EFFECTS OF OILSEED SUPPLEMENTAION ON PERFORMANCE AND REPRODUCTION OF BEEF COWS AND THEIR PROGENY

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Table of Contents

Chapter Page

List of Tables

Chapter II Page
Table

Chapter III Page
Table

Chapter IV Page
Table

Chapter V Page
Table

Format of Dissertation

This Dissertation is presented in the Journal of Animal Science style and format, as outlined by the Oklahoma State University graduate college style manual. The use of this format allows the individual chapters to be suitable for submission to scientific journals. Three papers have been prepared from the data collected for research to partially fulfill the requirements for the Ph.D. degree. Each paper is complete in itself with an abstract, introduction, materials and methods, implications, and literature cited section. These three papers can be found in chapters III, IV, and V.

Chapter I

Introduction

Optimizing reproductive efficiency is crucial to sustain a viable cow/calf enterprise. Consequently, numerous managementand nutrition strategies have been evaluated in an effort to optimize or in some cases maximize reproductive efficiency of beef cattle. Some of these strategies include early weaning, ruminally undegraded intake protein supplementation, biostimulation, and cow energy status at calving and breeding. Additionally, lipid supplementation (prepartum, postpartum, and pre- and postpartum) is another strategy that has been evaluated in the last 10 to 15 yr in an effort to improve reproductive efficiency. It has been theorized that lipid supplementation may improve reproductive efficiency of beef cows through a nutraceutical effect. In this dissertation, a nutraceutical effect will be defined as any change caused by a nutrient other than the traditional effect of that nutrient. In this case, the potential benefits of lipid supplementation on reproduction beyond the energetic contribution of the lipid supplement. Numerous lipid sources have been evaluated including oilseeds, calcium salts of long chain fatty acids, rice bran, yellow grease, and tallow. The oilseeds most commonly evaluated as lipid supplements are sunflower seed, safflower seed, canola, flaxseed, and soybeans.

The goal of this research was to determine if increased lipid intake from oilseed supplementation during late gestation could be used to improve reproductive efficiency of beef cows. Chapter Two provides a brief review of the factors that affect lipid digestion, the effects lipid supplementation has on digestion of various nutrients, and the effect lipid supplementation has on intake. Additionally, the published literature that has evaluated the effects of lipid supplementation on economically important measures of reproduction and the potential nutraceutical mechanism(s) via which lipid treatments may influence reproduction are also reviewed. Chapter Three investigates the effects high-oil whole sunflower seed supplementation has on cow and calf performance. Two experiments evaluating the effects of whole sunflower seed supplementation on performance, intake, and digestion are reported in Chapter Four. Experiment 1 details the effects of linoleic and mid-oleic sunflower seed supplementation on reproduction of multiparous beef cows, whereas Exp. 2 details the effects of linoleic and high-oleic sunflower seed supplementation on hay intake and digestion. Chapter Five investigates the effects of supplementing whole soybeans to cows of varying age on performance, intake, and digestion. Chapter Six provides a summary of the research efforts undertaken for the completion of this dissertation.

Chapter II

Review of Literature

Introduction

Because the economic value of reproduction has been estimated to be substantially greater compared with production or end product traits, optimizing reproduction is vital for cow/calf producers to survive (Melton, 1995). Consequently, individuals involved in beef cattle production are constantly looking for new management and nutritional strategies to optimize or in some situations maximize reproduction of beef cows. Because of potential nutraceutical effects, lipid supplementation is one strategy that has been researched as a tool to improve reproduction. In the following review, a nutraceutical effect will be defined as any change caused by a nutrient other than the traditional effect of that nutrient.

The goal of this review is to examine the current research pertaining to lipid supplementation of beef cattle. The first three sections briefly review the factors that affect lipid digestion, the effects of lipid supplementation on digestion, and the effect of lipid supplementation on intake. Additionally, the fourth section reviews the potential mechanisms through which lipid supplementation may impact reproduction of beef cattle. The final section details the effects of lipid supplementation on reproduction of beef cattle.

Factors that Affect Lipid Digestion

In a review of the literature Palmquist (1994) reported that a quadratic relationship exists between lipid intake and apparent lipid digestibility. However, it is interesting to note that true lipid digestibility actually decreases linearly as lipid intake increases (2.2%/100 g of lipid consumed). This reduction in true lipid digestibility is typically caused by the low digestibility of stearic acid (18:0).

Saturation and chain length also affect fatty acid digestion. As chain length of saturated fatty acids increases their digestibility decreases (i.e., 18:0 is less digestible than 16:0). This is evidenced by the fact that stearic acid is less digestible than the average fatty acid mixture presented to the ruminant small intestine and palmitic acid (16:0) is more digestible than the average fatty acid mixture (digestibility: palmitic acid > average fatty acid mixture > stearic acid). Additionally, fatty acid digestibility increases as unsaturation increases (i.e., 18:2 is more digestible than 18:1; Coppock and Wilks, 1991; Palmquist, 1994). For example, Borsting et al. (1992, as cited by Palmquist, 1994) reported digestibility coefficients of 0.948, 0.862, and 0.468, respectively, for vegetable oil, fish oil, and saturated fatty acids that were protected from ruminal metabolism by spray-drying with casein and formaldehyde. For a review of lipid digestion and absorption in ruminants the reader is referred to Moore and Christie (1984).

Effect of Lipid Supplementation on Digestion

Digestion of structural carbohydrates in the rumen can be reduced by as much as 50% with less than 10% added lipid (Jenkins, 1993). This reduction in fiber digestion is typically observed when dietary lipid content exceeds 5%. Although fiber digestion in the hindgut is increased, total tract fiber digestion is still reduced. The exception to this rule is when a major portion of the added lipid is inert in the rumen such as is the case when lipid supplementation occurs as calcium soaps or protein/formaldehyde treated products (Byers and Schelling, 1988; Jenkins, 1994). Additionally, it has been reported that this 5% threshold may be exceeded if lipid is supplemented as whole oilseeds in total mixed rations (Coppock and Wilks, 1991).

In contrast to fiber, numerous studies have reported that digestion of starch and other nonstructural carbohydrates were unaffected even when DM and fiber digestion were reduced due to high dietary lipid concentrations (Jenkins, 1993). The effect of lipid supplementation on protein digestion is inconsistent. Some reviews report decreased protein digestion (Byers and Schelling, 1988; Jenkins, 1993) while others report no change or increased protein digestion due to increased lipid intake (Doreau and Ferlay, 1995).

In addition to the amount of lipid in the diet, the fatty acid profile and structure of the lipid source can have varying effects on fiber digestion (Jenkins, 1993; Elliott, et al., 1997). For example, unsaturated fatty acids inhibit fiber digestion more than saturated fatty acids. Additionally, fatty acids that lack a free carboxyl group (i.e., calcium soaps and triglycerides) inhibit fiber digestion less than free fatty acids. Of the fatty acid factors that can inhibit fiber digestion it appears that the greatest depression in fermentation is related to the concentration of unsaturated free fatty acids in the rumen (Jenkins, 1993). Jenkins (1993) reviewed the mechanisms via which lipid supplementation may inhibit DM and fiber digestion.

Although data is limited, a few researchers have reported the effects of oilseed supplementation or diets containing oilseeds on digestion of chemical constituents.

Howlett et al. (2003) reported that total tract NDF, but not OM digestibility was significantly reduced for steers limit fed corn silage-based diets containing 15% whole cottonseed, 15% whole soybean, or 25% whole soybean compared with steers fed a control supplement. Dietary fatty acid concentrations were 4.5, 5.5, 7.4, and 2.5% for the 15% whole cottonseed, 15% whole soybean, 25% whole soybean, and control diets, respectively (Howlett et al., 2003). Total tract OM and NDF digestibility were significantly reduced and total tract N digestibility was significantly increased for beef heifers limit fed bromegrass hay and high-linoleic or high-oleic cracked safflower seeds compared with heifers fed hay and a control supplement (Scholljegerdes et al., 2004). However, there was no significant difference in unsaturated and total fatty acid postruminal disappearance between the safflower seed and control diets. Fatty acid content of the linoleic and oleic safflower seed diets was 8.44 and 8.65%, respectively (Scholljegerdes et al., 2004). Supplementation of crushed canola seed has been reported to reduce total tract digestion of OM of steers fed corn silage-based diets; however, total tract digestion of nonstructural carbohydrates, NDF, and ADF was not significantly reduced (Hussein et al., 1995). Long-chain fatty acid concentrations of the diets averaged across forage level were 4.0 and 9.4% for the control and crushed canola seed diets, respectively (Hussein et al., 1995).

University of Wyoming researchers reported that total tract OM, NDF, and N digestibility were not significantly different for heifers grazing bromegrass pastures and supplemented with corn or soybean oil (Brokaw et al., 2001). Crude fat of masticate samples was 3.9 and 4.1% for the corn and soybean oil diets, respectively (Brokaw et al., 2001). Krysl et al. (1991) reported that ruminal infusion of 300 mL of soybean oil per day significantly decreased total tract OM digestibility, but not total tract NDF or ADF digestibility of cannulated heifers fed fescue/orchardgrass hay.

Effect of Lipid Supplementation on Intake

The effect of lipid supplementation on intake may vary depending on the source and form of lipid fed. Effects of tallow and commercially available fat supplements on intake have been inconsistent with either no change (Coppock and Wilks, 1991; Elliott et al., 1997) or a decrease in intake (Coppock and Wilks, 1991); however, most studies that utilized oilseeds as lipid supplements reported no effect on intake. For example, in a review of 18 experiments, Coppock and Wilks (1991) reported that whole cottonseed could be included at up to 25% of the diet without influencing DMI of dairy cows. Supplementation of crushed canola seed has been reported not to influence DMI (kg/d) of steers fed corn silage-based diets (Hussein et al., 1995). Brokaw et al. (2001) reported that ruminal infusion of soybean oil did not influence forage or total OM intake of beef heifers grazing bromegrass pastures. Additionally, Krysl et al. (1991) reported that ruminal infusion of 300 mL of soybean oil per day did not influence OM intake (g/d) of cannulated heifers fed fescue/orchardgrass hay.

Lipids: Possible Nutraceutical Mechanism(s)

Two theories have been proposed to explain the mechanism(s) via which increased lipid intake may elicit nutraceutical effects on reproduction (Williams and Stanko, 1999). One theory suggests that lipid supplementation may improve reproductive efficiency through increased functional capability of the ovary by providing more cholesterol to the ovary for steroidogenisis. The other theory suggests that alterations in $PGF_{2\alpha}$ synthesis by the uterus may improve reproductive efficiency.

Cholesterol Theory

As dietary lipid content increases, cholesterol production by the liver and enterocytes increases, making more cholesterol available to reproductive tissues for steroidogenisis. High-density lipoproteins (HDL) are the major lipoprotein in systemic circulation of ruminants (Caravaglios and Cilotti, 1957, as cited by Williams and Stanko, 1999). Additionally, HDL is the only lipoprotein that can cross follicular membranes to gain access to intrafollicular compartments (Caravaglios and Cilotti, 1957, as cited by Williams and Stanko, 1999). Furthermore, saturated and polyunsaturated fatty acids tend to increase total and HDL-cholesterol more than highly polyunsaturated fatty acids like those found in fish oil (Thomas and Williams, 1997; Williams and Stanko, 1999).

Prostaglandin Theory

Saturation of fatty acids may play an important role in determining the potential effect of lipids on reproduction. Linoleic acid is a precursor for arachidonic acid which is a precursor for series two prostaglandins such as $PGF_{2\alpha}$. Additionally, linolenic is a precursor for eicosapentaenoic acid (EPA), which is a precursor for series three prostaglandins. Increased intake of ω-3 fatty acids (linolenic, EPA) suppresses the synthesis of series two prostaglandins and increased intake of ω-6 fatty acids (linoleic, arachidonic) suppresses the synthesis of series three prostaglandins. Thus the mix of fatty acids that may have the most potential to affect reproduction may vary depending on whether the fatty acids are being supplemented during late gestation, after parturition and before the breeding season, or during the breeding season. After parturition, ω-6 fatty acids may increase $PGF_{2\alpha}$ synthesis and thus enhance uterine involution. However, during the breeding season ω-3 fatty acids may suppress $PGF_{2\alpha}$ synthesis and thus reduce early embryonic mortality.

Sources of Lipid Supplements: Reproductive Responses

A considerable portion of research with lipid treatments has been conducted in beef cattle. However, the data becomes limiting for most scenarios when considering the various lipid sources fed, the length and timing of the treatment period, the physiological and energy status of the animal, and the basal diet. A large portion of experiments only evaluated follicular growth patterns, metabolites (progesterone, $PGF_{2\alpha}$, etc.) or luteal activity (Williams, 1989; Wehrman et al., 1991; Oss et al., 1993; Carr et al., 1994; Lammoglia et al., 1997b; Thomas et al., 1997; Filley et al., 1999; Grant et al., 2002). Additionally, Lake et al. (2004) reported the effects of lipid supplementation of beef cows on fatty acid deposition and mobilization. Bader et al. (2004) reported that lipid supplementation did not influence the number of transferable embryos recovered from super-ovulated multiparous beef cows. Although these experiments are beneficial in determining the effects of lipid treatments at a more basic level they do not directly correlate to economically important measures of reproduction such as first service conception rate and pregnancy rate. For example, the number and size of follicles and/or the concentration of $PGF_{2\alpha}$ can be altered without impacting economically important measures of reproduction. Consequently, the remaining portion of this review will only focus on those studies that reported first service conception or pregnancy rate. These studies are summarized in Tables 1 through 3.

Multiple Oilseed Sources

Heifers

Howlett et al. (2003) group fed 9 mo old virgin beef heifers a control diet, a whole cottonseed diet, or a whole soybean diet for 112 d prior to breeding. Diets were formulated to be isocaloric and isonitrogenous. No differences in ADG (0.87 kg) were observed among diets. Percent of pubertal heifers prior to synchronization was not different among diets and averaged 60, 53, and 69% for the control, cottonseed, and soybean diets, respectively. Additionally, first service conception rate was not different among diets and averaged 37, 38, and 57% for the control, cottonseed, and soybean diets, respectively.

Prepartum

In one study, Bellows et al. (2001) fed primiparous cows dietscontaining no added fat (2.4% ether extract [EE = ether extract]; n = 38), cracked safflower seeds (4.7% EE; n = 38), cracked soybeans (3.8% EE; n = 38), or cracked sunflower seeds (5.1% EE; n = 38) in a 3 x 4 factorial arrangement of treatments involving three calving seasons. Diets were formulated to be isocaloric and isonitrogenous and fed for cows to gain 0.5 kg/d. Diets were fed from approximately d 215 of gestation and continued until calving, which resulted in an average treatment period of 65 d prepartum. Although diets appeared to be isocaloric based on estimated TDN content they were in fact not isocaloric; the oilseed diets were actually higher in TDN. An ADF equation was used to calculate TDN; by using this ADF equation the extra energy from the lipid fraction in the oilseeds was not accounted for. Consequently, caution should be taken when interpreting if the results of this experiment were due to a nutraceutical effect of the oilseeds or just an energy effect. No difference in percentage of cows cycling at the beginning of the breeding season was observed among dietary treatments. However, pregnancy rates, after a 37-d natural service breeding season, were significantly greater for the oilseed containing diets compared with the control diet. Pregnancy rates were 79, 97, 93, and 92% for the control, safflower, soybean, and sunflower diets, respectively. When evaluating these pregnancy rates it is important to note that cows fed oilseeds had greater BCS before breeding than cows fed the control diet. Additionally, calves from cows fed oilseeds were numerically heavier at birth and statistically heavier at weaning than calves from cows fed the control diet, which further indicates that the cows fed oilseeds were on a greater plain of nutrition. In a second experiment, primiparous cows were fed diets containing no added fat (2.2% EE; n = 41), or cracked sunflower seeds (6.3% EE; n = 45) in a 2 x 3 factorial treatment design involving three calving seasons (Bellows et al., 2001). Diets were formulated to be isocaloric and isonitrogenous and fed for cows to gain 0.5 kg/d. In this experiment, diets were also fed from approximately d 215 of gestation and continued until calving, which resulted in an average treatment period of 68 d prepartum. Again caution should be taken when interpreting the results of this study, because the TDN estimate is incorrect for the oilseed diet. Diet did not influence percentage of cows cycling at the start of the breeding season (66 vs. 55%) or fall pregnancy rates (90 vs. 80%; $P = 0.13$) for the control and sunflower diets, respectively. There were no differences in BW or body condition throughout the study. A 35-d natural breeding season was used in this experiment. Pregnancy rates in these two experiments were greater than those normally observed with primiparous cows; this paper did not indicate when the breeding season started in relation to calving date (Bellows et al., 2001).

