancy rates were diagnosed on October 25 by rectal palpation.

Cow and calf performance were analyzed as a randomized complete block. The model included effects for treatment, pasture, and treatment(pasture). Treatment groups within individual pastures were considered the experimental unit. Treatment(pasture) was used as the error term. When protected by a significant F test ($P < 0.1$), least squares treatment means were separated using the method of least significant difference.

Pregnancy rates and cyclicity were analyzed using PROC GLM (SAS, 2007). The model used to assess differences in TAI pregnancy rates and overall pregnancy rates included effects for treatment, parity and cycling status. Simple arithmetic means for pregnancy rates were reported. The model used to analyze treatment effects on cyclicity included effects for treatment and pasture. Least squares treatment means for cyclicity were reported.

RESULTS AND DISCUSSION

Fat supplementation for 45 to 65 d prepartum had positive effects on pregnancy rates and follicular dynamics when oilseeds were used to supply fat (Bellows et al., 2001;

Graham et al., 2001). However, such effects were not universally observed (Alexander et al, 2002). Our study was designed to evaluate a fat source that historically produced improvements in reproductive performance of beef cows (i.e., whole raw soybeans) in comparison with one that had not been widely examined in that regard (i.e., whole fuzzy cottonseed).

Body weight and BCS were similar ($P > 0.05$) across treatments at calving, at the initiation of ovulation synchronization, and at the end of the breeding season (Tables 5 and 6). Cows fed the whole cottonseed supplement lost more BW ($P < 0.01$) from the beginning of the experiment to parturition than cows fed the whole soybean supplement or the control supplement (-54.3, -31.9, and -31.9 kg for cottonseed, soybeans, and control, respectively). During this period, cows fed the whole-cottonseed supplement and the control supplement lost more ($P < 0.03$) BCS than cows fed the whole-soybean supplement (0.65, 0.64 and 0.41 BCS units for cottonseed, control, and soybeans, respectively). Cows fed the control supplement gained more ($P < 0.02$) BW than cows fed the cottonseed supplement from the beginning of the trial to the start of the breeding season. Also, BW change of soybean-fed cows was intermediate to and not different ($P > 0.05$) from control- and cottonseed-fed cows during that period. Cottonseed-fed cows gained more BW than soybean-fed cows from parturition to the start of the breeding season ($P = 0.03$; 55.7 and 44.5 kg, respectively). Body weight change by control-fed cows between parturition and the start of the breeding season was not different ($P \geq 0.12$) from that by cottonseed-fed or soybean-fed cows.

Greater prepartum loss of body weight or body condition score by cows supplemented with cottonseed compared to cows supplemented with soybeans or the corn-soy control could have been due to differences in ruminally-degradable protein intake. While the supplements had similar concentrations of NE_m (Table 1), CP was less in the cottonseed supplement (21.1%) than in the control supplement or the soybean supplement (30.1 and 38.6%, respectively). These compositional differences may be interpreted to indicate that the whole cottonseed supplement was of lesser nutritional value than the other supplements.

The effects of fat supplementation on BW and BCS change by cows have been varied. Alexander and colleagues (2002) found no differences in BW at calving, at 56 d post-calving, or at weaning between cows fed 1 of 2 fat rich fat-rich supplements (13.2 and 13.5% crude fat) or a low-fat control supplement (3.2% crude fat). Conversely, control cows had greater BCS at calving than fat-supplemented cows in that study. Bellows et al. (2001) reported that cows fed 1 of 3 supplemental fat sources for 65 d prepartum had greater prebreeding BCS than cows fed a low-fat control supplement. In a subsequent study, these researchers found no BCS or BW differences between cows fed a low-fat supplement or a sunflower seed-based supplement.

There was no difference in calf birth weight between treatments ($P \geq 0.24$; Table 7). In addition, calf weights were similar ($P \geq 0.52$) among treatments at the end of the breeding season (average calf age = 139 ± 22 d). These results support previous research in which no differences in birth weight were observed among calves born to mothers fed a low-fat diet or a high-fat diet (Dietz et al., 2003). Encinias et al. (2004) also found no difference in birth weight of lambs born to mothers fed high-fat diets or low-fat diets prepartum.

