High Fat Supplements for Reproducing Beef Cows: Have We Discovered the Magic Bullet?

Bret W. Hess, Daniel C. Rule, and Gary E. Moss
Department of Animal Science
University of Wyoming, Laramie 82070

Introduction

Beef cattle producers are continually challenged with the need to maintain sustainable production systems. Improvements in biological efficiencies are important considerations for the sustainability of beef cattle production systems. Nutritional programs based on optimal diet formulation are pivotal cornerstones required to increase efficiency of beef cattle production. Improving economically important production traits through strategic nutritional inputs may afford beef cattle managers the opportunity to produce beef cattle more efficiently and become more sustainable. Specifically, provision of supplemental fat to reproducing beef cattle may be used to differentially regulate production traits. Knowledge of the effects of dietary fat on biological and production responses by beef cattle has expanded tremendously over the past decade. The purpose of this paper is to identify responses commonly noted by researchers who have studied responses to dietary fat. Accordingly, we have reviewed literature published primarily in refereed journals on the use of dietary fat for reproducing beef cattle. Our goal is to develop recommendations that will help beef cattle managers identify nutritional programs with potential to improve biological efficiencies, and thus, improve sustainability of their beef cattle operations.

Feeding Fat to Developing Replacement Beef Heifers

Ensuring adequate growth and development of replacement heifers through proper nutritional inputs is critical to the life-long stability of cattle within a cowherd. In this regard, Lesmeister *et al.* (1973) suggested that a beef heifer should attain puberty and conceive by 15 months of age. Yearling heifers that conceive early in the breeding season and calve early, as 2-year-olds are more likely to have greater lifetime productivity than later-breeding heifers. To achieve such a goal, beef heifers must reach 60 to 65% of their mature body size in order to reach puberty (Fox *et al.*, 1988). Byerley *et al.* (1987) indicated that fertility of heifers bred at the pubertal estrus was lower than for those bred at the third estrus. Thus, heifers should reach puberty 1 to 3 months before the breeding season to improve their chances of producing offspring in a restricted breeding season. As a result, the target weight principle of developing heifers to an optimum weight has been adopted as a method of ensuring that heifers reach puberty by the breeding season (Patterson *et al.*, 2000). The target weight principle calls for developing heifers to a prebreeding weight that represents 60 to 65% of the animal's projected mature weight. Heifers with the genetic potential to reach a heavier mature weight must attain a heavier prebreeding weight. Thus, nutritional programs should be designed to promote growth and development to ensure that the replacement heifer conceives early in her first breeding season.

Energy-dense feedstuffs are commonly required in the diets of replacement beef heifers to ensure proper growth and development. Provision of supplemental nonstructural carbohydrate sources, such as cereal grains, is a common nutritional management strategy used to increase energy content of replacement heifers' diets. Additionally, lipid sources can be added to supplements to increase dietary energy. Coppock and Wilks (1991) suggested that the primary reason for feeding supplemental fat is the increased energy density that occurs without needing to increase level of cereal grains in the ration. Increased energy density of the diet notwithstanding, supplemental fat may have positive effects on reproduction in beef heifers.

A summary of information presented in manuscripts published in the *Journal of Animal Science* and *The Professional Animal Scientist* that evaluated responses of peripurbertal heifers to dietary fat are presented in Table 1. The results are from five reports, which included nine experiments with a total of 16 dietary supplements and 21 possible dietary fat comparisons. Only the study of Pate *et al.* (1995) used fat as a method to increase dietary energy. The remaining studies fed supplements in which fat was formulated to be isoenergetic, and most often, isonitrogenous with the control supplement. As a result, ADG was not affected by dietary fat in 57% of the comparisons, increased in 28.5% and decreased in 14.5% of the comparisons. Of the 10 comparisons for gain efficiency (kg of gain/100 kg of feed), four reported an increase, two showed no effect, and four had decreased gain efficiency. However, it should be noted that heifers did not consume all of the supplements containing fat at the level anticipated in two of the studies (Rhodes *et al.*, 1978; Brokaw *et al.*, 2002). Reproductive events preceding repeat AI or natural services were negatively affected in only one (Rhodes *et al.*, 1978) of 10 comparisons, enhanced in 30% of the comparisons, and were not influenced by diet in 60% of the comparisons. Moreover, there was only one occurrence of reduced pregnancy rate with supplemental fat. In the first year of this study (Brokaw *et al.*, 2002), heifers did not consume sufficient quantities of the self-fed tub supplement to achieve 60% of mature BW before the onset of the breeding season. Results in Table 1 also lend support to the principle of growing heifers to an optimum prebreeding weight. A strong positive correlation ($r = 0.75$, $P < 0.001$) was noted between BW at the beginning of the breeding season and pregnancy rate. We do not advocate, however, that heifers be over conditioned by including supplemental fat in the diet because there were two instances (Rhodes *et al.*, 1978; Lammoglia *et al.*, 2000) where this nutritional regimen was not beneficial and may have been detrimental.