Alexander et al. (2002) individually fed primiparous cows a control supplement, a high-fat range supplement containing lipid from oilseeds (primarily sunflower or soybean), and a high-fat range supplement with lipid from soybean soapstock (n = 12, 12, and 10, respectively). Both high-fat range supplements were provided by Consolidated Nutrition, Omaha, NE. Treatment supplements were fed on average for 62 d prepartum and were not isocaloric or isonitrogenous. No difference in BW or BCS was observed among treatments. Additionally, first service conception rate (55, 38, and 71%) and overall pregnancy rate (73, 100, and 100%) were not different among treatments for the control supplement, high-fat range supplement, and soybean soapstock supplement, respectively. In a similar experiment, Alexander et al. (2002) group fed multiparous cows the same previously described treatment supplements (n = 49, 47, and 49, respectively, for control, high-fat range supplement, and soybean soapstock supplement). The multiparous cows were fed treatment supplements for an average of 59 d prepartum. No difference in BW change was observed among treatments; however, BCS was greater at the end of supplementation for the control cows compared with the cows fed the high-fat range supplements. First service conception rate (60, 67, and 71%) and overall pregnancy rate (88, 91, and 92%) were not different among treatments for the control supplement, high-fat range supplement and soybean soapstock supplement, respectively. The AI season started on d 64 postpartum and lasted for 45 d; after the AI season the cows were exposed to a bull for an additional 30 d.

Rice Bran

Postpartum

After calving, De Fries et al. (1998) fed multiparous Brahman cows a control diet (3.7% EE; n = 20) or a diet containing rice bran (5.2% EE; n = 20). Diets were formulated to be isonitrogenous and isocaloric and fed from d 1 after calving until completion of the first normal estrous cycle. No differences in days to first estrus (43) or first normal estrous cycle (45) were observed between treatments. However, pregnancy rates tended to greater for the cows fed rice bran compared with the control cows (94 vs. 71%; *P* = 0.09). Additionally, no difference in BW change was observed between treatments, however, cows receiving rice bran gained more body condition during the treatment period (1 vs. 0.6 BCS units).

Multiparous Brahman cows (n = 17/treatment) were fed diets containing rice bran or no rice bran, or lasalocid or no lasalocid in a 2 x 2 factorial arrangement of treatments. Diets were formulated to be isocaloric and isonitrogenous and fed from d 1 after parturition through the detection of first estrus. Ether extract was 3.7 and 5.2% for the control and rice bran diets, respectively. Diet did not affect BW or BCS change. Pregnancy rates (76, 75, 81, and 67%) and first service conception rates (71, 60, 50, and 73%) were not different for cows receiving the control, rice bran, lasalocid, or rice bran + lasalocid diets, respectively (Webb et al., 2001).

Pre- and Postpartum

Spring and fall calving primiparous Brahman cows were used to evaluate the effects of diets containing rice bran (Lammoglia et al., 1996). Cows were fed a low-fat diet with no rice bran (3.7% fat; n = 15), a medium-fat diet with rice bran (5.2% fat; n

=14) and a high-fat diet with rice bran (6.6% fat; n = 8) from 14 d before expected calving date through d 21 after calving. Body weight and BCS did not differ among treatments. Postpartum interval (90, 84, and 80 d) and percentage of cows cycling 90 d after calving (55, 75, and 55%) were not different among treatments. Pregnancy rates were not reported in this experiment.

Safflower Seed

Heifers

Lammoglia et al. (2000) pen fed prepubertal heifers of Hereford, Limousin, or Piedmontese breeding a low-fat diet (1.9% EE; n = 123) or a high-fat diet containing cracked safflower seeds (4.4% EE; n = 123). Diets were formulated to be approximately equal in energy and protein content; however, TDN was calculated based on an ADF equation which would underestimate the energy of the safflower seeds and thus the safflower diet. Heifers were fed treatment diets from approximately 254 d of age until puberty was reached or 162 d, whichever came first. No significant differences between the low-fat and high-fat diet were observed for number of AI services per pregnancy (1.38 vs. 1.44) or pregnancy rate after a 54-d AI breeding season (76 vs. 73%), respectively. Heifer gain and BCS were not different between diets.

Prepartum

Geary et al. (2002) pen fed primiparous cows a control diet (2.2% EE; n = 17) or a diet containing high-linoleate safflower seeds (5.3% EE; n = 16) from d –56 until calving. Diets were isocaloric and isonitrogenous. After calving cows were exposed to one bull from d 126 to 175. No differences in BW or BCS at calving were observed between the treatments. Additionally, pregnancy rate, postpartum anestrous interval, and interval from calving to conception did not differ between the control diet (88%, 130 d, and 140 d, respectively) and the high linoleate safflower seed diet (81%, 129 d, and 137 d, respectively).

Lammoglia et al. (1997a) fed primiparous cows a control diet (1.7% EE, n = 35), a high-oleic safflower seed diet (4.2% EE, n = 36), or a high-linoleic safflower seed diet (4.9% EE, n = 35) from d 230 of gestation to calving. Diets were formulated to be isocaloric and isonitrogenous and for cows to gain 0.46 kg/d. The 53 d AI season employed in the experiment started when the cows had been off the treatment diets for an average of 55 d. Pregnancy rates were greater for cows fed high-oleic (75%) and high-linoleic (77%) safflower seed compared with cows fed the control (57%; $P < 0.06$). No measurements of cow BW or BCS were reported in this experiment.

Grings et al. (2001) conducted an experiment over two years involving two fat supplements (high vs. low fat), three calving seasons, and two age classes of multiparous cows. The high-fat supplement consisted of high-linoleic safflower seeds and meal and the low-fat supplement consisted of safflower meal and barley. A three-way interaction involving calving season, fat supplement, and cow age was detected for pregnancy rate. This three-way interaction indicated that there were no consistent effects of fat supplementation across calving season or age class of cow. Estimated pregnancy rates for the low- and high-fat diets were 87 and 85%, respectively.

Bellows et al. (2000) fed multiparous cows (n = 140) bred to calve in February or April one of three supplements during late gestation. Supplements included: pelleted alfalfa hay, compressed blocks which contained fat from safflower seed either every day, or compressed blocks which contained fat from safflower seed every other day. A supplement x calving season interaction was detected for percent cycling at the start of the breeding season and final pregnancy rate. These results and the fact that this information is only published in an abstract from the 2000 National Animal Science meetings make it difficult to interpret, what if, any effect fat supplementation had on reproduction in this experiment.

Postpartum

Bottger et al. (2002) individually fed primiparous cows a control supplement (1.46 kg/d; n = 12), a high-linoleic cracked safflower seed supplement (1.62 kg/d; n =12), or a high-oleic cracked safflower seed supplement (1.43 kg/d; n = 12). Supplements were formulated to be isocaloric and isonitrogenous and fed for 90 d postpartum. Postpartum interval (88 d) and number of days to conception (108 d) were not different among treatments. Additionally, pregnancy rates were not different for the control (100%), high-linoleic (92%), or high-oleic supplemented cows (100%). Cow BW change was not affected by treatment.

<u>Soybeans</u>

Heifers

In experiment two of three, Whitney et al. (2000) individually fed virgin heifers a control diet of bromegrass hay, corn and soybean meal (crude fat = 5.9%; n = 12), or the control diet with 3% added soybean oil (crude fat = 10.5%, n = 12), or the control diet with 6% added soybean oil (crude fat = 13.1%; n = 12) for 104 d. All diets were fed as a total mixed ration (TMR) and formulated to be isonitrogenous and provide an ADG of 0.91 kg. Pregnancy rates after AI and natural mating were 91.7, 90.9, and 100% for the control, 3% added soybean oil and 6% added soybean oil, respectively. In the third experiment reported in this paper (Whitney et al., 2000), virgin heifers were group fed the same treatments as previously described. However, instead of being fed as a TMR the control diet was put in a bunk and the soybean oil was top-dressed onto the hay. Treatment diets were fed for 90 d and dietary crude fat concentration was 2.6, 4.6, and 5.8% for the control, 3% added soybean oil and 6% added soybean oil, respectively (n = 14 heifers/treatment). Pregnancy rates after AI and natural mating were 92.9, 100, and 92.9%, for the control, 3% added soybean oil and 6% added soybean oil, respectively. No statistical analysis was conducted on the pregnancy rate data (Whitney et al., 2000).

Prepartum

Whole soybean supplementation during late gestation has also been reported to statistically improve first service conception rate (Graham, et al., 2001) or numerically improve pregnancy rate (Graham, et al., 2001; Steele et al., 2002) of multiparous beef cows.

Postpartum

Whole soybeans are a desirable feedstuff both as a supplement and as part of a total mixed ration due to their desirable nutrient profile and palatability. However, depending on the physiological status of the animal caution should be exercised when feeding whole soybeans. Postpartum feeding of whole soybeans may increase the incidence of cystic ovaries (D. J. Patterson, 2003, University of Missouri-Columbia, S132 Animal Science Research Center, Columbia, MO, personal communication). Soybeans have been reported to contain up to 0.25% isoflavones (Adams, 1995). Phytoestrogens (isoflavones and coumestans) in other legumes have been associated with the development of cystic ovaries in cattle (Adams, 1995).

Sunflower Seed

Heifers

Funston et al. (2002) reported no difference in 72-h estrous response to synchronization (% of heifers observed in estrus after MGA/$PGF_{2\alpha}$ treatment) or pregnancy rate from AI between virgin heifers fed a control diet or a diet containing 0.91 kg/d of whole sunflower seeds for 30 or 60 d. Heifers were only inseminated once and those not exhibiting standing estrus after synchronization were timed AI. Diets were formulated to be isocaloric and isonitrogenous within each of four locations. Heifers fed the control diet gained 0.77 kg/d whereas ($P < 0.01$) heifers fed whole sunflower seeds only gained 0.64 kg/d. These weight gains should not necessarily be interpreted to mean that the sunflower heifers gained less energy, as composition of weight gain could be different between diets containing non-structural carbohydrates and those containing lipids (Rhodes et al., 1978).

Pre- and Postpartum

In one study, multiparous cows were either fed a low fat milo-based supplement (2% EE; 2.7 $kg\cdot cow^{-1}\cdot d^{-1}$) or a high-fat sunflower-based supplement (26% EE; 1.6 $kg\cdot cow^{-1}\cdot d^{-1}$) for an average of 64 d prepartum and/or 76 d postpartum in a 2 x 2 factorial arrangement of treatments (Johnson et al., 2001). The supplements were not isonitrogenous and may or may not have been isocaloric. Supplement type fed prepartum had no effect on reproductive measures. However, percentage of cows cycling at the beginning of the breeding season (74 vs. 65%) and first service conception rate (44 vs. 32%) were significantly greater for cows fed the low-fat supplement. Pregnancy rates (95%) were not influenced by fat supplementation postpartum.

Other Lipid Sources

Prepartum

Small et al. (2004) fed multiparous cows (n = 155) a limit-fed diet (60% rolled corn, 40% millet hay), with (4.63% dietary fat) or without (2.69% dietary fat) added fat for approximately 60 d prior to calving. Percent cycling (95 vs. 92%), first service conception rate (67 vs. 68%), and pregnancy rate (97 vs. 97%) were not different for the added fat or control diet, respectively. Additionally, no differences in cow BW, cow BCS, or calf weaning weight were reported. Although there were no differences in morbidity or mortality rates, calf IgG levels were greater for the added fat diet (15.44 mg/mL) compared with the control diet (11.00 mg/mL).

Pre- and Postpartum

Espinoza et al. (1995) reported that pre- and postpartum supplementation of Megalac increased percentage cycling and pregnancy rates of multiparous cows; however, it is important to note that the Megalac supplement provided considerably more energy than the control supplement.

Postpartum

Filley et al. (2000) reported that days to first estrus with ovulation (111 vs. 115), pregnancy rate (72 vs. 68%), and calving interval (390 vs. 401 d) were not different between primiparous cows supplemented with calcium salts (n = 20) or barely (n = 19) for the first 30 d postpartum, respectively. Cow BW and BCS were not different on d 1 or 30 postpartum. Lloyd et al. (2002) reported that supplementing calcium salts (Megalac) did not improve reproduction of pubertal heifers or postpartum cows.

Tjardes et al. (1998) reported a numerical reduction (*P* = 0.18) in calving rate (75 vs. 91%) for postpartum cows consuming a limit-fed diet consisting of hay, cracked corn, and 4% added yellow grease compared with cows fed an isocaloric control diet.

First service conception rate of primiparous cows supplemented with fishmeal prior to and during the breeding season tended (*P* = 0.12) to be greater compared with cows fed an isocaloric control (Burns et al., 2002a). However, pregnancy rate was not influenced by treatment. Furthermore, Burns et al. (2002b) found no difference in synchronized estrous response, first service conception rate, AI pregnancy rate, and overall pregnancy rate for 2- and 3-yr-old cows supplemented with fishmeal for 25 d prior to and during the breeding season compared with unsupplemented cows (Burns et al., 2002b).

Conclusions

Plasma metabolites and hormones are altered by lipid supplementation (Williams, 1989; Wehrman et al., 1991; Oss et al., 1993; Carr et al., 1994; Lammoglia et al., 1997b; Thomas et al., 1997; Filley et al., 1999; Grant et al., 2002); however these changes do not consistently result in improved first service conception and/or pregnancy rates. Additionally, in several of the studies in which lipid supplementation did result in increased first service conception and/or pregnancy rates the supplements were not isocaloric or may not have been isocaloric. Thus, future research taking a more detailed look at the length of supplementation, the specific fatty acid profile of lipid sources, and the physiological and nutritional status of the cow is needed before lipid supplementation can be recommended as a nutritional strategy to improve reproduction because of proposed nutraceutical effects.

Most studies indicate that moderate levels of lipid sources may be added to diets of beef cattle to increase energy density without detrimental effects on cow or calf performance. Thus if economically feasible, oilseeds and other lipid sources can be used as supplements or as part of a total mixed ration for beef cattle consuming forage-based diets. However, it should be noted that excessive lipid supplementation (> 5% of diet DM) may lead to decreased forage digestion.

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Table 1. Effects of prebreeding and prepartum lipid supplementation on first service conception and pregnancy rates

Reference	Parity	Supplement timing	Lipid source	(Treatment vs. control)
Multiple lipid sources				
Bellows et al., 2001	primiparous	prepartum	Exp. 1: cracked safflower seeds[a]	pos. effect
			Exp. 1: cracked soybeans[a]	pos. effect
			Exp. 1: cracked sunflower seeds[a]	pos. effect
	primiparous	prepartum	Exp. 2: cracked sunflower seeds[a]	no effect
Alexander et al., 2002	primiparous	prepartum	Exp. 1: sunflower/soybean range supplement[b]	no effect
			Exp. 1: soybean soapstock range supplement[b]	no effect
	multiparous	prepartum	Exp. 2: sunflower/soybean range supplement[b]	no effect
			Exp. 2: soybean soapstock range supplement[b]	no effect
Howlett et al., 2003	heifers	prebreeding	whole cottonseed	no effect
			whole soybean	no effect
Small et al., 2004	multiparous	prepartum	unknown	no effect
Safflower seed				
Lammoglia et al., 1997	primiparous	prepartum	high-oleic safflower seeds[a]	pos. effect
		prepartum	high-linoleic safflower seeds[a]	pos. effect
Lammoglia et al., 2000	heifer	prebreeding	safflower seeds	no effect
Grings et al., 2001	multiparous	prepartum	safflower seeds and meal	no effect
Geary et al., 2002	primiparous	prepartum	safflower seeds	no effect

Table 1. Continued

Reference	**Parity**	**Supplement timing**	**Lipid source**	**(Treatment vs. control)**
Soybeans				
Whitney et al., 2000	heifer	prebreeding and breeding	3 and 6% soybean oil	no effect
Grahman et al., 2001	multiparous	prepartum	whole soybeans[a]	pos. effect
Steele et al., 2002	multiparous	prepartum	whole soybeans	no effect
Sunflower seed				
Funston et al., 2002	heifer	prebreeding	whole sunflower seeds	no effect

[a] Treatments may not have been isocaloric.

[b] Treatments were not isocaloric or isonitrogenous.

Table 2. Effects of pre- and postpartum lipid supplementation on first service conception and pregnancy rates

Reference	**Parity**	**Lipid source**	**(Treatment vs. control)**
Calcium salts			
Espinoza et al., 1995	multiparous	Megalac[b]	pos. effect
Sunflower seed			
Johnson et al., 2001	multiparous	sunflower based supplement[a]	neg./no effect

[a] Treatments may not have been isocaloric.

[b] Treatments were not isocaloric or isonitrogenous.

Table 3. Effects of postpartum lipid supplementation on first service conception and pregnancy rates

Reference	**Parity**	**Lipid source**	**(Treatment vs. control)**
Other lipid sources			
Tjardes et al., 1998	multiparous	yellow grease	no effect
Filley et al., 2000	primiparous	calcium salts	no effect
Burns et al., 2002a	primiparous	fishmeal	no effect
Burns et al., 2002b	2nd & 3rd	fishmeal	no effect
Rice bran			
De Fries et al., 1998	multiparous	rice bran	pos. effect
Webb et al., 2001	multiparous	rice bran	no effect
Safflower seed			
Bottger et al., 2002	primiparous	high-linoleic cracked safflower seeds	no effect
		high-oleic cracked safflower seeds	no effect
Sunflower seed			
Funston et al., 2002	heifer	whole sunflower seeds	no effect

[a] Treatments may not have been isocaloric.

[b] Treatments were not isocaloric or isonitrogenous.