The proportion of cycling cows, ascertained 21 and 10 d prior to AI, was similar (P = 0.77) between control and oilseed-supplemented treatments (Table 8). In addition, the proportion of cycling cows was similar (P = 0.77) between the soybean and cottonseed treatments. Bellows et al. (2001) also reported that there were no differences in estrous behavior at the beginning of the breeding season when cows were supplemented prepartum with a 2.4%-fat control supplement or one of several supplements containing 3.8 to 5.1% fat.

Pregnancy rates to timed AI and final pregnancy rates were similar ($P \geq 0.69$) between control cows and oilseed-supplemented cows (Table 8). Conversely, supplementation with cottonseed tended to cause increased AI conception (P = 0.08; 54 and 39%, for cottonseed and soybeans, respectively) and caused greater final pregnancy rate compared to soybean-fed cows (P = 0.02; 100 and 93% for cottonseed and soybeans, respectively). In contrast, Graham and collegues (2001) reported that cows supplemented with whole soybeans for 45 d prepartum had greater first-service conception than those fed a control diet based on corn gluten feed.

Cows fed whole soybeans lost less BCS between the beginning of the trial and parturition than did cows fed whole cottonseed. In spite of this, soybean-fed cows had poorer TAI pregnancy rates and final pregnancy rates than whole cottonseed-supplemented cows. Greater retention of BCS was expected to be a mechanism for improved pregnancy rates when supplementing dietary fat.

Differences in TAI and total pregnancy between the soybean and cottonseed treatments may have been attributable to differences in the long-chain fatty acid composition of the supplements (Table 2). The cottonseed supplement had greater concentrations of palmitic acid (C16:0), vaccenic acid (C18:1n11c) and linoleic acid (C18:2n6c) than did the soybean supplement. Palmitic acid is the first fatty acid produced during lipogenesis and can be used by the body to produce longer-chain fatty acids. In addition, the C18:1n11c isomer of vaccenic acid is converted to 9-cis, 11-trans conjugated linoleic acid in the rumen (Turpeinen et al., 2002). Cows were fed a high-linoleate diet had greater relative plasma concentrations of both linoleic acid and arachidonic acid than cows fed a corn-soybean meal control diet or a high-oleate diet (Grant et al., 2005). Linoleic acid is used in the synthesis of arachidonic acid and prostaglandin; moreover, prostaglandin stimulates ovulation by promoting regression of the corpus luteum.

In addition, fat supplementation appears to consistently alter follicular dynamics of cows. Cows supplemented with rice bran postpartum (5.2% EE) had more total follicles than cows fed an isonitrogenous, isocaloric control supplement (3.7% EE); moreover, the largest follicle in fat-supplemented cows was of greater size than that in control cows between d 15 and d 24 postpartum, 3 wk postpartum, and 1 wk before initial estrous behavior was detected (DeFries et al., 1998). Similarly, fat-supplemented cows (5.2% dietary fat) had greater numbers of small, medium, and total follicles compared with control cows (3.74% dietary fat; Lammoglia et al., 1996). The size of the largest follicle was greater also in fat-supplemented cows compared with cows fed the control supplement in that study.

The whole soybean treatment may also have exerted direct negative affects on reproductive performance. Soybeans contain high levels of isoflavones, such as glycetin, diadzein, and genistein (Adams, 1995). Feedstuffs containing phytoestrogens such as these have caused infertility in ruminants. Signs of infertility caused by phytoestrogens include enlargement of the uterus, mammary development, swelling of the vulva and discharge of cervical mucus (Adler and Trainin, 1960). Greater levels of phytoestrogens were found in the urine and plasma of cows fed soybeans than those fed a control diet (Woclawek-Potocka et al., 2005). Moreover, pregnancy rates were greater for control-supplemented cows than soybean-supplemented cows in that study. In contrast, cows supplemented with whole soybeans for 45 d prepartum had greater first-service conception than those fed a control diet based on corn gluten feed (Graham et al., 2001).