Chi-square analysis of data from experiments summarized in Table 1 indicated that overall pregnancy rate was enhanced ($P = 0.005$) with the provision of supplemental fat to the peripubertal beef heifer. Overall pregnancy rates for the 363 heifers fed supplemental fat was 73.6% versus 63.8% for the 373 non-fat supplemented heifers. Thus, we postulate that it is reasonable to expect a 15.4% improvement in pregnancy rates when peripubertal heifers are fed supplemental fat.

Until results are available to the contrary, we suggest feeding supplemental fat to beef heifers before they reach target BW or for 60 to 90 d before the onset of the breeding season. Funston *et al.* (2001) reported that feeding whole sunflower seeds for 30 d before AI did not improve reproduction. Additional support for our recommendation was provided by Thomas and Williams (1996), who noted that maximal differences in ovarian follicle numbers in cycling beef heifers were observed 6 to 7 wk after dietary fat supplementation (Ryan *et al.*, 1992). Moreover, dietary fat-induced increases in serum cholesterol concentrations of beef heifers appeared to plateau between d-55 and 88 after feeding (Lammoglia *et al.*, 2000; Whitney *et al.*, 2000; Lloyd *et al.*, 2002). However, supplemental dietary fat may be more beneficial to reproductive performance when fed to heifers that have been maintained in less than optimal body condition (BCS ~ 6) and (or) have not reached target BW.

Feeding whole sunflower seeds (Funston *et al.*, 2001) to cycling (92.5%) beef heifers in good condition (BCS = 5 to 6) or Ca-fatty acids to pubertal heifers with BCS = 5 to 7 (Lloyd *et al.*, 2002) has not improved reproduction. Although body condition score did not increase in the study of Lammoglia *et al.* (2000), Rhodes *et al.* (1978) and Lammoglia *et al.* (2000) reported that ultrasonography measurements of backfat thickness increased with supplemental fat by d-92 and 112, respectively. The number of heifers reaching puberty on test was reduced (Rhodes *et al.*, 1978) and pregnancy rates were similar between fat-supplemented and control heifers (Rhodes *et al.*, 1978; Lammoglia *et al.*, 2000). Reduced or lack of a diet effect on reproduction prompted each group of researchers to suggest that there may be a dietary fat-reproduction antagonism. Lammoglia *et al.* (2000) hypothesized that a feeding period of 60 d before the beginning of the breeding season may have been more suitable than the prolonged feeding period used in each of these studies (>160 d). This hypothesis was based partially on the observation that backfat thickness was similar among treatments after 56 d of feeding and the leaner heifers (Piedmontese) responded more favorably to supplemental fat. The shortest period of fat supplementation for the experiments summarized in Table 1 was 90 d prebreeding. Hence reproductive data from these experiments could not be used to support this contention. Results of Funston *et al.* (2001), therefore, are not surprising because the heifers used were in good condition and the duration of the feeding fat may have been slightly inadequate. Alternatively, the lack of response noted by Funston *et al.* (2001) may have been related to feeding whole rather than processed sunflower seeds. Lammoglia *et al.* (1999a) demonstrated that processing safflower seeds through a roller mill with sufficient pressure to crack approximately 90% of the seed hulls increased 48-h ruminal *in situ* disappearance of DM from 12 to 56.5%. Heifers fed whole sunflower seeds also had lower ADG than heifers fed the control diets (Funston *et al.*, 2001), which may have influenced the outcomes of reproduction.