Chapter III

Effects of whole sunflower seed supplementation during late gestation on performance of beef cows and their progeny

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ABSTRACT: This experiment was conducted to determine the effects of supplemental whole linoleic sunflower seed on performance of beef cows as well as feedlot performance and carcass characteristics of their steer progeny. During late gestation, 144 multiparous spring calving beef cows (initial BW = 588 kg; initial BCS = 5.6; age = 4 to 13 yr) were individually fed one of three supplements for 76 d. Supplements (DM basis) included: 1) 0.39 kg/d of soybean meal (NCON); 2) 1.72 kg/d of a soybean hull-based supplement (PCON); and 3) 0.95 kg/d of whole linoleic sunflower seed (WSUN). Supplements were formulated to provide similar amounts of CP and ruminally degraded intake protein; PCON and WSUN were also formulated to be isocaloric. During the supplementation period, cows had free choice access to bermudagrass (*Cynodon dactylon*) and tall-grass prairie hay. By the end of the 76-d supplementation period, cows fed PCON and NCON had gained more ($P < 0.05$) BW than cows fed WSUN (33, 23, and 10 kg, respectively). However, from the end of this supplementation period to the beginning of the breeding season 84 d later, cows supplemented with PCON had lost more ($P < 0.01$) BW than cows supplemented with WSUN (-123 kg vs. -111 kg). Cow BW change throughout the entire experiment (-50 kg, $P = 0.43$) and final cow BW (536 kg, $P = 0.70$) at weaning were not different among supplements. Furthermore, cow BCS was not different among cows fed different supplements at the end of the supplementation period (5.3, $P = 0.09$), at the start of the breeding season (4.8, $P = 0.38$), or at weaning (4.7, $P = 0.08$). No difference among cows fed different supplements was detected for calf birth weight (36 kg, $P = 0.46$), calf weaning weight (235 kg, $P = 0.69$), percent of cows cycling at the start of the breeding season (57%, $P = 0.29$), or pregnancy rate (88%, $P = 0.44$). However, first service conception rate was greater ($P < 0.05$) for cows fed PCON (79%) and tended ($P < 0.07$) to be greater for cows fed WSUN (74%) than for cows fed NCON (53%). After weaning, all steer calves were placed in a feedlot and fed a high-concentrate finishing ration for an average of 188 d. Supplements fed to dams did not influence feedlot performance or carcass characteristics. Compared with a soybean hull-based supplement, a supplement composed of whole sunflower seed did not significantly alter cow reproduction or calf performance.

Key Words: Beef Cows, Prepartum Lipid Supplementation, Sunflower

Introduction

Lipid supplements have been proposed as nutraceuticals to improve reproductive efficiency through increased functional capability of the ovary and/or alterations in $PGF_{2\alpha}$ synthesis by the uterus (Williams and Stanko, 2000). Lipid supplementation during late gestation may improve reproductive efficiency of beef cows (Bellows et al., 2001; Hess et al., 2002). Lipid sources rich in polyunsaturated fatty acids, especially linoleic acid, appear more beneficial in altering reproductive physiology than lipid sources composed primarily of saturated fatty acids (Williams and Stanko, 2000).

Sunflower types include whole high-oil seed that may contain more than 40% of DM as oil and confectionary seed that is lower in oil content and marketed as treats for birds and humans. Whole high-oil sunflower seed has several characteristics of a desirable supplement for range cows; these include a high lipid concentration, a moderate concentration of protein, and excellent storage and handling characteristics. However, when cows consume low to moderate quality forage, excess lipid intake may reduce fiber digestion (Jenkins, 1993). Supplementation of beef cattle with sunflower seed or feeding diets containing sunflower seed has variable effects on BW and reproduction (Bellows et al., 2001; Alexander et al., 2002; Funston et al., 2002). We hypothesized that increased lipid intake during late gestation could improve reproduction of beef cows. Thus, our primary objective was to determine responses to feeding whole high-oil sunflower seed during late gestation on reproduction and performance of beef cows and performance of their progeny. Studies with pigs and rats suggest that prepartum diet composition may alter prenatal development and postnatal body composition (Musser et al., 1999; Poulos et al., 2001). Consequently, our second objective was to determine if late-gestation lipid supplementation would influence carcass characteristics of steer progeny.

Materials and Methods

This experiment was conducted at the Range Cow Research Center, North Range Unit located approximately 16 km west of Stillwater, OK, in accordance with an approved Oklahoma State University Animal Care and Use Committee protocol. During the winter of 2001-2002, 144 multiparous spring calving Angus x Hereford crossbred beef cows were assigned to one of three different supplements in a completely randomized design. Cows were assigned to supplements so that mean age (average = 8.8 yr; range = 4 to 13 yr), initial BW, and initial BCS would be similar. During the 76-d supplementation period (November 30 to February 14, 2002), cows were managed as a contemporary group in a single pasture with free choice access to bermudagrass hay (*Cynodon dactylon*), tall-grass prairie hay (Table 1), and a mineral supplement (NaCl, 41.9%; Ca, 9.5%; P, 8.3%; Mg, 0.3%; Cu, 1039 ppm; Se, 12 ppm; Zn, 3110 ppm; DM basis). Although hay was the major forage component of the diet during the supplementation period, cows had access to a negligible amount of dormant tall-grass prairie pasture. Diets were formulated to meet or exceed CP requirements (NRC, 1996).

Supplements (DM basis) included: 1) 0.39 kg/d of soybean meal (**NCON**); 2) 1.72 kg/d of a soybean hull-based supplement (**PCON**); and 3) 0.95 kg/d of whole linoleic sunflower seed (**WSUN**; CP = 22%, ether extract = 44%; 59% linoleic acid, 28% oleic acid). The NCON and PCON supplements were fed as 0.64 cm pellets. Supplements were formulated to provide similar amounts of CP and ruminally degraded intake protein (Table 2). In addition, PCON was formulated to be isocaloric to WSUN. Each cow was fed its appropriate supplement in an individual stall on Monday, Tuesday, Thursday, and Saturday mornings. The amount of supplement fed on each of these 4 d was determined by calculating the amount of supplement needed per week (daily supplement amount x 7 d) and dividing that amount by 4 (i.e., cows receiving WSUN were fed 1.66 kg/feeding). Following the 76-d supplementation period, all cows were managed as a contemporary group and were given free access to either bermudagrass pasture or tall-grass prairie pasture and the mineral supplement described above.

Individual cow BW and BCS was determined: at the beginning and end of the supplementation period (11/30/01 and 2/14/02, respectively), at the onset of breeding (5/9/02), and at weaning (10/14/02). Cows were weighed 16 h after withdrawal from feed and water. Body condition scores (1 = emaciated, 9 = obese) were assigned by two independent evaluators. The same evaluators assigned condition scores throughout the experiment.

Early- and mid-lactation milk production was determined using the weigh-suckle-weigh technique. At 1630 on d 131 and d 200 of the experiment, approximately 20 cows fed each supplement and their calves were gathered and the calves were separated from their dams; cows were returned to the pasture to graze but calves were held in pens until 0730 the following morning at which time calves were allowed to nurse their dams until they stopped nursing. After nursing, the calves again were separated and 24-h milk production was measured using three consecutive 8-h weigh-suckle-weigh periods (0800 to 1600, 1600 to 0000, and 0000 to 0800). When not being nursed, cows were given access to tall-grass prairie pasture or hay. The cows that calved earliest from each supplement group were used to determine milk production; the same cows were used to determine both early- and mid-lactation milk production.

Early-lactation milk composition was determined on April 4, 2002, using five cows fed each supplement (average calf age = 31 d, range = 24 to 37d). Cows were separated from calves at 2000 and allowed to graze until 0800 the following morning. Prior to milking, a 1.0 mL injection of oxytocin (20 USP units/mL, i.m.; Phoenix Pharmaceutical, Inc., St. Joseph, MO) was administered to each cow to facilitate milk let-down. Cows were then individually milked using a portable milking machine. Total milk from thefour quarters was mixed; a sample of approximately 40 mL was then mixed with a Broad Spectrum Microtab II (D & F Control Systems, Inc., Sam Ramon, CA) and sent to the Heart of America DHIA (Manhattan, KS) for analysis.

The 72-d calving season lasted from February 14 to April 25, 2002 (average calving date: March 6, 2002). The percentage of cows cycling at the start of the breeding season was determined by quantifying progesterone concentration (Vizcarra et al., 1997) in plasma samples obtained via tail venipuncture 9 d before and again on the first day of the breeding season. Cows with one or more plasma samples containing ≥ 0.5 ng/mL progesterone were considered to be cycling (i.e., exhibiting luteal activity). Cows were artificially inseminated during the first 27 d of the 67-d breeding season (May 9 to July 15). Cows were observed each morning and evening for 1 h to detect standing estrus; all cows exhibiting standing estrus were artificially inseminated approximately 12 h after estrus observation. First service conception rate was determined based on calving date the following year and pregnancy rate was determined by rectal palpation at weaning. Birth weight of each calf was determined within 24 h of birth and all bull calves were castrated at this time. At weaning (October 14; average age = 222 d), calves were weighed directly off the cows without any restriction of feed or water.

Fifteen days after weaning, all steer calves (n = 24, 24, and 22, respectively, for NCON, PCON, WSUN) were transported to the Willard Sparks Beef Research Center, Stillwater, OK, to determine the effects of late gestation cow supplement composition on subsequent feedlot performance and carcass characteristics. Steers were blocked by BW, and within block, randomly assigned to pens based on the supplement fed to their dam. Steers were fed for an average of 188 d until harvest. A dry-rolled corn based finishing ration was fed from d 36 until harvest; diets are described by Krehbiel et al. (2004). Steers were implanted with Component E-S (VetLife, West Des Moines, IA) on d 0 and Revalor-S (Intervet Inc., Millsboro, DE) on d 98 of the finishing period. Steers were harvested at IBP (Emporia, KS) and chilled for 24 h before collection of carcass data.

Statistical Analysis

Cow was the experimental unit because supplements were fed to each cow individually. Data were analyzed using MIXED MODEL procedures of SAS (SAS Inst. Inc., Cary, NC). Interactions were removed from the model when $P > 0.30$. All covariates remained in the model regardless of significance. When the P-value for the F-statistic was ≤ 0.05, least squares means were separated using the LSD procedure of SAS ($\alpha = 0.05$). For various reasons (failure to calve, n = 1; cow injury or illness, n = 4; severe mastitis, n = 1) data from six cows and their calves were removed from the experiment. No relationship was apparent between any of these factors and late-gestation supplement composition. Only data from the 138 cows that weaned a calf in October were used for statistical analysis.

The model for cow performance included supplement as a fixed effect and cow age as a covariate. The initial models for milk production included supplement and calf sex as fixed effects; cow and calf age were included as covariates. The model for milk composition was the same as the milk production models except that calf sex was not included. The initial model for calf performance included supplement and calf sex as fixed effects and calf sire as a random effect. Cow age was included as a covariate in all the calf performance models and calf age was included as a covariate in the weaning weight model.

The model for days from calving to the start of the breeding season and days from calving to first AI date included supplement as a fixed effect. A 2 x 3 contingency table was developed for proportional differences among supplements for percent cycling, first service conception rate, and pregnancy rate and tested using a chi-square test. Proportional data were analyzed using FREQ procedures of SAS. The standard error for proportional data was calculated as: $\sqrt{P(1-P)/n}$ where P = proportion of the variable in question (M. Payton, Department of Statistics, Oklahoma State University, Stillwater, personal communication).

The model for feedlot performance and carcass characteristics of steer progeny included supplement as a fixed effect and sire and block as random effects. Covariates included cow age and calf age at harvest.

Results and Discussion

Cow Weight and BCS. During the 76-d supplementation period, cows fed PCON gained 10 kg more BW than cows fed NCON and 23 kg more BW than cows fed WSUN (Table 3). However, from the end of the supplementation period to the beginning of the breeding season cows fed WSUN lost 12 kg less weight than cows fed PCON (Table 3). From the start of the breeding season until weaning, cow BW change was not different among supplements (Table 3). Although differences in BW change were observed during certain time periods, mean BW change during the entire 318-d experiment was not different among supplements (-51 kg; start of supplementation to weaning; Table 3). During the 76-d supplementation period, changes in BCS followed the same pattern as changes in BW. Cows fed PCON lost less body condition than cows fed either WSUN or NCON (Table 3). Changes in BCS from the end of the supplementation period to the start of the breeding season, from the start of the breeding season to weaning, and during the entire experiment were not different among supplements (Table 3). Additionally, final BCS at weaning was not different among supplements (Table 3).

Differences in cow BW change during late gestation may be due to reduced forage digestion by cows fed sunflower seed (Jenkins, 1993). Given an average cow BW of 583, 590, and 589 kg, and assuming a hay intake of 1.6% of BW and a fat concentration of 2% for the hay, the diets with the three supplements would have contained approximately 2.0, 2.0, and 5.8% dietary lipid for NCON, PCON, and WSUN, respectively. Decreased fiber digestion is typically experienced when lipid content of a diet exceeds 5% (Byers and Schelling, 1988).

Additionally, some of the differences in cow BW change and BCS change could be attributed to reduced consumption of WSUN by some cows. Of the total feeding events (feeding events = number of cows per supplement x 43 feedings), cows fed WSUN did not consume all of their sunflower seed 5.9% of the time. In contrast cows feed NCON and PCON did not consume their entire supplement 0.3 and 0.2% of the time, respectively.

Milk Production and Composition. A supplement x calf sex interaction was detected for early-lactation milk production ($P = 0.03$), but not for mid-lactation milk production ($P = 0.44$). This interaction was due to reduced ($P < 0.05$) milk production by those cows nursing steer calves that were fed WSUN compared with those fed NCON and PCON (5.4 vs. 7.2 and 7.7 kg/d, respectively). Milk production was not different ($P = 0.65$) among cows fed different supplements that were nursing heifer calves (data not shown). Since calf sex did not determine how the cows were managed and no biological explanation for this difference is apparent, only main effect means for supplements are discussed and reported in Table 4. The source of supplement did not influence early-lactation (6.7 kg/d) or mid-lactation (6.7 kg/d) milk production. Additionally, source of supplement did not significantly alter concentrations of milk urea nitrogen, protein, butterfat, lactose, solids not fat, or somatic cell count (Table 5).

Considering that milk production was first measured 55 d after supplementation had ceased, it was not surprising that no supplement differences were observed for milk production or milk composition. Alexander et al. (2002) also reported no effect of prepartum lipid supplementation on subsequent milk production or composition.

*Calf Performance***.** No supplement x calf sex interaction was observed for calf birth (*P* = 0.64) or weaning weight (*P* = 0.87). Additionally, neithercalf birth (36 kg) nor weaning weight (235 kg) was significantly influenced by late gestation supplement composition (Table 6). Differences in weaning weight would not be expected since, milk production and composition were not altered by supplementation. In a review of the literature, Hess et al. (2002) concluded that prepartum lipid supplementation did not influence calf birth or weaning weight.

Cow Reproductive Performance. No significant differences in days from calving to the start of the breeding season (63 d) or percent of cows cycling at the start of the breeding season (57%) were observed among supplements (Table 7). However, first service conception rate was greatest (*P* < 0.05) for cows fed PCON (79%) and tended to be greater (*P* < 0.07) for cows fed WSUN (74%) compared with cows fed NCON (53%). No difference in first service conception rate was observed between cows fed PCON and cows fed WSUN. Although first service conception rate tended to be greater for PCON and WSUN compared with NCON, no difference in pregnancy rate (88%) was observed among cows fed different supplements (Table 7).

Others have reported no difference in percentage of cows cycling at the beginning of the breeding season (Bellows et al., 2001; Alexander et al., 2002) or in pregnancy rates (Alexander et al., 2002) for cows fed prepartum lipid treatments compared with control cows. Funston et al. (2002) found no difference in pregnancy rate to AI for heifers fed whole sunflower seed for 30 or 60 d prebreeding compared with control heifers. Prepartum supplementation of a high-fat range supplement did not improve first conception rate (Alexander et al., 2002). However, Graham et al. (2001) reported that first service conception was greater for cows fed whole soybeans prepartum and Bellows et al. (2001) observed that pregnancy rate was increased for cows fed whole soybeans prepartum.

Feedlot Performance and Carcass Characteristics of Steers. Feedlot performance and carcass characteristics of steer progeny were not influenced by supplements fed to dams during late gestation (Table 8). However, steers in this experiment were fed longer than desired for detecting differences in marbling score or fat deposition as indicated by their high mean 12th rib fat thickness (1.63 cm). However, even when steers having more than 1.78 cm of 12th rib fat were removed from the data set, no significant differences in feedlot performance or carcass characteristics were observed among progeny of cows fed different supplements during late gestation (data not shown). We are not aware of other studies that have examined the effects of prepartum lipid supplementation of beef cows on carcass characteristics of their progeny.