The difference in TAI pregnancy between soybean-fed cows and cottonseed-fed cows may also be attributed to treatment differences in weight gain during the period between parturition and the start of the breeding season (Table 5). The practice of flushing has been used to increase reproductive performance of litter-bearing livestock species. Flushing consists of a period of dietary protein or energy restriction followed by a period of realimentation immediately before the breeding season. This practice attempts to produce a rapid weight gain during the prebreeding period and has resulted in improved reproductive performance by ewes (Hulet et al., 1962; Torrell et al., 1972) and sows (Zimmerman et al., 1960; Moore et al., 1973; Rhodes et al., 1991). Although cattle are mono-ovulators, the greater relative weight gain that occurred between calving and breeding in our study may have allowed the cottonseed-supplemented cows to respond to TAI more favorably than the soybean-supplemented cows.

In conclusion, cows supplemented with whole, fuzzy cottonseed tended to have a greater TAI pregnancy rate and had a greater final pregnancy rate than cows supplemented with whole, raw soybeans. This occurred in spite of the fact that cottonseed-fed cows lost more BW than soybean-fed cows during the prepartum period and that cycling status was similar among treatments.

Implications

At this time, it does not seem reasonable to conclude that crude fat supplementation is useful for improving reproduction in female ruminants. Future research should perhaps focus on specific fats that are precursors for compounds associated with the reproductive cycle, such as linoleic acid. Researchers also may choose to examine various flushing strategies for beef cattle. A third avenue for future research may be to examine how cows of differing body condition scores respond to specific fat sources supplemented pre- and postpartum. Cows in poor body condition may benefit from supplementation with specific fatty acids.

Table 1. Chemical composition of supplements fed to mature beef cows for 45 d prepartum

	Supplement		
	Control[a]	Soybeans	Cottonseed
DM %	92.7	91.6	88.0
OM %	95.4	94.2	94.6
	---------------------- % DM----------------------		
NDF	10.0	14.3	45.8
ADF	4.2	7.5	36.3
CP	30.6	38.6	21.1
Crude Fat	2.6	21.6	21.7
NEm, Mcal/kg[b]	2.2	2.2	2.4
Calcium, mg/g	4.77	7.90	4.24
Phosphorus, mg/g	5.16	21.87	6.73

[a] Control supplement consisted of 50:50 mixture of corn and soybean meal on a dry matter basis

[b] Adapted from NRC (2000)

Table 2. Fatty acid composition of whole raw soybeans (21.6% fat), whole fuzzy cottonseed (21.7% fat), and a 50:50 mixture of corn and soybean meal (2.6% fat) fed to mature beef cows for 45 d prepartum

			Supplement[a]		
Isomer	Systematic Name	Common Name	Control	Soybean	Cottonseed
C6:0	Hexanoic acid	Caproic acid	37.40	58.97	124.83
C11:0	Undecanoic acid		10.21	0.00	13.16
C12:0	Dodecanoic acid	Lauric acid	4.70	56.58	22.00
C14:0	Tetradecanoic acid	Myristic acid	17.71	127.72	1545.53
C15:0	Pentadecanoic acid		11.98	57.79	64.54
C16:0	Hexadecanoic acid	Palmitic acid	3372.06	20704.79	47648.16
C16:1	Hexadecenoic acid	Palmitoleic acid	31.93	216.89	1173.48
C17:0	Heptadecanoic acid	Margaric acid	43.31	275.76	275.99
C18:0	Octadecanoic acid	Stearic acid	766.88	10076.86	5028.37
C18:1n11t		Vaccenic acid	4.87	27.07	0.00
C18:1n11c		Vaccenic acid	220.28	2945.84	16153.14
C18:1n9c		Oleic acid	4263.94	41323.61	30199.95
C18:2n6c		Linoleic acid	10907.79	2945.84	109508.88
C18:3n3		α-Linolenic acid	866.89	12903.48	458.82
C20:0	Eicosanoic acid	Arachidonic acid	90.62	684.79	557.01
C20:1	Eicosenoic acid	Gadoleic acid	40.63	297.86	179.61
C20:2	Eiconsadienoic acid		8.75	136.54	49.08
C20:3n6	Eicosatrienoic acid		0.00	21.76	24.79
C21:0	Heneicosanoic acid		5.26	58.70	37.10
C22:0	Docosanoic acid	Behenic acid	67.05	710.76	341.05
C22:1n9		Erucic acid	5.00	36.09	10.37
C22:5n3	Docosapentenoic acid		2.11	38.48	0.00
C23:0	Tricosanoic acid		21.24	105.60	78.57
C24:0	Tetracosanoic acid	Lignoceric acid	77.86	270.78	255.56
CLA 10t,12c			13.96	0.00	0.00
CLA 9c,11c			0.00	7.78	67.92
CLA 9t,11t			12.41	71.77	23.47