Improved reproductive performance by beef heifers may be attributed to the ability of fat supplementation to modify ovarian follicular growth and physiology and (or) to increase the lifespan of the corpus luteum (CL) (Staples *et al.*, 1998; Williams and Stanko, 2000). We located three studies that evaluated ovarian follicular responses in cycling beef heifers fed fat (Table 2). We are not, however, aware of studies on specific mechanisms through which supplemental fat effects corpora luteal function in peripubertal beef cattle. Results of the experiments summarized in Table 2 suggest that feeding fat to cycling beef heifers increases medium-sized follicles, but does not increase hormone-induced ovulation rate. Nonetheless, high-density lipoprotein cholesterol (HDL-CH) was increased in the follicular fluid. Williams and Stanko (2000) indicated that HDL was a potent stimulator of progesterone (P_4) production by granulosa and thecal cells. Moreover, Ryan *et al.* (1992) reported that dietary fat decreased estradiol-17β (E_2) production by granulosa cells. Ryan *et al.* (1992) suggested that granulosa cells are potential luteal cells, and therefore mimic the metabolic potential of transforming luteal cells. Therefore, increased P_4 and decreased E_2 by cells destined to become luteal cells could increase lifespan of the CL. Staples *et al.* (1998) proposed that lowered production of E_2 prevented premature regression of the CL as well as early embryonic death.

Only one study (Lloyd *et al.*, 2002) in Table 1 evaluated the potential of fat supplementation to reduce the incidence of embryonic death in pregnant beef heifers. Calving rate in this study was defined as the percentage of total heifers diagnosed pregnant that calved. Heifers fed calcium salts of fatty acids (Ca-fatty acids) tended to have greater ($P = 0.12$) calving rate. Lloyd *et al.* (2002) postulated that this response was associated with 12% higher ($P = 0.20$) P_4 concentrations in plasma from pregnant heifers 83 d after the feeding trial. Although the mechanisms associated with increased circulating P_4 have not been definitively determined (Williams and Stanko, 2000), results of research reviewed herein and by others (Staples *et al.*, 1998; Williams and Stanko, 2000) would suggest that improved reproduction by beef heifers fed fat may be associated with increased P_4.

Feeding Fat to Postpartum Beef Cows

The largest reproductive loss experienced by the beef producer is failure of cows to exhibit regular estrus and conceive by the end of a restricted breeding season (Bellows and Short, 1994). Reproductive success in beef cows is a function of interval from parturition to first ovulatory estrus (postpartum interval) and conception rates in estrous cycling cows. It is well accepted that nutrition has dramatic effects on reproductive processes in the beef cow (Short and Adams, 1988; Randel, 1990, Short *et al.*, 1990; Lemenager *et al.*, 1991; Dunn and Moss, 1992). Williams and Stanko (2000) posed the question "Does increased intake of fat, aside from its obvious contribution to caloric density of the diet, contribute to postpartum recovery" of biological events leading to reproductive success? These authors answered with a guarded "yes", and indicated that mechanisms through which fat supplementation influences reproductive performance seemed to involve mainly increased functional capability at the ovarian level. Therefore, we summarized experiments in which researchers evaluated ovarian responses in beef cows fed supplemental fat postpartum (Table 3). Cows were ovariectomized to determine specific effects of fat supplementation on ovarian responses. Comparable to the experiments with beef heifers, feeding fat to postpartum beef cows increased the number of medium-sized follicles. This response was heightened in cows fed soybean oil (Thomas *et al.*, 1997) and was not apparent in cows fed to maintain a BCS of 3 (Ryan *et al.*, 1994). In addition to increased HDL-CH in follicular fluid (Wehrman *et al.*, 1991; Thomas *et al.*, 1997), follicular fluid concentrations (Thomas *et al.*, 1997) and granulosa cell production of IGF-I (Ryan *et al.*, 1995) were enhanced with fat supplementation.

Table 4 summarizes 13 additional experiments conducted to elucidate potential reproductive responses of postpartum beef cows to supplemental fat. Three studies used ultrasonography to determine ovarian follicle sizes. Only one (Webb *et al.*, 2001) of the three reports showed no effect of supplemental fat on ovarian follicular growth dynamics. Consistent with experiments previously discussed, the other researchers noted increased medium- and large-sized follicles (Hightshoe *et al.*, 1991; De Fries *et al.*, 1998) and increased percentage of cows with large-sized follicles (De Fries *et al.*, 1998). Once again, one would expect increased numbers of ovarian follicles in the larger classification groups with provision of supplemental fat to reproducing beef cattle.