Implications

Compared with supplemental energy from traditional carbohydrate supplements, supplemental energy in the form of lipid from whole sunflower seeds was not as effective in maintaining late-gestation weight gain of beef cows fed hay. However, the reduced weight gain during gestation did not impact cow reproduction or calf performance. Palatability of whole sunflower seed was limited; this concern must be addressed if and when whole sunflower seed is supplemented to beef cows. High-oil whole sunflower seed has a nutrient profile ideal for winter supplementation of gestating beef cows. When economically advantageous and if palatability issues with whole sunflower seed could be eliminated by mixing with a more palatable feedstuff, whole sunflower seed could prove useful as a supplement.

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Table 1. Chemical composition of hay fed during the supplementation period[a]

	Hay		
Item, % of DM	Bermudagrass 1	Bermudagrass 2	Prairie
CP	6.5	8.4	4.9
ADF	37.5	41.1	38.5
NDF	69.5	70.7	68.1
TDN	56	56	56
Feeding period	12/3/01 to 2/4/02	2/4 to 2/14/02	12/3/01 to 1/6/02

[a] Chemical composition determined via wet chemistry (Dairy One Forage Lab, Ithaca, NY).

Table 2. Supplement composition and amount of nutrients supplied daily[a]

	Supplement[b]		
Item, % of DM	NCON	PCON	WSUN
Whole sunflower seed	-	-	100
Soybean meal	100	-	-
Soybean hulls	-	94.75	-
Wheat middlings	-	5.25	-
DM, kg/d	0.39	1.72	0.95
CP, kg/d	0.21	0.22	0.21
Degradable intake protein, kg/d	0.15	0.16	0.16
NE_m, Mcal/d	0.83	3.17	3.27
Lipid, kg/d	0.004	0.038	0.418

[a] Nutrient composition from tabular values.

[b] NCON = protein control, PCON = protein and energy control, WSUN = whole linoleic sunflower seed.

Table 3. Effect of late-gestation supplement on cow weight and BCS

	Supplement[a]				
Item	NCON	PCON	WSUN	SEM[b]	*P*-Value[c]
n =	49	45	44		
Initial wt (11/30/01), kg	583	590	589	9.3	0.81
Wt change (11/30/01 to 2/14/02), kg	23^y	33^x	10^z	2.8	< 0.01
Wt change (2/14 to 5/9/02), kg	-116^{xy}	-123^x	-111^y	2.9	0.02
Wt change (5/9 to 10/14/02), kg	44	42	46	3.2	0.54
Wt change (11/30/01 to 10/14/02), kg	-49	-48	-55	3.9	0.43
Final wt (10/14/02), kg	533	542	534	8.5	0.70
Initial BCS (11/30/01)	5.66	5.58	5.55	0.11	0.76
BCS change (11/30/01 to 2/14/02)	-0.27^y	-0.09^x	-0.40^y	0.06	< 0.01
BCS change (2/14 to 5/9/02)	-0.51	-0.57	-0.41	0.07	0.29
BCS change (5/9 to 10/14/02)	-0.01	-0.17	-0.16	0.06	0.07
BCS change (11/30/01 to 10/14/02)	-0.79	-0.83	-0.97	0.08	0.26
Final BCS (10/14/02)	4.87	4.75	4.58	0.09	0.08

[a] Supplements (DM basis) included: 1) 0.39 kg/d of soybean meal (NCON); 2) 1.72 kg/d of a soybean hull-based supplement (PCON); and 3) 0.95 kg/d of whole linoleic sunflower seed (WSUN).

[b] Most conservative SEM, n = 44.

[c] Probability of a greater F-statistic.

[xy] Within a row, means without a common superscript letter differ ($P \le 0.05$).

Table 4. Effect of late-gestation supplement on early- and mid-lactation milk production, kg/d

	Supplement[a]				
Item	NCON	PCON	WSUN	SEM[b]	*P*-Value[c]
n =	21	21	20		
Early-lactation[d]	6.8	7.1	6.3	0.43	0.43
Mid-lactation[e]	6.8	7.2	6.6	0.44	0.59

[a] Supplements (DM basis) included: 1) 0.39 kg/d of soybean meal (NCON); 2) 1.72 kg/d of a soybean hull-based supplement (PCON); and 3) 0.95 kg/d of whole linoleic sunflower seed (WSUN).

[b] Most conservative SEM, n = 20.

[c] Probability of a greater F-statistic.

[d] Measured on 4/10/02, avg calf age = 44 d, range = 34 to 55 d.

[e] Measured on 6/18/02, avg calf age = 113 d, range = 103 to 124 d.

Table 5. Effect of late-gestation supplement on early-lactation milk composition[a]

	Supplement[b]				
Item	NCON	PCON	WSUN	SEM[c]	*P*-Value[d]
n =	5	5	5		
12-h yield, kg	3.5	3.3	3.3	0.35	0.84
Butterfat, %	2.37	2.39	2.77	0.33	0.66
Protein, %	3.17	2.87	3.03	0.13	0.29
Lactose, %	5.52	5.52	5.45	0.07	0.68
Solids not fat, %	10.10	9.74	9.84	0.18	0.38
Somatic cell count per mL (x1,000)	14	64	66	33	0.51
Milk urea nitrogen, mg/100 mL	2.84	1.97	2.27	0.30	0.16

[a] Measured on 4/4/02, avg calf age = 31 d, range = 24 to 37d.

[b] Supplements (DM basis) included: 1) 0.39 kg/d of soybean meal (NCON); 2) 1.72 kg/d of a soybean hull-based supplement (PCON); and 3) 0.95 kg/d of whole linoleic sunflower seed (WSUN).

[c] Most conservative SEM, n = 5.

[d] Probability of a greater F-statistic.

Table 6. Effect of late-gestation supplement on calf birth and weaning weight

	Supplement[a]				
Item	NCON	PCON	WSUN	SEM[b]	*P*-Value[c]
n =	49	45	44		
Birth wt, kg	35	36	35	0.8	0.46
Weaning wt, kg (avg age = 222 d)	229	232	232	5.7	0.69

[a] Supplements (DM basis) included: 1) 0.39 kg/d of soybean meal (NCON); 2) 1.72 kg/d of a soybean hull-based supplement (PCON); and 3) 0.95 kg/d of whole linoleic sunflower seed (WSUN).

[b] Most conservative SEM, n = 45.

[c] Probability of a greater F-statistic.

Table 7. Effect of late-gestation supplement on cow reproductive performance

	Supplement[a]				
Item	NCON	PCON	WSUN	SEM[b]	*P*-Value[c]
n =	49	45	44		
Days from calving to breeding[d]	60	63	66	2.3	0.15
Cows cycling, %[e]	53	67	50	7.5	0.29
Pregnancy rate at weaning, %	84	91	91	5.3	0.44
n =	43	39	34		
Days from calving to first AI date	74	76	79	2.5	0.41
First service conception rate, %	53^{y}	79^{x}	74^{x}	7.6	0.03

[a] Supplements (DM basis) included: 1) 0.39 kg/d of soybean meal (NCON); 2) 1.72 kg/d of a soybean hull-based supplement (PCON); and 3) 0.95 kg/d of whole linoleic sunflower seed (WSUN).

[b] Most conservative SEM.

[c] Probability of a greater F-statistic.

[d] Days from calving to the start of the breeding season.

[e] Cows cycling at the start of the breeding season.

[xy] Within a row, means without a common superscript differ ($P \leq 0.07$).

Table 8. Effect of late-gestation supplement on feedlot performance and carcass characteristics of steer progeny

Item	Supplement[a]			SEM[b]	*P*-Value[c]
	NCON	PCON	WSUN		
n =	24	24	22		
Feedlot arrival wt, kg	223	229	233	24	0.11
Harvest wt, kg	534	550	539	19	0.35
ADG, kg	1.65	1.69	1.62	0.07	0.31
Hot carcass wt, kg	340	352	350	10	0.29
Fat thickness, cm[d]	1.63	1.59	1.59	0.12	0.93
Ribeye area, cm^2	76.7	78.1	78.2	4.0	0.82
KPH, %	2.20	2.40	2.46	0.14	0.26
Yield grade[d]	3.63	3.65	3.64	0.14	0.99
Marbling score[d]	44.8	45.6	45.6	2.1	0.94
% Choice or greater[d]	67	71	82	8.2	0.49

[a] Supplements (DM basis) included: 1) 0.39 kg/d of soybean meal (NCON); 2) 1.72 kg/d of a soybean hull-based supplement (PCON); and 3) 0.95 kg/d of whole linoleic sunflower seed (WSUN).

[b] Most conservative SEM, n = 22.

[c] Probability of a greater F-statistic.

[d] Fat thickness opposite the ribeye; Calculated yield grade; Small 00 = 40 and Small 30 = 43; Quality grade based on marbling score.

Chapter IV

Linoleic and oleic sunflower supplements for beef cattle: Effects on intake, digestion, performance, and reproduction

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ABSTRACT: Two experiments were conducted to determine the effects of sunflower supplements with varying fatty acid profiles on intake, digestion, performance, and reproduction. In Exp. 1, 127 multiparous spring calving beef cows were individually fed one of three supplements for an average of 83 d during late gestation. Supplements (DM basis) included: 1) 1.23 kg/d of a soybean hull-based supplement (Positive); 2) 0.68 kg/d of linoleic sunflower grain and 0.23 kg/d of the Positive supplement (Linoleic); and 3) 0.64 kg/d of mid-oleic sunflower grain and 0.23 kg/d of the Positive supplement (Oleic). During the first 62 d of supplementation, cows fed Positive gained 8 kg more BW than ($P = 0.01$) cows fed Linoleic and 14 kg more BW than ($P < 0.01$) cows fed Oleic. However, from before calving to the start of the breeding season (-65 kg; $P = 0.83$), from the start of the breeding season to weaning (30 kg; $P = 0.28$), and throughout the 303-d experiment (-31 kg; $P = 0.49$) there were no differences in weight change among supplements. Cow body condition change followed the same pattern as weight change. At the start of the breeding season more cows fed Positive (43%; $P < 0.03$) were cycling compared with cows fed either Linoleic (20%) or Oleic (16%). However, first service conception rate (67%; $P = 0.22$) and pregnancy rate at weaning (92%; $P = 0.18$) were not different among supplements. No differences ($P = 0.11$ to 0.83) were detected in calf birth weight, calf weaning weight, or feedlot performance and carcass characteristics of steer progeny. In Exp. 2, eight ruminally cannulated steers were used in two 4 x 4 Latin squares to determine the effects of sunflower seed supplementation on forage intake and digestion. Supplements (DM basis) included: 1) no supplement (NCON); 2) a soybean hull-based supplement fed at 0.292 kg·100 kg of $\text{BW}^{-1}\cdot\text{d}^{-1}$ (PCON); 3) whole linoleic sunflower seed fed at 0.162 kg·100 kg of $\text{BW}^{-1}\cdot\text{d}^{-1}$ (LIN); and 4) whole high-oleic sunflower seed fed at 0.162 kg·100 kg of $\text{BW}^{-1}\cdot\text{d}^{-1}$ (OLE). Hay intake was not influenced by supplement (1.51 kg/100 kg of BW); however, DMI was greatest for PCON and least for NCON. Additionally, DM and fiber digestibility were reduced with sunflower seed supplementation. However, lipid and CP digestibility were greater with sunflower seed supplementation. In conclusion, these experiments suggest that whole sunflower seed can be used as a winter supplement without impacting cow reproduction or calf performance.

Key Words: Beef Cows, Prepartum Lipid Supplementation, Sunflower

Introduction

Reproduction has the greatest impact in determining the economic success and sustainability of cow/calf enterprises. Consequently, those involved with the cow/calf enterprise are constantly looking for ways to improve reproduction through different nutrition or management strategies. Lipid supplementation or diets high in lipid content have been evaluated as nutraceuticals to improve reproductive efficiency through increased functional capability of the ovary and/or alterations in $PGF_{2\alpha}$ synthesis by the uterus (Williams and Stanko, 2000). Limited research suggests that prepartum lipid supplementation during late gestation may improve reproductive efficiency of beef cattle (Bellows et al., 2001; Hess et al., 2002). Additionally, lipid sources rich in polyunsaturated fatty acids, especially linoleic acid, appear more beneficial in altering reproductive physiology than lipid sources composed primarily of saturated fatty acids (Williams and Stanko, 2000). Little data is currently available which directly compares performance and reproduction of beef cows fed diets with varying polyunsaturated fatty acid profiles (Lammoglia et al., 1997; Bottger et al., 2002). Furthermore, effects on BW change and reproduction are inconsistent for beef cattle supplemented with sunflower seed or fed diets containing sunflower seed (Bellows et al., 2001; Alexander et al., 2002; Funston et al., 2002).

In addition to potential effects on cow reproduction, prepartum diet composition may alter prenatal development and postnatal body composition based on studies with pigs and rats (Musser et al., 1999; Poulos et al., 2001). Thus the objectives of these experiments were to determine the effects of feeding high-lipid sunflower seed or grain with varying amounts of linoleic and oleic fatty acids on: 1) reproduction and performance of mature beef cows and performance of their progeny; 2) feedlot performance and carcass characteristics of steer progeny; and 3) forage intake and digestion.

Materials and Methods

Experiment 1

This experiment was conducted at the Range Cow Research Center, North Range Unit located approximately 16 km west of Stillwater, OK, in accordance with an approved Oklahoma State University Animal Care and Use Committee protocol. During the winter of 2002 to 2003, 127 multiparous spring calving Angus x Hereford crossbred beef cows were assigned to one of three different supplements in a completely randomized design. Cows were assigned to supplements so that age (average = 8.8 yr; range = 4 to 13 yr), initial BW, and initial BCS would be similar. Treatment supplementation started on December 2, 2002, and ended at calving or on February 26, 2003, whichever came first (average supplementation = 83 d; range = 69 to 85 d). During the supplementation period, cows were managed as a contemporary group in a single pasture and had free choice access to bermudagrass hay (*Cynodon dactylon*; CP, 8.3%; TDN, 55%; crude fat 2.0%; DM basis; Dairy One Forage Testing Laboratory, Ithaca, NY) and a mineral supplement (NaCl, 24.6%; Ca, 16.8%; P, 8.7%; Mg, 1.2%; Cu, 1,038 ppm; Se, 12 ppm; Zn, 3,099 ppm; DM basis). At calving, treatment supplementation was terminated and cow/calf pairs were moved to an adjacent pasture where they were also managed as a contemporary group. Cow/calf pairs had free choice access to the same bermudagrass hay and mineral supplement and were fed a protein supplement. Although hay was the primary forage component of the diet during the treatment period, cows had access to a limited supply of dormant tall-grass prairie pasture. Diets were formulated to meet or exceed CP requirements (NRC, 1996).

Supplements (DM basis) included: 1) 1.23 kg/d of a soybean hull-based supplement (**Positive**; fed as 0.64 cm pellets); 2) 0.68 kg/d of linoleic sunflower grain and 0.23 kg/d of the Positive supplement (**Linoleic**; 59% linoleic acid, 28% oleic acid, tabular values); and 3) 0.64 kg/d of mid-oleic sunflower grain and 0.23 kg/d of the Positive supplement (**Oleic**; 31% linoleic acid, 58% oleic acid, tabular values). The Linoleic and Oleic supplements included 0.23 kg/d of the Positive supplement in an effort to eliminate palatability problems encountered in a previous experiment when whole sunflower seed was fed (Banta, 2005). Supplements were formulated to provide similar amounts of protein and energy (Table 1). Each cow was fed its appropriate supplement in an individual stall on Monday, Tuesday, Thursday, and Saturday mornings. The amount of supplement fed on each of these 4 d was determined by calculating the amount of supplement needed per week (daily supplement amount x 7 d) and dividing that amount by 4 (i.e., cows receiving Linoleic were fed 1.59 kg/feeding). Following the treatment supplementation period, all cows were managed as a contemporary group and were given access to either bermudagrass pasture or tall-grass prairie pasture and a mineral supplement (NaCl, 42.1%; Ca, 9.5%; P, 8.3%; Mg, 0.3%; Cu, 1,039 ppm; Se, 12 ppm; Zn, 3,110 ppm; DM basis).

Individual cow BW and BCS were determined at the beginning of supplementation (12/3/02), after the first 62 d of supplementation before any cows had calved (2/3/03), at the onset of breeding (5/12/03), and at weaning (10/2/03). Cows were weighed 16 h after withdrawal from feed and water. Body condition scores were determined by the same two independent evaluators throughout the experiment (1 = emaciated, 9 = obese).

Milk production was determined on d 142 of the experiment, using the weigh-suckle-weigh technique as previously described (Banta, 2005). Additionally, eight of the earliest calving cows from each supplement were used to determine milk composition on d 95 of the experiment (Banta, 2005). Cows were selected so that calving date would be similar among supplements. Additionally, cows were randomly assigned to one of eight time blocks so that milking times for each supplement would be equally represented throughout the morning. Because of severe mastitis, data from three cows was removed from the milk composition analysis.