[a]Concentrations reported are μg/g

Table 3. Average chemical composition of native tallgrass forage grazed by cows during the prepartum period and during calving (March 6 to May 1)

	Month	
	March	April
DM %	90.8	93.2
OM %	88.9	86.8
NDF, % DM	76.0	72.5
ADF, % DM	44.6	43.2
CP, % DM	5.3	5.4

Table 4. Average chemical composition of native tallgrass forage grazed by cows during the prebreeding and breeding periods (June 6 to August 1)

	Month	
	June	July
DM %	74.9	79.7
OM %	89.1	90.9
NDF, % DM	79.7	78.0
ADF, % DM	43.9	43.1
CP, % DM	10.8	8.0

Table 5. Effect of prepartum supplementation with whole raw soybeans (21.6% fat), whole fuzzy cottonseed (21.7% fat), or a 50:50 mixture of corn and soybean meal (2.6% fat) on body weight and body weight change by mature cows

	Treatment		
Body Weight	Control	Soybean	Cottonseed
Weight at parturition, kg[*]	544.1 ± 7.3	546.7 ± 7.3	530.0 ± 7.7
Weight at breeding, kg[†]	592.2 ± 7.1	591.3 ± 7.1	585.7 ± 7.4
Weight post-breeding, kg[‡]	583.8 ± 6.5	580.5 ± 6.4	578.8 ± 6.8
Body Weight Change			
February 15 to parturition	-31.9 ± 4.5	-31.9 ± 4.6	-54.3 ± 4.8
February 15 to start of breeding	16.2 ± 4.2^{a}	12.7 ± 4.3^{a}	2.0 ± 4.5^{b}
Parturition to start of breeding	48.1 ± 3.4^{ab}	44.5 ± 3.4^{a}	55.7 ± 3.6^{b}

[a,b,c] Rows with differing subscripts differ ($P < 0.05$)

[*] Average date of parturition was April 5

[†] Measured on June 1

[‡] Measured 67 d after timed AI (Aug 27)

Table 6. Effect of prepartum supplementation with whole raw soybeans (21.6% fat), whole fuzzy cottonseed (21.7% fat), or a 50:50 mixture of corn and soybean meal (2.6% fat) on body condition score and body condition score change by mature cows

	Treatment		
Body Condition Score	Control	Soybean	Cottonseed
Body Condition Score, parturition[*]	4.88 ± 0.07	5.02 ± 0.07	4.84 ± 0.08
Body Condition Score, breeding[†]	4.87 ± 0.08	4.81 ± 0.08	4.76 ± 0.08
Body Condition Score, post breeding[‡]	6.28 ± 0.54	5.22 ± 0.54	5.08 ± 0.57
Body Condition Score Change			
February 15 to parturition	-0.64 ± 0.07[a]	-0.41 ± 0.07[b]	-0.65 ± 0.08[a]
February 15 to start of breeding	-0.65 ± 0.07	-0.61 ± 0.07	-0.73 ± 0.08
Parturition to start of breeding	-0.02 ± 0.08	-0.21 ± 0.08	-0.08 ± 0.08

[e,f] Rows with differing subscripts differ ($P < 0.05$)

[*] Average date of parturition was April 5

[†] Measured on June 1

[‡] Measured 67 d after timed AI (Aug 27)

Table 7. Body weights of calves born to dams fed whole raw soybeans (21.6% fat), whole fuzzy cottonseed (21.7% fat), or a 50:50 mixture of corn and soybean meal (2.6% fat) for 45 d prepartum

	Treatment[a]		
Calf Weight	Control	Soybean	Cottonseed
Birth, kg[*]	40.4 ± 0.6	40.3 ± 0.6	39.4 ± 0.6
End of breeding season, kg[†]	188.1 ± 4.5	192.2 ± 4.5	192.2 ± 4.7

[a] No effect of treatment ($P \geq 0.24$)

[*] Average date of parturition was April 5

[†] Measured 67 d after timed AI (Aug 27); average calf age = 139 ± 22 d.