Lammoglia *et al.* (1997b) reported decreased E_2:P_4 ratios in dominant follicles of cows fed rice bran. The consequence of reduced E_2:P_4 ratio in the dominant follicle of cows fed fat has not been investigated, but it could be speculated that this response could make the CL less sensitive to $PGF_{2\alpha}$. Sensitivity of the CL to the luteolytic actions of endogenous prostaglandin $F_{2\alpha}$ increased in the presence of estradiol (Howard *et al.*, 1990). Assuming our speculation is correct, life of the CL would be maintained (Staples *et al.*, 1998) and short cycles may be less prevalent in fat-supplemented cows. Indeed, Williams (1989) demonstrated that feeding fat during the early postpartum period increased circulating P_4 and reduced the incidence of short estrous cycles. Williams and Stanko (2000) suggested that enhancement of luteal lifespan could be related to the ability of fat supplementation to modify growth and physiology of the preovulatory follicle (see Table 3). Increased serum concentrations of P_4 with a concomitant decrease in E_2 accompanied an increase in medium- to large-sized ovarian follicles of fat-supplemented cows in the study of Hightshoe *et al.* (1991). Furthermore, Hightshoe *et al.* (1991) reported that fat supplementation increased serum concentrations of LH during three periods surrounding calf removal. Luteal cells secrete P_4 after exposure to LH, which may explain why increased circulating P_4 has been reported in postpartum cows consuming fat.

A logical conclusion to draw from the literature reviewed in the text thus far would be that reproduction should be improved by supplementing fat to postpartum beef cows. However, increased circulating P_4 was not observed in four of the six experiments summarized in Table 4. Likewise, studies on luteal growth and physiology have not shown beneficial effects of fat in the diets of postpartum beef cows (Table 3). *In vitro* steriodogenesis by granulosa and luteal cells collected from cows were unaltered by dietary fat (Hawkins *et al.*, 1995; Ryan *et al.*, 1995; Lammoglia *et al.*, 1997b). Our unpublished observations (Grant *et al.*) and those of Morgan and Williams (1989) were that the quantity of LH released in response to GnRH challenge was not affected by postpartum feeding of fat. Furthermore, supplementing fat to postpartum beef cows had no effect on the number or affinity of LH receptors in GnRH-induced CL (Ryan *et al.*, 1995). Thus, feeding fat to cycling beef cows may stimulate ovarian follicular growth and development, but luteal growth and physiology appear to be unaffected.

The uterus is another reproductive organ implicated to mediate the effects of supplemental fat on reproduction. The uterus is a primary site of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) in the postpartum cow (Guilbault *et al.*, 1984). Uterine production of $PGF_{2\alpha}$ is important during the early postpartum period because increased synthesis and secretion of $PGF_{2\alpha}$ may decrease number of days to complete uterine involution and hence, the length of postpartum anestrus (Madej *et al.*, 1984). Plasma or serum concentrations of a metabolite produced when the lungs and uterus metabolize $PGF_{2\alpha}$ (13, 14-dihydro-15-keto-$PGF_{2\alpha}$ metabolite; PGFM) have been used to assess the role of $PGF_{2\alpha}$ in reproductive processes (Staples *et al.*, 1998). The length of the postpartum anestrus period and time to conception was reduced in beef cows by inducing higher concentrations of PGFM through uterine manipulation (Velez *et al.*, 1991). We are aware of three reports in the refereed literature (Filley *et al.*, 1999, 2000; Webb *et al.*, 2001) where researchers evaluated circulating PGFM in beef cattle given supplemental fat during the early postpartum period (d-1 to 15 after parturition). Transient increases in plasma concentrations of PGFM were noted for two (Filley *et al.*, 1999; 2000) of the five fat treatments, and PGFM was not affected by the other three fat treatments. Based on this information, we conclude that supplemental fat during the early postpartum period does not influence circulating PGFM sufficiently to impact reproductive processes. However, we also recognize that timing and length of the fat-feeding period, as well as fatty acid composition of the fat source may be factors affecting PGFM response to supplemental fat.