The 72-d calving season lasted from February 10 to April 22, 2003 (average calving date: March 9, 2003). The percentage of cows cycling at the start of the breeding season was determined by quantifying progesterone concentration (Vizcarra et al., 1997) in plasma samples obtained via tail venipuncture 10 d before and again on the first day of the breeding season. Cows with one or more plasma samples containing ≥ 0.5 ng/mL progesterone were considered to be cycling (i.e., exhibiting luteal activity). Cows were artificially inseminated from May 12 through June 13, followed by natural mating from June 13 through July 16 which resulted in a 65-d breeding season. Cows were observed each morning and evening for 1 h to detect standing estrus; all cows exhibiting standing estrus were artificially inseminated approximately 12 h after estrus observation. First service conception rate was determined by transrectal ultrasonography approximately 30 d after AI and pregnancy rate was determined by rectal palpation at weaning. Birth weight of each calf was determined within 24 h of birth and all male calves were castrated at this time. Weaning weight was determined on October 2, 2003; all calves were weighed directly off the cow without any restriction from feed or water.

At weaning all steer calves were transported to the Willard Sparks Beef Research Center, Stillwater, OK, to determine the effects of late gestation cow supplement composition on subsequent feedlot performance and carcass characteristics. Steers were randomly assigned to pens based on supplement fed to their dams. A high-concentrate finishing ration was fed for 190 d until harvest; diets are Ross et al., 2004. Steers were implanted with Component E-S (VetLife, West Des Moines, IA) on d 0 and Revalor-S (Intervet Inc., Millsboro, DE) on d 105 of the finishing period. Feedlot arrival and harvest weight were determined for each steer and a pencil shrink was applied to these weights to calculate shrunk initial weight (3%; transportation resulted in a 1% shrink), shrunk harvest weight (4%), and ADG. Steers were harvested at Excel Corporation (Dodge City, KS) and chilled for 72 h before collection of carcass data.

Statistical Analysis

Cow was the experimental unit because supplements were individually fed to each cow. All non-categorical data was analyzed using MIXED MODEL procedures of SAS (SAS Inst. Inc., Cary, NC) and the Satterthwaite approximation for degrees of freedom. Interactions were removed from the model if $P > 0.30$. All covariates remained in the model regardless of significance. When the P-value for the F-statistic was ≤ 0.05, least squares means were separated using the LSD procedure of SAS ($\alpha = 0.05$). Least squares means are reported in all tables and overall means in the text represent the simple average of the least squares means, except for percent of cows cycling, first service conception rate, and pregnancy rate which are raw means. For various reasons (calf death, n = 5; cow death, n = 1; cow injury, n = 2; severe mastitis, n = 1) data from nine cows and their calves were removed from the experiment. No relationship was apparent between any of these factors and late-gestation supplement composition. Only data from the 118 cows that weaned a calf in October were used for statistical analysis.

The model for cow performance included supplement as a fixed effect and cow age as a covariate. The initial models for milk production included supplement and calf sex as fixed effects; cow and calf age were included as covariates. The model for milk composition was the same as the milk production model except that calf sex was not included and block was included as a random effect. The initial model for calf performance included supplement and calf sex as fixed effects and calf sire as a random effect. Cow age was included as a covariate in all the calf performance models and calf age was included as a covariate in the weaning weight model.

The model for days from calving to the start of the breeding season and days from calving to first AI date included supplement as a fixed effect. A 2 x 3 contingency table was developed for proportional differences among supplements for percent cycling, first service conception rate, and pregnancy rate and tested using a chi-square test. Reproductive data were analyzed using FREQ procedures of SAS. The standard error for proportion data was calculated as: $\sqrt{}$P(1-P)/n were P = proportion of the variable in question (M. Payton, Department of Statistics, Oklahoma State University, Stillwater, personal communication).

The model for feedlot performance and carcass characteristics of steer progeny included supplement as a fixed effect and sire as a random effect. Covariates included cow age and calf age at harvest.

Experiment 2

This experiment was conducted at the Nutrition Physiology Research Center, Stillwater, OK, in accordance with an approved Oklahoma State University Animal Care and Use Committee protocol. The experimental design for this experiment consisted of two simultaneous 4 x 4 Latin squares; a unique treatment order which balanced for carry over effects was used for each square. At the beginning of the experiment, eight mature Angus and Angus x Hereford crossbred ruminally cannulated steers (initial BW = 642 kg) were randomly assigned to one of four different supplements. During the experiment, steers were housed in individual indoor 3- x 4-m pens with ad libitum access to fresh water.

Steers were given ad libitum access to bermudagrass hay by providing 2.27 kg (as-fed) more hay than had disappeared the previous day; the hay was processed through a hammer mill before feeding (Table 2). Supplements (DM basis) included: 1) no supplement (**NCON**); 2) a soybean hull-based supplement fed at 0.292 kg·100 kg of BW^{-1}·d^{-1} (**PCON;** 94.75% soybean hulls, 5.25% wheat middlings); 3) whole linoleic sunflower seed fed at 0.162 kg·100 kg of BW^{-1}·d^{-1} (**LIN**; 59% linoleic acid, 28% oleic acid, tabular values); and 4) whole high-oleic sunflower seed fed at 0.162 kg·100 kg of BW^{-1}·d^{-1} (**OLE**; 3% linoleic acid, 88% oleic acid, tabular values). All supplements except for NCON were formulated to provide similar amounts of CP, ruminally degraded intake protein, and energy. The supplements were fed at approximately the same rate as supplements fed in a previous experiment that we conducted with whole sunflower seed (Banta, 2005) and in Exp. 1. Pre-experiment analysis of hay CP was low (5.75%, DM basis), so each steer received soybean meal at a rate of 0.034 kg·100 kg of BW^{-1}·d^{-1} in addition to the treatment supplements in order to meet nitrogen requirements of ruminal microbes. Supplements were offered at 0800 each morning and any supplement that was not consumed by 0900 was inserted in the rumen via the ruminal cannula.

Each 21-d period consisted of 12 d of adaptation, 7 d of fecal collection, and 1 d of ruminal fluid sampling. Chromic oxide (10 g·steer·$^{-1}$d^{-1}) was dosed intraruminally at 0800 and 1600 from d 10 through 21 in gelatin capsules to predict fecal output. Hay intake was measured from d 13 through 19 and fecal grab samples were collected twice daily at 0800 and 1600 from d 15 through 21. Additionally, ruminal fluid samples were collected on d 21 at 0, 2, 4, 8, 12, and 24 h, starting at 0800 prior to feeding to determine ruminal pH and NH_3 concentration.

Sub-samples of supplements, hay, and orts were dried at 100ºC to determine DM. Hay, ort, and fecal samples were dried at 50ºC and ground in a Wiley mill (Model-4, Thomas Scientific, Sweedesboro, NJ) to pass a 2-mm screen before analysis. The supplements were dried at 50ºC and the Positive supplement was ground in the Wiley mill. However, the sunflowers were ground in a household coffee and spice mill (Regal Ware, Inc., Kewaskum, WI) to pass a 2-mm sieve. After grinding, supplement and hay samples were composited within period; ort and fecal samples were composited within period and steer. All composite samples were analyzed for aNDF, ADF, CP, and lipid content (Table 2). Neutral detergent fiber and ADF content were determined using an ANKOM Fiber Analyzer (ANKOM Technology, 2005a,b). Crude protein was determined using a Leco NS-2000 Nitrogen Analyzer (Leco Corporation, St. Joseph, MI). An ether extraction procedure with a pre-extraction acid hydrolysis treatment was used to estimate lipid content of samples because Ca soaps are formed in the hindgut and excreted in feces (analysis performed by Servi-Tech Laboratories, Dodge City, KS). Additionally, Cr concentration of fecal composites was determined on an Inductively Coupled Plasma Spectrophotometer (ICP Spectro Analytical Instruments, Fitchburg, MA;

Williams et al., 1962; Choat et al., 2002). Apparent DM, OM, CP, and lipid digestibility as well as true NDF and ADF digestibility were calculated for each steer. Additionally, digested OM intake (OM intake kg/100 kg of BW x OM digestibility) was calculated for each steer.

Ruminal fluid samples were collected from the center of the ruminal mat and strained through eight layers of cheesecloth before analysis. Immediately after straining, pH of ruminal fluid was determined. Nine milliliters of strained ruminal fluid was then acidified with 1 mL of 1 *N* HCL and frozen until NH_3 analysis. Ruminal NH_3 concentration was determined colorimetrically on a Beckman DU 530 Spectrophotometer (Beckman Instruments, Inc., Fullerton, CA; Broderick and Kang, 1980).

Statistical Analysis

Intake and digestibility measurements were analyzed with a model appropriate for simultaneous Latin squares using MIXED MODEL procedures of SAS and the Satterthwaite approximation for degrees of freedom. The supplement x period interaction was not included in the analysis. Supplement and period were included as fixed effects in the model. Additionally, square and steer nested within square were included as random effects. Ruminal pH and ruminal NH_3 concentration were analyzed with a model appropriate for simultaneous Latin squares with repeated measures using MIXED MODEL procedures of SAS and the Kenward-Roger approximation for degrees of freedom. Supplement, period, time and their interactions were included in the model as fixed effects. Square and steer nested within the period x supplement interaction were included as random effects. Additionally, steer nested within the period x supplement interaction was included in the repeated statement and an autoregressive covariance structure was used to account for the relationship between the repeated measures. When the *P*-value for the F-statistic was ≤ 0.05, least squares means were separated using the LSD procedure of SAS ($\alpha = 0.05$). Least squares means are reported in all tables and overall means in the text represent the simple average of the least squares means.

Results and Discussion

Experiment 1

Cow Weight and BCS. Length of the treatment supplementation period was not different among supplements (83 d, Table 3). During the first 62 d of the supplementation period, before any cows had calved, cows fed Positive gained 8 kg more BW than cows fed Linoleic and 14 kg more BW than cows fed Oleic (Table 3). Additionally, cows fed Linoleic gained 6 kg more BW than cows fed Oleic. However, during the following period from before calving to the start of the breeding season no difference in weight change was observed among supplements (-65 kg, Table 3). Additionally, there was no difference in cow BW change among supplements from the start of the breeding season to weaning (30 kg) and during the entire 303-d experimental period (-31 kg, Table 3). Initial (5.03), precalving (4.92, $P = 0.53$), prebreeding (4.76, $P = 0.51$), and final BCS (4.94) were not different among supplements. Additionally, BCS change during the 303-d experiment was not different among supplements (Table 3).

During late gestation, the change in BW between the sunflower treatments and the positive control may be explained by reduced forage digestion (Byers and Schelling, 1988; Jenkins, 1993). Other researchers (Howlett et al., 2003; Scholljegerdes et al., 2004) have reported that diets high in lipid reduce fiber digestibility of forage-based diets. Jenkins (1994) suggested that diets containing more than 2 to 4% added lipid from plant oils is likely to decrease fiber digestion. Based on mean cow weights of 578, 576, and 577 kg and an estimated hay intake of 1.6 kg/100 kg of BW, the diets contained approximately 4.8, 4.7, and 2.0% dietary lipid for Linoleic, Oleic, and Positive, respectively. The difference in weight change during the treatment supplementation period between cows fed Linoleic and Oleic is not easily explained. Scholljegerdes et al. (2004) reported that postruminal disappearance of long-chain monounsaturated and polyunsaturated fatty acids was greater for heifers fed high-linoleic compared with heifers fed high-oleic cracked safflower seeds. Additionally, Palmquist (1994) reported that fatty acid digestion decreased as saturation increased. Although fatty acid digestion is increased as unsaturation increases, ruminal fiber digestion is inhibited more by unsaturated than by saturated fatty acids (Jenkins, 1993). Thus the linoleic acid from the linoleic sunflower grain may be more digestible, but it may also inhibit fiber digestion to a greater extent than the oleic acid in the high-oleic sunflower grain. As evidenced by the previously cited literature (Jenkins, 1993; Palmquist, 1994; Scholljegerdes et al., 2004), differences in fatty acid profile do not clearly explain the difference in weight change observed between cows fed Linoleic and Oleic during the treatment period. Although Bottger et al. (2002) reported that weight gain was not different between primiparous cows fed high-linoleic (-16.3 kg) or high-oleic (-32.6 kg) cracked safflower seeds for 90 d after calving, their results are in the same direction as those in the present experiment.

Milk Production and Composition. A supplement x calf sex interaction was not detected ($P = 0.19$) for early-lactation milk production. Additionally, neither supplement nor calf sex ($P = 0.29$, data not shown) influenced early-lactation milk production (7.2 kg/d; Table 4). Furthermore, the source of supplement did not significantly alter concentrations of milk urea nitrogen, protein, butterfat, lactose, solids not fat, or somatic cell count (Table 4).

Considering that milk production was first measured 55 d after supplementation had ceased, it was not surprising that no supplement differences were observed for milk production or milk composition. Alexander et al. (2002) reported no effect of prepartum lipid supplementation on milk production, percent milk fat, or percent solids non-fat measured 30, 60, and 90 d postpartum. Additionally, Bottger et al. (2002) found no difference in milk production, milk protein, solids not fat, total solids, or somatic cell count between primiparous cows fed high-linoleic or high-oleic cracked safflower seeds for 90 d after calving. However in their experiment (Bottger et al., 2004), milk fat was lower for cows fed linoleic compared with cows fed oleic safflower seeds on two of the three sampling dates.

*Calf Performance***.** No supplement x calf sex interaction was observed for calf birth weight ($P = 0.31$) or weaning weight ($P = 0.17$). Additionally, no differences in calf birth weight (35 kg) or weaning weight (227 kg; Table 5) were detected due to supplement. Steers were 3 kg heavier ($P < 0.01$) at birth and 10 kg heavier ($P = 0.03$) at weaning than heifers. One would not expect differences in weaning weight if milk production and composition were not altered by supplementation. In a review of the literature, Hess et al. (2002) concluded that prepartum lipid supplementation had no influence on calf birth weight or weaning weight.

Cow Reproductive Performance. No differences in days from calving to the start of the breeding season (64 d) or days from calving to first AI date (79 d; Table 6) were observed among supplements. Percent of cows cycling at the start of the breeding season was greater for cows fed Positive (43%) compared with cows fed Linoleic (20%) or Oleic (16%; Table 6). However, first service conception rate (67%) and pregnancy rate at weaning (92%; Table 6) were not different among supplements.

Prepartum lipid treatments have not been reported to influence percent of cows cycling at the start of the breeding season (Bellows et al., 2001; Geary et al., 2002; Banta, 2005). The effects of prepartum lipid treatment on first service conception and pregnancy rates are varied and inconsistent. First service conception and pregnancy rate were not different for cows fed whole sunflower seed during late gestation compared with cows fed a positive control (Banta, 2005). Funston et al. (2002) observed no difference in pregnancy rate to AI for heifers fed whole sunflower seed for 30 or 60 d prebreeding compared with control heifers. Additionally, Alexander et al. (2002) reported no improvement in first service conception rate or pregnancy rate for prepartum cows fed a high-fat range supplement. However, in contrast to our experiment, first service conception rate (Graham et al., 2001) and pregnancy rate (Bellows et al., 2001) were increased for cows fed soybeans prepartum. The improvement in pregnancy rate observed by Bellows et al. (2001) may be due to differences in caloric intake among treatments, instead of a nutraceutical effect, because dietary TDN was predicted from an ADF equation which does not account for the increased caloric content of fat. Based on reproductive data in the present experiment and others (Banta, 2005), lipid supplementation of mature and geriatric cows in adequate body condition does not appear to be beneficial.

Feedlot Performance and Carcass Characteristics of Steers. Feedlot performance and carcass characteristics of steer progeny were not influenced by supplements fed to dams during late gestation (Table 7). Additionally, no differences in feedlot performance or carcass characteristics of steer progeny were observed when linoleic whole sunflower seed was fed during late gestation (Banta, 2005).

Experiment 2

Dietary lipid content of the diets ranged from 2.05% for steers fed NCON to 6.24% for steers fed LIN (Table 8). Supplement composition did not influence ($P = 0.25$) hay intake (1.51 kg/100 kg of BW; Table 8). However, DMI was greatest for steers fed PCON, and least for steers fed NCON (Table 8); fecal output expressed as kg/100 kg of BW followed the same pattern as DMI (Table 8). Apparent DM digestibility was greatest for PCON followed by LIN and least for NCON and OLE. In contrast, NDF and ADF digestibility were greatest for steers fed PCON and least for steers fed LIN and OLE (Table 8). Crude protein and lipid digestibility were greatest for LIN and OLE and least for NCON. Although OM intake and digestibility of OM, fiber, CP, and lipid differed depending on supplement composition, there were no significant differences in digested OM intake except that PCON was greater than the other supplements (Table 8).

In the present experiment, DMI was reduced with sunflower seed supplementation; however, no significant difference was observed in hay intake. In contrast to the present experiment, most research shows little if any reduction in intake when oilseeds are included in the ration or fed as supplements. For example, Coppock and Wilks (1991) reviewed 18 experiments with dairy cows and reported that the inclusion of up to 25% whole cottonseed (DM basis) in the ration did not reduce DMI. Additionally, forage OM intake and total OM intake were not significantly different for heifers supplemented with corn or soybean oil (Brokaw et al., 2001).

As might be expected, DM and fiber digestibility were reduced in the present experiment when dietary lipid concentration exceeded 5% of DM (Byers and Schelling, 1988; Jenkins et al., 1994). Howlett et al. (2003) reported that apparent total tract OM digestibility was not reduced, but that total tract NDF digestibility was lower for steers limit fed silage-based diets with added whole cottonseed or whole soybean compared with steers fed silage-based diets with added corn. Furthermore, total tract OM and NDF digestibility were reduced for heifers fed cracked linoleate or oleate safflower seed compared with heifers fed a control supplement (Scholljegerdes et al., 2004).