Table 8. Effect of prepartum supplementation with whole raw soybeans (21.6% fat), whole fuzzy cottonseed (21.7% fat), or a 50:50 mixture of corn and soybean meal (2.6% fat) on cycling status and pregnancy rates of mature cows

	Treatment			Contrast[a]	
	Control	Soybean	Cottonseed	Control vs Oilseeds	Soybeans vs Cottonseed
Cows cycling, %[*]	72.5	69.2	71.6	0.77	0.77
TAI pregnancy, %[†]	49.2	39.1	54.2	0.69	0.08
Final pregnancy, %[**]	98.5	93.8	100	0.75	0.02

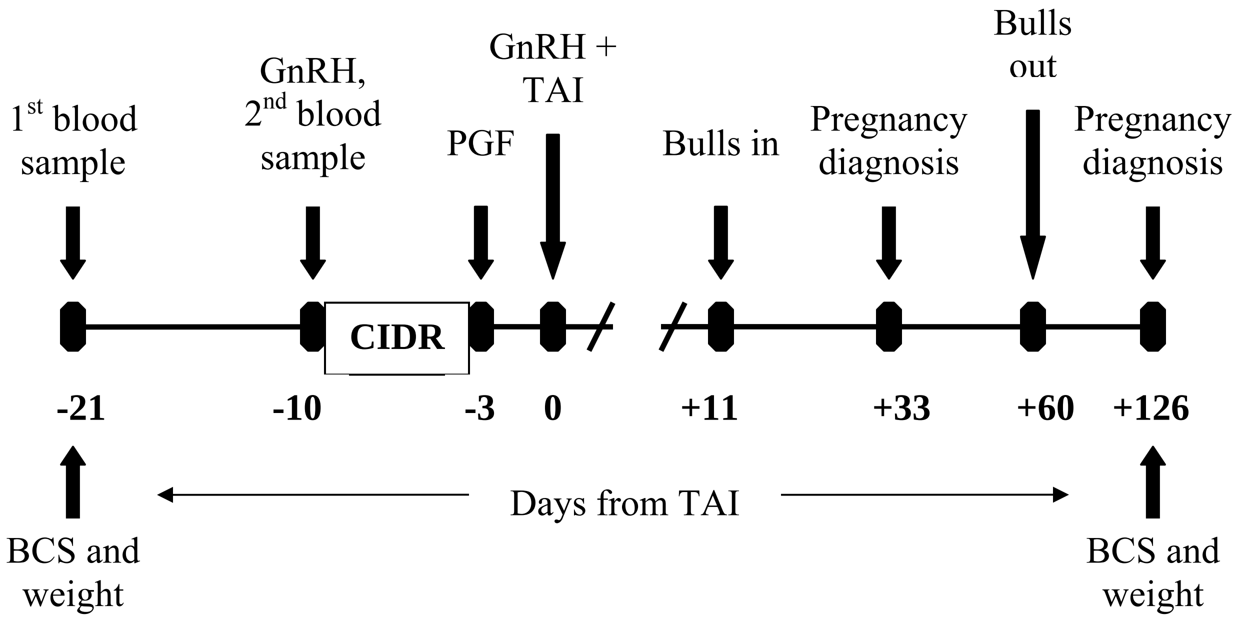
[a] Probability of a greater value of F

[*] Determined by blood samples taken 21 and 10 days prior to breeding; least squares means presented

[†] Percentage of cows classified as being pregnant only from timed AI; simple arithmetic treatment means presented

[**] Percentage of cows classified as being pregnant from timed AI or any period of natural service breeding; simple arithmetic treatment means presented

Figure 1. Design of ovulation synchronization and timed breeding protocols



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