Feeding fat to cows from 2 wk before expected calving date through the early postpartum period increased plasma PGFM concentrations from 12 to 96 h postpartum (Lammolgia *et al.*, 1996). Lammoglia *et al.* (1997b) observed that peak concentrations of PGFM in plasma tended to increase in cows fed fat from d 1 of the first estrous cycle until emergence of the dominant follicle in the second estrous cycle. Our laboratory (Grant *et al.*, 2002) recently reported that supplemental fat increased serum PGFM concentrations from d-25 to 90 postpartum. Moreover, the fatty acid composition of the fat supplement evoked differential effects on PGFM. Serum concentrations of PGFM were greater in cows fed high-linoleate safflower seeds (647 ± 62 pg/mL) than cows fed either high-oleate safflower seeds (371 ± 68 pg/mL) or the control supplement (452 ± 68 pg/mL). Our results (Grant *et al.*, 2002) contrast Staple's *et al.* (1998) proposed mechanism by which supplemental fat affects prostaglandin synthesis. These authors suggested that increasing delivery of linoleate (18:2) and eicosapentanoate (20:5, EPA) to the uterus inhibited the secretion of $PGF_{2\alpha}$. In our companion study to Grant *et al.* (2002), Scholljegerdes *et al.* (2001) demonstrated that intestinal supply of 20:5 was increased from 0.2 g/d for control to 0.5 g/d in cows fed high-oleate safflower seeds but 20:5 was not increased by feeding high-linoleate safflower seeds (0.3 g/d). Moreover, flow of 18:2 to the duodenum was 2.85 times greater in cows fed the high-linoleate safflower seeds (9.7, 8.4, and 27.8 g/d for control, high-oleate, and high-linoleate, respectively). Feeding fat sources with relatively high 18:2 content also increased plasma concentrations of 18:2 (Whitney *et al.*, 2000; Alexander *et al.*, 2002). Taken together, results from our laboratory suggest that increased dietary 18:2 will lead to an increase in circulating concentrations of PGFM. The apparent anomaly between results from our laboratory and the mechanism proposed by Staples *et al.* (1998) could be related to the quantity of fatty acids delivered. Staples *et al.* (1998) showed that the suppressing effect of fat on PGFM was more prevalent when the fat source supplied greater quantities of 18:2. It is also possible that smaller amounts of 18:2 are required for or stimulate the synthesis of $PGF_{2\alpha}$. Nonetheless, potential effects of fat supplementation-induced changes in PGFM on postpartum reproduction have not been established (Williams and Stanko, 2000).

Duration of postpartum anestrus has been identified as one of the main factors influencing reproductive efficiency of beef cows because pregnancy rates during a restricted breeding season may be improved by shortening this postpartum period (Wiltbank, 1970). Studies in which researchers reported luteal activity and (or) postpartum interval of beef cows in response to consumption of fat postpartum are summarized in Table 4. Although the incidence of luteal activity increased in three of the six experiments, only one (Webb *et al.*, 2001) of 14 supplemental fat regimens reduced the duration of postpartum anestrus. Moreover, although Williams (1989) and Hightshoe *et al.* (1991) reported dietary fat increased the number of cows exhibiting normal estrus, six other studies demonstrated an equivocal effect of postpartum dietary fat. Of the 11 dietary fat treatments summarized, only one (Webb *et al.*, 2001) reduced the percentage of cows exhibiting normal estrous cycles. Results of this summary are both not surprising and perplexing. Provision of dietary fat to the postpartum beef cow does not appear to influence luteal function. These results are, however, perplexing because high serum concentrations of PGFM in fat-supplemented animals could be expected to increase the incidence of estrous cycles with abbreviated luteal phases (Burke *et al.*, 1996). Nevertheless, the summary of results from Table 4 indicated that feeding fat to postpartum beef cows did not consistently decrease the postpartum anovulatory period. It is, however, equally important to point out that feeding fat to postpartum beef cows did not elicit deleterious effects on luteal activity nor does this nutritional strategy increase the period of time to resumption of normal estrus.

Thatcher *et al.* (1997) proposed that increased PGFM during the postpartum interval could cause premature regression of the CL in early pregnant cows resulting in the subsequent failure to maintain pregnancy. The inability of cows to become pregnant in a defined period may have the single greatest effect upon reproduction cost and efficiency (Bellows *et al.*, 2002). However, first service conception rates were not affected by feeding fat to postpartum beef cows (Table 4). Likewise, none of these studies reported a detrimental effect on overall pregnancy rates and only one of the 11 dietary fat treatments improved pregnancy rates. Since the greatest number of cattle used in any of the experiments was 24/treatment, a number that may have been insufficient to obtain statistically meaningful results, we conducted Chi-square analysis of the pregnancy rate data from these studies. This data set contained 324 individual observations with 170 cows given fat for four to 90 d during the postpartum period. Pregnancy rate was not affected ($P = 0.84$) by diet, and was 82.9% if cows consumed fat and 83.8% if cows did not consume supplemental fat postpartum. Hence, we conclude that provision of supplemental fat to beef cows postpartum does not improve pregnancy rates.