In agreement with our results, total tract N digestibility was significantly greater for heifers fed cracked safflower seed compared with heifers fed a control supplement (Scholljegerdes et al., 2004). This increase in N digestibility may be explained by the fact that lipid supplementation usually reduces protozoa numbers and increases bacterial numbers. Proteolytic activity is greater for bacteria than protozoa, thus by increasing bacterial numbers proteolytic activity and protein digestion are increased (Doreau and Ferlay, 1995). It is commonly believed that lipid supplementation increases microbial efficiency (Jenkins, 1993; Doreau and Ferlay, 1995). Although this is true, in most cases the amount of protein reaching the duodenum is not increased. Instead the increase in microbial efficiency is due to a decrease in ruminal OM digestion (Doreau and Ferlay, 1995).

Reports on the effects of oilseed supplementation on lipid digestibility are lacking. However, it would be expected that oilseed supplementation would increase apparent lipid digestibility because of the increased percentage of fatty acids contained in the ether extract of oilseeds compared with forages or concentrates (Byers and Schelling, 1988). Additionally, apparent fat digestibility increases with increasing dietary lipid concentration (Palmquist, 1994).

Fatty acid length and saturation not only influence digestion of other chemical constituents but also digestion of the specific fatty acid in question (Coppock and Wilks, 1991; Jenkins, 1993). Scholljegerdes et al. (2004) reported that total tract OM and NDF digestion were numerically reduced and CP digestion and unsaturated as well as total fatty acid postruminal disappearance were statistically reduced for heifers fed cracked oleate safflower seed compared with heifers fed cracked linoleate safflower seed diets. In our experiment, we observed numerical reductions in DM, fiber, and CP digestibility and a statistical reduction in lipid digestibility for steers fed whole sunflower seed rich in oleic acid compared with steers fed sunflower seed rich in linoleic acid. The increase in apparent lipid digestibility for steers fed LIN compared with those fed OLE may be due to both an increase in dietary lipid concentration and a greater concentration of linoleic acid (Palmquist, 1994).

No supplement x time interaction was detected for ruminal pH ($P = 0.25$). Additionally, ruminal pH was not influenced by supplement composition (6.49; Table 8). A supplement x time interaction was detected for ruminal NH_3 concentration ($P < 0.01$). However, this interaction resulted from differences in the magnitude of increases in NH_3 among supplements over time, so only supplement means averaged across sampling times are reported. Ruminal NH_3 concentration was greatest for steers fed LIN and OLE and least for steers fed NCON (Table 8).

In agreement with our results, neither safflower seed supplementation (Scholljegerdes et al., 2004) nor soybean oil supplementation (Brokaw et al., 2001) influenced ruminal pH. However, whole cottonseed and soybean supplementation increased ruminal pH compared with supplementation of a positive control (Howlett et al., 2003). Others have reported no significant increase in ruminal NH_3 concentration due to either safflower seed supplementation (Scholljegerdes et al., 2004) or soybean oil supplementation (Brokaw et al., 2001). Howlett et al. (2003) observed either no change or an increase in ruminal NH_3 depending on the level and type of oilseed supplemented. In a review article Doreau and Ferlay (1995), reported that ruminal NH_3 concentration either decreased or more often than not did not change due to lipid supplementation. Furthermore, Doreau and Ferlay (1995) concluded that when changes in ruminal NH_3 concentration did occur that they could be explained by alterations in ruminal protein digestion or ruminal protein synthesis.

In general, the intake and digestibility measurements observed in Exp. 2 support differences in weight change and BCS change observed during the supplementation period in Exp. 1. In conclusion, these experiments suggest that whole sunflower seed supplementation during late gestation will result in reduced BW and body condition gain of cows compared with cows fed an isocaloric, isonitrogenous supplement. However, supplement composition did not influence cow reproduction or calf performance.

Implications

During the supplementation period, linoleic and mid-oleic whole sunflower grain supplementation was associated with a slight reduction in body weight gain compared with a soybean hull-based supplement. However, neither cow reproduction nor calf performance was impacted due to supplement composition. The mixing of a traditional supplement with the sunflower grain eliminated almost all the palatability problems that have been observed with the feeding of whole sunflower seed. If economically advantageous and palatability issues with whole sunflower seed can be eliminated by mixing with a more palatable feedstuff, then whole sunflower grain can be used as part of a winter supplement for gestating beef cows. Additionally, statistical and numerical differences in these experiments indicate that lipid sources rich in linoleic acid may be more favorable as winter supplements compared with lipid sources rich in oleic acid.

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Table 1. Supplement composition and amount of nutrients supplied daily (Exp. 1)[a]

	Supplement		
Item, DM basis	Linoleic	Oleic	Positive
Whole sunflower grain, kg/d	0.68	0.64	-
Soybean hull-based supplement, kg/d[b]	0.23	0.23	1.23
DM, kg/d	0.91	0.87	1.23
CP, kg/d	0.15	0.16	0.15
TDN, kg/d	0.99	0.94	0.94
Fat, kg/d	0.30	0.29	0.03

[a] Nutrient composition from tabular and wet chemistry values.

[b] 94.75% soybean hulls, 5.25% wheat middlings; DM basis.

Table 2. Hay and supplement composition (DM basis; Exp. 2)

		Supplement		
Item	Hay	LIN	OLE	PCON
CP, %	7.1	25.2	25.6	14.7
NDF, %	73.2	15.0	23.4	54.5
ADF, %	33.7	10.5	15.4	39.5
Lipid, %	2.1	44.3	37.4	3.9

[a] PCON = a soybean hull-based supplement (94.75% soybean hulls, 5.25% wheat middlings); LIN = whole linoleic sunflower seed; and OLE = whole high-oleic sunflower seed.

Table 3. Effect of late-gestation supplement on cow weight and BCS (Exp. 1)

	Supplement[a]				
Item	Linoleic	Oleic	Positive	SEM[b]	*P*-Value[c]
n =	41	37	40		
Length of supplementation period, d	83	83	82	0.7	0.73
Initial wt (12/3/02), kg	578	576	577	10.2	0.99
Wt change (12/3/02 to 2/3/03), kg	3^{y}	-3^{z}	11^{x}	2.3	< 0.01
Wt change (2/3 to 5/12/03), kg	-66	-64	-64	3.4	0.83
Wt change (5/12 to 10/2/03), kg	31	33	26	3.4	0.28
Wt change (12/3/02 to 10/2/03), kg	-32	-34	-27	4.3	0.49
Final wt (10/2/03), kg	546	541	550	9.3	0.80
Initial BCS (12/3/02)	5.05	5.08	4.98	0.11	0.80
BCS change (12/3/02 to 2/3/03)	-0.19	-0.16	0.01	0.07	0.08
BCS change (2/3 to 5/12/03)	-0.17	-0.17	-0.15	0.08	0.98
BCS change (5/12 to 10/2/03)	0.21	0.27	0.08	0.08	0.22
BCS change (12/3/02 to 10/2/03)	-0.15	-0.06	-0.06	0.10	0.75
Final BCS (10/2/03)	4.90	5.01	4.92	0.11	0.73

[a] Supplements (DM basis) included: 1) 1.23 kg/d of a soybean hull-based supplement (Positive); 2) 0.68 kg/d of linoleic sunflower grain and 0.23 kg/d of the Positive supplement (Linoleic); and 3) 0.64 kg/d of mid-oleic sunflower grain and 0.23 kg/d of the Positive supplement (Oleic).

[b] Most conservative SEM, n = 37.

[c] Probability of a greater F-statistic.

[xyz] Within a row, means without a common superscript differ ($P \leq 0.05$).

Table 4. Effect of late-gestation supplement on milk production and milk composition (Exp. 1)

	Supplement[a]				
Item	Linoleic	Oleic	Positive	SEM[b]	*P*-Value[c]
Milk production[d]					
n =	23	23	23		
kg/d	7.4	7.4	6.8	0.35	0.35
Milk composition[e]					
n =	6	7	8		
12-h yield, kg[f]	4.4	3.7	3.8	0.76	0.47
Butterfat, %	3.51	3.94	3.30	0.33	0.35
Protein, %	2.69	2.76	2.84	0.17	0.47
Lactose, %	5.19	5.04	5.14	0.05	0.09
Solids not fat, %	8.99	8.88	9.10	0.17	0.32
Somatic cell count per mL (x1,000)	148	75	148	112	0.86
Milk urea nitrogen, mg/dL	4.87	4.65	4.82	0.66	0.97

[a] Supplements (DM basis) included: 1) 1.23 kg/d of a soybean hull-based supplement (Positive); 2) 0.68 kg/d of linoleic sunflower grain and 0.23 kg/d of the Positive supplement (Linoleic); and 3) 0.64 kg/d of mid-oleic sunflower grain and 0.23 kg/d of the Positive supplement (Oleic).

[b] Most conservative SEM.

[c] Probability of a greater F-statistic.

[d] Milk production was measured on 4/23/03 using the weigh-suckle-weigh technique, avg calf age = 50 d, range = 28 to 72 d.

[e] Milk composition was measured on 3/7/03, avg calf age = 17 d, range = 10 to 25 d.

[f] Measured using a portable milking machine.

Table 5. Effect of late-gestation supplement on calf birth and weaning weight (Exp. 1)

	Supplement[a]				
Item	Linoleic	Oleic	Positive	SEM[b]	*P*-Value[c]
n =	41	37	40		
Birth wt, kg	35	36	36	0.8	0.46
Weaning wt, kg[d]	229	227	225	8.7	0.74

[a] Supplements (DM basis) included: 1) 1.23 kg/d of a soybean hull-based supplement (Positive); 2) 0.68 kg/d of linoleic sunflower grain and 0.23 kg/d of the Positive supplement (Linoleic); and 3) 0.64 kg/d of mid-oleic sunflower grain and 0.23 kg/d of the Positive supplement (Oleic).

[b] Most conservative SEM, n = 37.

[c] Probability of a greater F-statistic.

[d] Average age = 207 d.

Table 6. Effect of late-gestation supplement on cow reproductive performance (Exp. 1)

	Supplement[a]				
Item	Linoleic	Oleic	Positive	SEM[b]	*P*-Value[c]
n =	41	37	40		
Days from calving to breeding[d]	64	64	63	2.8	0.95
Cows cycling, %[e]	20^y	16^y	43^x	7.8	0.02
Pregnancy rate at weaning, %	98	86	93	5.6	0.18
n =	34	27	31		
Days from calving to first AI date	79	82	78	3.1	0.65
First service conception rate, %	76	56	68	9.6	0.22

[a] Supplements (DM basis) included: 1) 1.23 kg/d of a soybean hull-based supplement (Positive); 2) 0.68 kg/d of linoleic sunflower grain and 0.23 kg/d of the Positive supplement (Linoleic); and 3) 0.64 kg/d of mid-oleic sunflower grain and 0.23 kg/d of the Positive supplement (Oleic).

[b] Most conservative SEM, n = 37.

[c] Probability of a greater F-statistic.

[d] Days from calving to the beginning of the breeding season.

[e] Cows cycling at the beginning of the breeding season.

[xy] Within a row, means without a common superscript differ ($P \leq 0.05$).

Table 7. Effect of late-gestation supplement on feedlot performance and carcass characteristics of steer progeny (Exp. 1)

	Supplement[a]				
Item	Linoleic	Oleic	Positive	SEM[b]	*P*-Value[c]
n =	19	22	20		
Feedlot arrival wt, kg	225	215	214	12.2	0.31
Harvest wt, kg	536	519	538	9.9	0.31
ADG, kg	1.63	1.61	1.69	0.04	0.26
Hot carcass wt, kg	336	328	339	7.1	0.45
Fat thickness[d], cm	1.75	1.76	1.68	0.12	0.83
Ribeye area, cm^2	76.1	75.5	80.0	1.7	0.11
KPH, %	2.53	2.79	2.38	0.22	0.11
Yield grade[d]	3.77	3.80	3.49	0.18	0.39
Marbling score[d]	40.3	43.3	42.5	1.7	0.33
% Choice or greater[d]	68	86	65	10.6	0.24

[a] Supplements (DM basis) included: 1) 1.23 kg/d of a soybean hull-based supplement (Positive); 2) 0.68 kg/d of linoleic sunflower grain and 0.23 kg/d of the Positive supplement (Linoleic); and 3) 0.64 kg/d of mid-oleic sunflower grain and 0.23 kg/d of the Positive supplement (Oleic).

[b] Most conservative SEM, n = 19.

[c] Probability of a greater F-statistic.

[d] Fat thickness opposite the ribeye; Calculated yield grade; Small 00 = 40 and Small 30 = 43; Quality grade based on marbling score.

Table 8. Effect of supplement on daily intake, digestibility (DM basis), ruminal pH, and NH$_3$ (Exp. 2)

	Supplement[a]					
Item	NCON	LIN	OLE	PCON	SEM[b]	*P*-value[c]
Dietary lipid[d]	2.05[z]	6.24[w]	5.51[x]	2.35[y]	0.18	< 0.01
Dietary CP[d]	8.03[z]	9.77[x]	9.77[x]	9.02[y]	0.14	< 0.01
Hay intake[e]	1.50	1.45	1.50	1.60	0.17	0.25
DM intake[e]	1.54[z]	1.65[yz]	1.69[y]	1.93[x]	0.17	< 0.01
OM intake[e]	1.46[z]	1.56[yz]	1.61[y]	1.83[x]	0.16	< 0.01
Fecal output[e]	0.95[y]	0.99[y]	1.06[xy]	1.10[x]	0.10	0.04
DM digestibility, %	38.4[y]	40.0[xy]	37.2[y]	43.0[x]	1.20	0.02
OM digestibility, %	41.1[y]	42.3[xy]	39.6[y]	45.3[x]	1.18	0.01
NDF digestibility, %	42.4[xy]	40.2[yz]	37.9[z]	45.4[x]	1.29	< 0.01
ADF digestibility, %	37.2[y]	35.4[yz]	32.8[z]	44.2[x]	1.44	< 0.01
CP digestibility, %	41.4[z]	52.4[x]	50.8[x]	45.2[y]	1.24	< 0.01
Lipid digestibility, %	20.7[z]	45.7[w]	38.9[x]	27.4[y]	2.22	< 0.01
Digested OM intake[e]	0.59[z]	0.66[z]	0.64[z]	0.83[y]	0.07	< 0.01
pH	6.56	6.37	6.46	6.55	0.06	0.06
NH$_3$, mM	2.23[z]	4.75[y]	4.40[y]	3.11[z]	0.77	< 0.01

[a] Supplements (DM basis) included: 1) no supplement (NCON); 2) a soybean hull-based supplement fed at 0.292 kg·100 kg of BW^{-1}·d^{-1} (PCON); 3) whole linoleic sunflower seed fed at 0.162 kg·100 kg of BW^{-1}·d^{-1} (LIN); and 4) whole high-oleic sunflower seed fed at 0.162 kg·100 kg of BW^{-1}·d^{-1} (OLE).

[b] Most conservative SEM, n = 19.

[c] Probability of a greater F-statistic.

[d] % of DM

[e] kg/100 kg of BW.

[xyz] Within a row, means without a common superscript differ ($P \leq 0.05$).

Chapter V

Whole soybean supplementation and cow age class: Effects on intake, digestion, performance, and reproduction

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ABSTRACT: Two experiments were conducted to determine the effects of soybean supplementation on intake, digestion, and performance of beef cows of varying age. Treatments were arranged in a 2 x 3 factorial with two supplements and three age classes of cows (2-yr-old, 3-yr-old, and mature cows). Supplements (DM basis) included: 1) 1.36 kg/d of whole raw soybean grain (Soybean) and 2) 1.56 kg/d of a soybean meal/hull supplement (Positive; DM basis). Supplements were formulated to provide similar amounts of protein and energy. In Exp. 1, 166 spring calving Angus and Angus x Hereford crossbred beef cows were individually fed supplements for an average of 80 d during late gestation. There were no relevant interactions between supplement composition and cow age class. During the first 50 d of supplementation, cows fed Positive gained more BW (10 kg; $P < 0.01$) and body condition (0.18 BCS units; $P < 0.01$) than cows fed Soybean. However, weight change (-19 kg; $P = 0.87$) and BCS score change (-0.60; $P = 0.25$) during the 296-d experiment were not different between supplements. Although calves from cows fed Positive were 2 kg heavier ($P < 0.01$) at birth, there was no difference in calf weight at weaning (218 kg; $P = 0.94$) between supplements. Additionally, cows cycling at the start of the breeding season (26%; P = 0.27), first service conception rate (68%; P = 0.24), and pregnancy rate (73%; P = 0.21) were not different between supplements. In Exp. 2, 24 cows from Exp. 1 were used in a randomized complete block design to determine the effect of supplement composition on forage intake and digestion. The same supplements described in Exp. 1 were used in Exp. 2. Supplement composition did not influence any intake or digestibility measurements. Hay intake and DMI averaged 1.63 and 1.92 kg/100 kg of BW, respectively. Dry matter, NDF, and CP digestibility averaged 54.1, 55.1, and 63.2%, respectively. Furthermore, digested DMI averaged 1.03 kg/100 kg of BW. The results from the digestion and performance experiments suggest that whole soybeans can be used as a winter supplement during late gestation without impacting reproduction of beef cows or performance of their calves.

Key Words: Beef Cows, Soybeans, Prepartum

Introduction

Reproduction is one of the most crucial factors in determining profitability of a beef cow/calf enterprise. Thus, nutrition and management strategies to optimize or maximize reproductive efficiency are continually being researched. One nutrition strategy that has received considerable research in recent years is the potential nutraceutical effect of lipid supplementation. Williams and Stanko (2000) reported that increased lipid intake may improve reproductive efficiency through increased functional capacity of the ovary and/or alterations in $PGF_{2\alpha}$ synthesis by the uterus.

Effects of oilseed and commercial fat supplements on reproduction are inconsistent and may increase (Bellows et al., 2001; Hess et al., 2002), not influence

(Alexander et al., 2002; Hess et al., 2002), or numerically reduce (Bellows et al., 2001) reproductive efficiency of beef cows. Of the oilseeds and commercial lipid supplements that have been evaluated to this point, soybeans show the most consistent results. Soybeans are the only oilseed that have either numerically (Steele et al., 2002; Howlett et al., 2003) or statistically (Bellows et al., 2001; Graham, et al., 2001) increased reproductive efficiency in all reported research. Although lipid supplementation may improve reproductive efficiency, excess dietary lipid intake may reduce fiber digestion of forage-based diets (Byers and Schelling, 1988; Jenkins, 1993). Based on the available literature, we hypothesized that increased lipid intake during late gestation from whole soybeans could improve reproduction of beef cows. Thus the objectives of these experiments were to determine the effects of supplementing whole raw soybeans to beef cows of varying age on: 1) reproduction and performance of beef cows as well as performance of their progeny; and 2) forage intake and digestion.

Materials and Methods

Experiment 1

This experiment was conducted at the Range Cow Research Center, North Range Unit located approximately 16 km west of Stillwater, OK, in accordance with an approved Oklahoma State University Animal Care and Use Committee protocol. Treatments were arranged in a 2 x 3 factorial with two supplements and three age classes of cows (2-yr-old, n = 50; 3-yr-old, n = 54; and mature cows, n = 48). During the winter of 2003 and 2004, 166 spring calving Angus and Angus x Hereford crossbred beef cows were assigned to one of six different treatment combinations in a completely randomized design. Cows were assigned to treatments so that initial BW and BCS would be similar within age class. Additionally, cows were assigned to supplements so that cow age class and age of cow within the mature age class (average = 7.2 yr; range = 5 to 12 yr) would be similar.

Supplements (DM basis) included: 1) 1.36 kg/d of whole raw soybean grain (**Soybean**) and 2) 1.56 kg/d of a soybean meal/hull supplement (**Positive**; 54.4% soybean meal, 45.6% soybean hulls, DM basis). Supplements were formulated to provide similar amounts of protein and energy (Table 1). Supplements were individually fed on Monday, Tuesday, Thursday, and Saturday mornings. The amount of supplement fed on each of these 4 d was determined by calculating the amount of supplement needed per week (daily supplement amount x 7 d) and dividing that amount by 4 (i.e., cows receiving Soybean were fed 2.38 kg/feeding, DM basis).

Treatment supplementation started on December 22, 2003, and continued until calving or April 6, 2004, whichever came first (average supplementation = 80 d; range = 52 to 108 d). Treatment supplementation was terminated on the 18 cows that had not calved by April 6, 2004, because of the growth of green grass. During the treatment period, cows were managed as a contemporary group in a single pasture and had free choice access to bermudagrass hay (*Cynodon dactylon*; CP, 8.4%; TDN, 55%; crude fat, 1.6%; DM basis; Dairy One Forage Testing Laboratory, Ithaca, NY) and a mineral supplement (NaCl, 28.6%; Ca, 12.8%; P, 8.5%; Mg, 1.2%; Cu, 1044 ppm; Se, 12 ppm; Zn, 3117 ppm; DM basis). Although hay was the primary forage component of the diet during the treatment period, cows had access to a limited supply of dormant tall-grass prairie pasture. Diets were formulated to meet or exceed ruminally degraded intake protein and CP requirements (NRC, 1996). At calving, treatment supplementation was terminated and cow/calf pairs were moved to an adjacent pasture where they were also managed as a contemporary group. Cow/calf pairs had free choice access to the same bermudagrass hay and mineral supplement and were provided a protein supplement.

Following the supplementation period, all cows were managed as a contemporary group and were given access to either bermudagrass pasture or tall-grass prairie pasture and a mineral supplement (NaCl, 42.1%; Ca, 9.5%; P, 8.3%; Mg, 0.3%; Cu, 1039 ppm; Se, 12 ppm; Zn, 3110 ppm; DM basis).

Individual cow BW and BCS was determined at the start of supplementation (12/22/03), after the first 50 d of supplementation before any cows had calved (2/10/04), at the onset of breeding (5/4/04), and at weaning (10/13/04). Cows were weighed 16 h after withdrawal from feed and water. Body condition scores were determined by the same two independent evaluators throughout the experiment (1 = emaciated, 9 = obese).

Prior to the start of this experiment, all cows were bred to calve over a 66-d period from February 18 to April 24, 2004 (assuming a 282 d gestation). The 2-yr-old cows were bred to start calving at the same time as the 3-yr-old and mature cows. The calving season lasted for 79 d from February 12 to May 1, 2004 (average calving date: March 13, 2003).

The percentage of cows cycling at the start of the breeding season was determined by quantifying progesterone concentration (Vizcarra et al., 1997) in plasma samples obtained via tail venipuncture 7 d before and again on the first day of the breeding season. Cows with one or more plasma samples containing ≥ 0.5 ng/mL progesterone were considered to be cycling (i.e., exhibiting luteal activity). Cows were artificially inseminated from May 4 through June 14, followed by natural mating from June 14 through July 6, which resulted in a 63-d breeding season. Cows were observed each morning and evening for 1 h to detect standing estrus; all cows exhibiting standing estrus were artificially inseminated approximately 12 h after estrus observation. First service conception rate was determined by transrectal ultrasonography approximately 30 d after AI and pregnancy rate was determined by rectal palpation at weaning.

Birth weight of each calf was determined within 24 h of birth and all male calves were castrated at this time. Additionally, calf weights were also determined on June 14 and October 12, 2004, without any restriction from feed, milk, or water. Calves were weaned on October 12.

Statistical Analysis

Cow was considered to be the experimental unit because supplements were individually fed to each cow. All non-categorical data was analyzed using MIXED MODEL procedures of SAS (SAS Inst. Inc., Cary, NC) and the Satterthwaite approximation for degrees of freedom. All interactions and covariates remained in the model regardless of significance. When the *P*-value for the F-statistic was ≤ 0.05, least squares means were separated using the LSD procedure of SAS ($\alpha = 0.05$). Least squares means are reported in all tables; overall means in the text represent the simple average of the least squares means, except for percent of cows cycling, pregnancy rate, and first service conception rate which are raw means. For various reasons (failure to calve, n = 2; calf death, n = 7; injury, n = 2; miscellaneous, n = 3) data from14 cows and their calves were removed from the experiment. No relationship was apparent between any of these factors and late-gestation supplement composition. Only data from the 152 cows that weaned a calf in October were used for statistical analysis. Cow and calf sire were not included in any of the models because they are partially confounded with cow age class.

The models for cow and calf performance included supplement and cow age class as fixed effects. Additionally, the models for calf performance included supplement, cow age class, and calf sex as a fixed effects; calf age was included as a covariate for the June 14 and weaning weight models.

The models for days from calving to the start of the breeding season and days from calving to first AI date included supplement and cow age class as fixed effects. Categorical modeling procedures (PROC CATMOD) were used to test reproductive data for interactions between supplement and cow age class. If no interactions were detected, contingency tables were developed for proportional differences among main effects for percent cycling, first service conception rate, and pregnancy rate. These main effects were analyzed using FREQ procedures of SAS and a chi-square test. The standard error for proportion data was calculated as: $\sqrt{}P(1-P)/n$ where P = proportion of the variable in question (M. Payton, personal communication, Department of Statistics, Oklahoma State University, Stillwater).

Experiment 2

This experiment was also conducted at the Range Cow Research Center, North Range Unit located approximately 16 km west of Stillwater, Oklahoma, in accordance with an approved Oklahoma State University Animal Care and Use Committee protocol. During late gestation, 24 spring calving beef cows from Exp. 1 were used to determine the effects of supplement composition and cow age class on hay intake and digestion. Based on expected calving date and treatment from Exp. 1, cows were assigned to one of two collection periods in a randomized complete block design. Two cows from each treatment combination were represented in each period. Cows were given ad libitum access to the same bermudagrass hay fed in Exp. 1. The cows were maintained in individual outdoor 3.7- x 9.1-m pens, so that they would be exposed to the same environmental conditions as their herd mates in Exp. 1.

Each 16-d period consisted of 7 d of adaptation to the pens and hay feeders, and 9 d of data collection. Hay intake was measured from d 8 through 14 and fecal grab samples were collected twice daily at 0800 and 1600 from d 10 through 16 to predict fecal output from acid detergent insoluble ash concentration. Sub-samples of supplements, hay, and orts were dried at 100ºC to determine DM. Hay, ort, and fecal samples were dried at 50ºC and ground in a Wiley mill (Model-4, Thomas Scientific, Sweedesboro, NJ) to pass a 2-mm screen before analysis. The supplements were dried at 50ºC and the Positive supplement was ground in the Wiley mill; however, the soybeans were ground in a household coffee and spice mill (Regal Ware, Inc., Kewaskum, WI) to pass a 2-mm sieve. After grinding, supplement and hay samples were composited within period; ort and fecal samples were composited by cow. All composite samples were analyzed for aNDF, ADF, CP, and acid detergent insoluble ash. Neutral detergent fiber and ADF content were determined using an ANKOM Fiber Analyzer (ANKOM Technology, 2005a,b). Crude protein was determined using a Leco NS-2000 Nitrogen Analyzer (Leco Corporation, St. Joseph, MI). Acid detergent insoluble ash was determined as the residue following complete combustion of the ADF residue (Van Soest et al., 1991). Apparent DM, OM and CP digestibility as well as true NDF and ADF digestibility were calculated for each cow. Additionally, digested DMI (DMI kg/100kg of BW x DM digestibility) and digested OM intake were also calculated for each cow.

Statistical Analysis

Intake and digestibility measurements were analyzed as a randomized complete block design using MIXED MODEL procedures of SAS and the Satterthwaite approximation for degrees of freedom. The models included supplement and cow age class as fixed effects, period as a random effect, and days from last measured hay intake to calving as a covariate. When the *P*-value for the F-statistic was ≤ 0.05, least squares means were separated using the LSD procedure of SAS ($\alpha = 0.05$). Least squares means are reported in all tables and overall means in the text represent the simple average of the least squares means. One cow was removed from the digestion experiment because she aborted sometime after the start of Exp. 1 and before the start of Exp. 2. Another cow was also removed from Exp. 2 because she calved prior to the end of Exp. 2. Consequently, only 22 cows were used in the statistical analysis.

Results

Experiment 1

No supplement x cow age class interactions (*P* = 0.06 to 0.96) were observed for any of the cow weight, cow BCS, or calf performance data. Additionally, no interactions were observed for first service conception rate or pregnancy rate. Consequently, only main effect means are reported for these data. A supplement x cow age class interaction was observed for percent of cows cycling at the start of the breeding season. Since there were no significant interactions observed for first service conception or pregnancy rate only main effect means for percent cycling at the start of the breeding season are reported in Tables 4 and 7. Interaction means for percent cycling are reported in the text.

Main Effect of Supplement

Cow Weight and BCS. Length of the supplementation period was not different between supplements (80 d; Table 2). During the first 50 d of treatment supplementation, cows fed Positive gained 10 kg more BW than cows fed Soybean (Table 2). However, supplement composition did not influence BW change during any of the subsequent weigh periods (Table 2). Additionally, final BW at weaning and BW change over the 296-d experiment (-19 kg; Table 2) were not different between treatments. Body condition score change followed the same pattern as weight change. During the first 50 d of treatment supplementation, cows fed Positive gained more body condition than cows fed Soybeans (Table 2). However, BCS before calving (5.18; $P = 0.16$), at the start of the breeding season (4.86; $P = 0.58$), and final BCS at weaning (4.60; Table 2) were not different between supplements.

Calf Performance. At birth, calves from cows fed Positive were 2 kg heavier than calves from cows fed Soybean (Table 3); however, there were no apparent differences in dystocia. Additionally, supplement composition did not influence fetal mortality (Positive = 2; Soybean = 0) or calf mortality from birth through weaning (Positive = 4; Soybean = 3). Furthermore, calf weight on June 14 (121 kg) and October 12 (218 kg; Table 3) were not different between supplements.

Cow Reproductive Performance. No differences in days from calving to the start of the breeding season (53 d) or days from calving to first AI date (77 d; Table 4) were observed between supplements. As previously mentioned, a supplement x cow age class interaction ($P = 0.03$) was observed for percent cycling at the start of the breeding season. Percent cycling was 79, 11, and 2% for the mature, 3-yr-old, and 2-yr-old cows fed soybeans, respectively; compared with 46, 19, and 0% for the mature, 3-yr-old, and 2-yr-old cows fed soybeans, respectively. Supplement composition did not significantly influence percent of cows cycling at the start of the breeding season (26%), first service conception rate (68%), or pregnancy rate at weaning (73%; Table 4).

Main Effect of Cow Age Class

Some of the differences observed among the different age classes of cows may partly be due to genetic differences, because sires used to produce the mature cows were different than the sires used to produce the 2- and 3-yr-old cows. The 2- and 3-yr-old cows are daughters of the mature cows and cow sires are common among the 2- and 3-yr-old cows.

Cow Weight and BCS. Length of the supplementation period was not different among cow age class (80 d; Table 5). During the first 50 d of treatment supplementation, mature cows gained 10 kg more BW than 3-yr-old cows and 19 kg more BW than the 2-yr-old cows. However, during the subsequent period from before calving to the start of the breeding season the mature cows lost 29 kg more BW than the 3-yr-old cows and 37 kg more BW than the 2-yr-old cows. From the start of the breeding season to weaning the 3-yr-old cows gained 9 and 14 kg more BW than the mature and 2-yr-old cows, respectively. During the 296-d experiment, the 3-yr-old cows lost the least weight and the mature cows lost the most weight (Table 5). Initial BCS was greatest for the 2-yr-old cows (5.49), intermediate for the mature cows (5.17) and least for the 3-yr-old cows (4.90; Table 5). During the supplementation period, a slight gain of body condition was observed for the 3-yr-old and mature cows and a slight loss of body condition was observed for the 2-yr-old cows (Table 5). However, during the subsequent periods all age groups lost body condition. During the entire experiment the 2-yr-old cows lost the most body condition and the 3-yr-old cows lost the least body condition. These losses resulted in no significant difference in BCS among the age classes at weaning (4.59; Table 5).

Calf Performance. Calf weights were least for the 2-yr-old cows and greatest for the mature cows (Table 6). These differences are probably due to both genetics and age of cow. Male calves were heavier at birth than female calves (33 vs. 34 kg; $P = 0.05$). Additionally, steer calves tended ($P = 0.08$) to be heavier on June 14 (118 vs. 123 kg) and were heavier ($P = 0.03$) at weaning (214 vs. 223 kg) than heifer calves.

Cow Reproductive Performance. Days from calving to the start of the breeding season were not significantly different among age groups (53; Table 7). However, only one of the 2-yr-old cows was cycling at the start of the breeding season compared with 15% of the 3-yr-old cows and 63% of the mature cows (Table 7). Pregnancy rates were significantly greater for the 3-yr-old (83%) and mature cows (83%) compared with the 2-yr-old cows (50%). Days from calving to first AI date were greatest for the 2-yr-old cows and least for the mature cows, however, no significant difference was observed for first service conception rate among the age groups (68%; Table 7).

Experiment 2

No supplement x cow age class interactions ($P = 0.10$ to 0.69) were detected for any of the intake or digestibility measurements. Additionally, neither supplement nor cow age class had a significant influence on any of the intake or digestibility measurements (Tables 8 and 9, respectively). Hay intake and DMI averaged 1.63 and 1.92 kg/100 kg of BW, respectively. Dry matter, NDF, and CP digestibility averaged 54.1, 55.1, and 63.2%, respectively. Furthermore, digested DMI averaged 1.03 kg/100 kg of BW.

Discussion

Cow Weight and BCS. Reduced weight gain or weight loss of cattle fed lipid supplements compared with control cattle is commonly attributed to a reduction in fiber digestibility by cattle fed lipid supplements (Byers and Schelling, 1988; Jenkins, 1993). However, the lack of statistical differences in fiber digestion from the present digestion experiment (Exp. 2) do not support this theory. Furthermore, the lack of differences in intake and digestion and the increased BW gain of cows fed Positive may suggest a difference in metabolizable energy efficiency between the diets. Potential differences in composition of BW change may also help explain the differences in performance during the treatment period (Rhodes et al., 1978). Additionally, less heat production from fermentation may account for some of the observed performance differences during the treatment period.

In agreement with the results in the present experiment, others have also reported no differences in intake due to lipid supplementation. In a review of 18 experiments, Coppock and Wilks (1991) reported that whole cottonseed could be included at up to 25% of the diet without influencing DMI of dairy cows. Brokaw et al. (2001) reported that ruminal infusion of soybean oil did not influence forage or total OM intake of beef heifers grazing bromegrass pastures. Supplementation of crushed canola seed has did not influence DMI (kg/d) of steers fed corn silage-based diets (Hussein et al., 1995).

In contrast with results from the present experiment, Scholljegerdes et al. (2004) observed a significant reduction in total tract OM and NDF digestibility for heifers limit fed bromegrass hay and high-linoleic or high-oleic cracked safflower seeds compared with heifers fed hay and a control supplement. However, it should be noted that the dietary fatty acid content of the linoleic and oleic safflower seed diets was 8.44 and 8.65% (DM basis), respectively. These diets (Scholljegerdes et al, 2004) contained considerably more fat than the diets in the present experiment. Additionally, Howlett et al. (2003) found that total tract NDF but not OM digestibility was significantly reduced for steers limit fed corn silage-based diets containing 15% whole cottonseed, 15% whole soybean, or 25% whole soybean compared with steers fed a control supplement. Dietary fatty acid concentration was 4.5, 5.5, 7.4, and 2.5% for the 15% whole cottonseed, 15% whole soybean, 25% whole soybean, and control diets, respectively.

Calf performance. In previous studies at our facility, prepartum sunflower seed supplementation did not influence calf birth or weaning weight (Banta, 2005). After a review of the literature, Hess et al. (2002) concluded that prepartum lipid supplementation did not influence calf birth or weaning weight. Consequently, the 2 kg increase in birth weight observed in the present study for cows fed Positive is somewhat surprising. This increase in birth weight, along with increased BW and body condition gain during the treatment period may suggest that cows fed Positive may have been in a slightly greater energy balance than cows fed Soybean.

Cow Reproductive Performance. In contrast to the present experiment, previous research with soybean supplementation during late gestation has resulted in either numerical (Steele et al., 2002) or statistical increases (Bellows et al., 2001) in reproductive efficiency. However, caution should be taken when interpreting the results of Bellows et al. (2001), because dietary TDN was calculated from an ADF equation which does not account for the increased energy value of the fat. The lack of statistical differences found in the present experiment and the one conducted by Steele et al. (2002) indicate that whole soybean supplementation during late gestation does not have a nutraceutical effect on reproduction.

Pregnancy rates were lower than expected in this experiment, especially for the mature cows. Pregnancy rate of the mature cows would have been expected to be between 90 and 95%, based on BCS before calving (5.10), percent of cows cycling at the start of the breeding season, and previous pregnancy rates at this location (Banta, 2005). Unfortunately, there is no clear explanation for the reduced pregnancy rate observed for the mature cows. In contrast, the low pregnancy rate observed for the 2-yr-old cows is easier to explain. Using the NRC (1996) computer model and predicted dietary and environmental variables, intake and body condition gain was predicted for each age class of cows before the experiment. Based on these predictions it was determined that the amount of supplements fed would be sufficient for all cows to gain a similar amount of body condition given their differences in maintenance and growth requirements. The computer predictions over predicted intake for all age classes and thus the amount of body condition that they would gain. However, the over prediction in intake was greater for the 2-yr-old cows (2.37 vs. 1.90 kg/100 kg of BW) compared with the 3-yr-old (2.19 vs. 1.91 kg/100 kg of BW) and mature cows (2.10 vs. 1.93 kg/100 kg of BW), which resulted in a loss of body condition for the 2-yr-old cows. Given the length of the breeding season (63 d) and the fact that the 2-yr-old cows were losing body condition before calving and at the start of the breeding season their low pregnancy rate is not surprising. The low pregnancy rate observed for the 2-yr-old cows reaffirms the need to manage primiparous and multiparous cows differently, as recently reviewed by Banta et al. (2005) and Whittier et al. (2005).

Implications

Whole soybean supplementation was associated with a reduction in body weight and body condition gain compared with a soybean hull-based supplement. This apparent reduction in energy status may indicate that energy from lipid sources may not be used as efficiently as energy from carbohydrate sources or that the current tabular energy values provided for soybeans are overestimated. There does not appear to be any reproductive advantages or detrimental effects of using whole soybeans as a winter supplement for gestating beef cows. Consequently if economically viable whole soybeans can be used as a winter supplement for beef cows. The present research also indicates that lipid supplementation does not have differential reproductive effects on cows of varying age. Finally, this research suggests that current intake predictions may be less accurate for predicting intake of primiparous cows compared with mature multiparous cows.

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Table 1. Supplement composition and amount of nutrients supplied daily[a]

	Supplement	
Item, (DM basis)	Positive	Soybean
Whole soybeans, kg/d	-	1.36
Soybean hulls, kg/d	0.71	-
Soybean meal, kg/d	0.85	-
Dry matter, kg/d	1.56	1.36
CP supplied, kg/d	0.55	0.55
NE_m, Mcal/d	3.20	3.20
Fat, kg/d	0.02	0.25

[a] Nutrient composition from tabular values.

Table 2. Effect of late-gestation supplement on cow weight and BCS (Exp. 1)

	Supplement[a]			
Item	Positive	Soybean	SEM[b]	*P*-Value[c]
n =	74	78		
Length of treatment period, d	80	80	1.9	0.95
Initial wt (12/22/03), kg	505	502	5.3	0.70
Wt change (12/22/03 to 2/10/04), kg	33	23	1.3	< 0.01
Wt change (2/10 to 5/4/04), kg	-93	-89	2.2	0.15
Wt change (5/4 to 10/13/04), kg	42	47	2.3	0.16
Wt change (12/22/03 to 10/13/04), kg	-18	-19	2.6	0.87
Final wt (10/13/04), kg	487	484	5.2	0.64
Initial BCS (12/22/03)	5.15	5.23	0.07	0.35
BCS change (12/22/03 to 2/10/04)	0.08	-0.10	0.05	< 0.01
BCS change (2/10 to 5/4/04)	-0.35	-0.29	0.04	0.31
BCS change (5/4 to 10/13/04)	-0.28	-0.25	0.05	0.59
BCS change (12/22/03 to 10/13/04)	-0.55	-0.64	0.06	0.25
Final BCS (10/13/04)	4.60	4.60	0.06	0.97

[a] Supplements (DM basis) included: 1) 1.36 kg/d of whole raw soybean grain (Soybean) and 2) 1.56 kg/d of soybean meal/hull supplement (Positive).

[b] Most conservative SEM, n = 74.

[c] Probability of a greater F-statistic.

Table 3. Effect of late-gestation supplement on calf performance (Exp. 1)

	Supplement[a]			
Item	Positive	Soybean	SEM[b]	*P*-Value[c]
n =	74	78		
Birth wt, kg	35	33	0.5	< 0.01
June 14 wt, kg (avg age = 94 d)	121	120	1.8	0.65
Oct. 12 wt, kg (avg age = 214 d)	218	218	2.8	0.94

[a] Supplements (DM basis) included: 1) 1.36 kg/d of whole raw soybean grain (Soybean) and 2) 1.56 kg/d of soybean meal/hull supplement (Positive).

[b] Most conservative SEM, n = 74.

[c] Probability of a greater F-statistic.

Table 4. Effect of late-gestation supplement on cow reproductive performance (Exp. 1)

	Supplement[a]			
Item	Positive	Soybean	SEM[b]	*P*-Value[c]
n =	74	78		
Calving to start of the breeding season, d	53	53	2.1	0.98
Cows cycling, %[de]	22	29	5.2	0.27
Pregnancy rate at weaning, %	77	68	5.3	0.21
n =	50	45		
Days from calving to first AI date	77	76	2.6	0.79
First service conception rate, %	62	73	6.7	0.24

[a] Supplements (DM basis) included: 1) 1.36 kg/d of whole raw soybean grain (Soybean) and 2) 1.56 kg/d of soybean meal/hull supplement (Positive).

[b] Most conservative SEM.

[c] Probability of a greater F-statistic.

[d] Cows cycling at the beginning of the breeding season.

[e] Supplement x cow age class interaction ($P = 0.03$); interaction means are reported in the text.

Table 5. Effect of cow age class on cow weight and BCS (Exp. 1)

Item	Cow age class			SEM[a]	*P*-Value[b]
	Two	Three	Mature		
n =	50	54	48		
Length of treatment period, d	81	83	78	2.3	0.31
Initial wt (12/22/03), kg	438[z]	492[y]	582[x]	6.5	< 0.01
Wt change (12/22/03 to 2/10/04), kg	19[z]	28[y]	38[x]	1.6	< 0.01
Wt change (2/10 to 5/4/04), kg	-76[x]	-84[y]	-113[z]	2.7	< 0.01
Wt change (5/4 to 10/13/04), kg	38[y]	52[x]	43[y]	2.8	< 0.01
Wt change (12/22/03 to 10/13/04), kg	-19[y]	-4[x]	-32[z]	3.3	< 0.01
Final wt (10/13/04), kg	418[z]	488[y]	549[x]	6.4	< 0.01
Initial BCS (12/22/03)	5.49[x]	4.90[z]	5.17[y]	0.08	< 0.01
BCS change (12/22/03 to 2/10/04)	-0.15[y]	0.05[x]	0.07[x]	0.06	< 0.01
BCS change (2/10 to 5/4/04)	-0.42[y]	-0.20[x]	-0.33[xy]	0.05	< 0.01
BCS change (5/4 to 10/13/04)	-0.42[y]	-0.14[x]	-0.24[x]	0.06	< 0.01
BCS change (12/22/03 to 10/13/04)	-0.99[z]	-0.29[x]	-0.51[y]	0.07	< 0.01
Final BCS (10/13/04)	4.51	4.61	4.66	0.07	0.27

[a] Most conservative SEM, n = 48.

[b] Probability of a greater F-statistic.

[xyz] Within a row, means without a common superscript differ ($P \leq 0.05$).

Table 6. Effect of cow age class on calf performance (Exp. 1)

	Cow age class				
Item	Two	Three	Mature	SEM[a]	*P*-Value[b]
n =	50	54	48		
Birth wt, kg	30^{z}	33^{y}	37^{x}	0.6	< 0.01
June 14 wt, kg (avg age = 94 d)	107^{z}	117^{y}	137^{x}	2.2	< 0.01
Weaning wt, kg (avg age = 214 d)	198^{z}	218^{y}	239^{x}	3.4	< 0.01

[a] Most conservative SEM, n = 50.

[b] Probability of a greater F-statistic.

[xyz] Within a row, means without a common superscript differ ($P \leq 0.05$).

Table 7. Effect of cow age class on cow reproductive performance (Exp. 1)

Item	Cow age class Two	 Three	 Mature	SEM[a]	*P*-Value[b]
n =	50	54	48		
Calving to start of the breeding season, d	52	50	56	2.6	0.31
Cows cycling, %[cd]	2^{z}	15^{y}	63^{x}	7.0	< 0.01
Pregnancy rate at weaning, %	50^{y}	83^{x}	83^{x}	7.1	< 0.01
n =	13	37	45		
Days from calving to first AI date	84^{x}	75^{xy}	71^{y}	4.3	0.04
First service conception rate, %	69	73	62	12.8	0.58

[a] Most conservative SEM.

[b] Probability of a greater F-statistic.

[c] Cows cycling at the beginning of the breeding season.

[d] Supplement x cow age class interaction ($P = 0.03$); interaction means are reported in the text.

[xyz] Within a row, means without a common superscript differ ($P \leq 0.05$).

Table 8. Effect of late-gestation supplement on intake and digestibility (DM basis; Exp. 2)

	Supplement[a]			
Item	Positive	Soybean	SEM[b]	*P*-Value[c]
n =	11	11		
Dietary lipid, % of DM	1.2	3.4	-	-
Hay intake[d]	1.56	1.70	0.13	0.13
DM intake[d]	1.85	1.98	0.13	0.18
Fecal output[d]	0.84	0.92	0.06	0.13
DM digestibility, %	54.8	53.4	0.91	0.31
NDF digestibility, %	55.5	54.6	0.91	0.48
ADF digestibility, %	53.1	51.4	1.20	0.32
CP digestibility, %	64.4	62.0	1.77	0.26
Digested DMI[d]	1.01	1.05	0.07	0.44
OM intake[d]	1.75	1.87	0.12	0.17
OM digestibility, %	56.2	54.7	0.88	0.28
Digested OM intake[d]	0.98	1.02	0.07	0.41

[a] Supplements (DM basis) included: 1) 1.36 kg/d of whole raw soybean grain (Soybean) and 2) 1.56 kg/d of soybean meal/hull supplement (Positive).

[b] Most conservative SEM, n = 11.

[c] Probability of a greater F-statistic.

[d] kg/100 kg of BW.

Table 9. Effect of cow age class on intake and digestibility (DM basis; Exp. 2)

	Cow age class				
Item	Two	Three	Mature	SEM[a]	*P*-Value[b]
n =	6	8	8		
Dietary lipid, % of DM	2.4	2.3	2.2	-	-
Hay intake[c]	1.59	1.62	1.69	0.13	0.68
DM intake[c]	1.90	1.91	1.93	0.14	0.96
Fecal output[c]	0.89	0.86	0.88	0.07	0.90
DM digestibility, %	53.0	54.7	54.7	1.23	0.53
NDF digestibility, %	53.6	56.1	55.4	1.23	0.34
ADF digestibility, %	50.4	54.6	51.8	1.62	0.14
CP digestibility, %	64.3	63.4	61.8	2.19	0.63
Digested DMI[c]	1.01	1.04	1.05	0.08	0.80
OM intake[c]	1.80	1.80	1.83	0.13	0.95
OM digestibility, %	54.4	56.1	55.9	1.19	0.52
Digested OM intake[c]	0.98	1.01	1.02	0.07	0.82

[a] Most conservative SEM, n = 6.

[b] Probability of a greater F-statistic.

[c] kg/100 kg of BW.

Chapter VI

Summary and Conclusions

A major goal of cattle producers is to optimize reproduction of beef cows while minimizing feed costs. Lipid supplementation and its potential nutraceutical effect is one method that has been researched in an effort to accomplish this goal. The research reported in this dissertation was conducted to determine if lipid supplementation from whole oilseeds could improve reproductive performance of beef cows.

Three separate performance experiments were conducted to determine the effects of oilseed supplementation on performance of beef cows and their progeny. In the first performance experiment, multiparous spring calving cows were supplemented with a negative control, a positive control, or whole sunflower seed during late gestation. During the supplementation period, cows fed whole sunflower seed lost more weight and body condition than cows fed the positive or negative control; however, BW and condition change during the entire 318-d experiment were not different. Additionally, calf performance was not different among supplements. Although first service conception rates were greater for cows fed the positive control or whole sunflower seed compared with cows fed the negative control, pregnancy rates were not influenced by supplement composition. In the second performance experiment, multiparous spring calving cows were supplemented with a positive control, whole linoleic sunflower seed, or whole mid-oleic sunflower seed during late gestation. During the supplementation period, weight and body condition gain of cows fed sunflower seed supplements was lower than cows fed the positive control. However, weight and body condition change from the start of supplementation to weaning 303 d latter and calf performance were not different among supplements. Furthermore, cow reproduction was not influenced by supplement composition. In the third performance experiment, cows of varying age were supplemented with either a positive control or whole soybeans. Cows fed soybeans gained less BW and body condition during the treatment period. However, cow BW, cow body condition, and calf weight at weaning were not influenced by supplement composition. No differences in reproduction were observed among cows fed either supplement.

In addition to the performance experiments, two intake and digestion experiments with oilseeds were also conducted. In the first experiment, steers received no supplement, a soybean hull-based supplement, whole linoleic sunflower seed, or whole high-oleic sunflower seed. Hay intake was not influenced by supplement composition; however, dry matter and fiber digestion were reduced with sunflower seed supplementation. In the other intake and digestion experiment, cows of varying age were supplemented with either a positive control or whole soybeans. Neither cow age nor supplement composition influenced any of the intake or digestion measurements.

In conclusion, the observed reductions in weight and body condition gain for cows fed oilseeds compared with cows fed a positive control may indicate that energy from lipid sources may not be used as efficiently as energy from carbohydrate sources or that the current tabular energy values provided for whole sunflower seed and whole soybeans are overestimated. There does not appear to be any advantages or detrimental effects on reproduction of using whole sunflower seed or whole soybeans as supplements for gestating beef cows. Consequently if economically viable, these oilseeds can be used as winter supplements for gestating beef cows. The lack of reproductive differences between oilseed and control supplements indicates that increased lipid intake from oilseeds during late gestation does not have a nutraceutical effect on reproduction regardless of cow age T his research also suggests that the same intake prediction equations can be used for both primiparous and multiparous cows.

VITA

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