It should be noted, however, that our conclusion regarding pregnancy rates might change if observations from the non-refereed literature were included in the analysis. One study (Appeddu-Richards, 1999 as cited by Hawkins *et al.*, 2000) showed no effect of postpartum fat supplementation to range cows, whereas two other studies (Gambill *et al.*, 1995; Wilkins *et al.*, 1996) observed an improvement in pregnancy rates with supplemental fat for range beef cows. Pregnancy rates were 83% for cows fed fat versus 76 and 66% for cows fed a supplement with low and high protein, respectively (Gambill *et al.*, 1995). Pregnancy rates were increased from 61 to 77% in the study of Wilkins *et al.* (1996). Therefore, it may be speculated that inclusion of dietary fat postpartum may be a viable nutritional strategy to improve pregnancy rates in beef herds with relatively low conception rates. However, it is also important to note that the fat supplements used in these studies non-refereed studies (Gambill *et al.*, 1995; Wilkins *et al.*, 1996) provided more energy than the control supplements. Dietary treatments used in experiments summarized in Table 4 were generally formulated to be isocaloric.

Feeding Fat to Beef Cows Pre- and Postpartum

Espinoza *et al.* (1995) increased pregnancy rates (first 95 d of breeding) of range beef cows fed a fat supplement containing more energy than the control supplement. Fat supplementation from the third trimester of gestation through the third postpartum estrous cycle caused the postpartum anestrus interval to be prolonged, but reduced the incidence of short estrus cycles (Oss *et al.*, 1993). Other effects of pre- and postpartum fat supplementation on reproductive performance are summarized in Table 5. It is difficult to draw definitive conclusions based on the limited reports available; however, beef cow responses to supplemental fat pre- and postpartum appear to be comparable to responses observed when feeding fat to postpartum beef cows.

Feeding Fat to Cows During Late Gestation

The importance of prepartum nutrition on subsequent postpartum reproduction is well established (Randel, 1990; Short *et al.*, 1990; Dunn and Moss, 1992). It is difficult to effectively compensate for and reverse the negative impacts of prepartum nutritional inadequacy on reproductive performance through nutritional inputs postpartum (Lalman *et al.*, 2000). Minimal reduction in postpartum interval can be achieved by increasing the beef cow's nutritional plane during lactation (Lalman *et al.*, 1997). Feeding supplemental fat to beef cows during late gestation has been evaluated as method to alleviate the negative impacts of prepartum nutritional inadequacy on reproductive performance.

Based on personal communications with D. Palmquist, Filley *et al.* (1999) suggested that essential fatty acids are selectively stored as cholesterol esters for incorporation into phospholipids used for essential functions, such as prostaglandin synthesis. Increasing dietary 18:2 via supplementation with high-linoleate safflower seeds increased 18:2 content of muscle to a greater extent than that of adipose tissue (Bolte *et al.*, 2002). Furthermore, attenuation of PGFM in cows abomasally infused with yellow grease carried over into subsequent 35-d experimental periods (Oldick *et al.*, 1997). This influence of diet on the phospholipid pools of fatty acids may lead to carry-over effects (Staples *et al.*, 1998), which could influence subsequent reproduction of cows provided with supplemental fat during late gestation.

Experiments published in *The Professional Animal Scientist* where researchers fed fat to beef cows before calving are summarized in Table 6. The length of the supplemental fat period ranged from 59 to 68 d before calving. Duration of the postpartum interval was only determined in one (Alexander *et al.*, 2002) of the four experiments and was not affected by prepartum dietary fat. Likewise, percentage of cows detected in estrus and first-service conception rates were not affected by feeding fat to cows during late gestation. In only one experiment (Bellows *et al.*, 2001) did more cows become pregnant as a result of feeding fat prepartum. Numerical trends for pregnancy rates favored the non-fat supplement in one trial (Bellows *et al.*, 2001), whereas prepartum supplemental fat numerically increased pregnancy rates in the two experiments of Alexander *et al.* (2002). Because of the limited number of reports and limited number of animals used in each of these experiments, results from these two manuscripts were combined to conduct Chi-square analysis. This data set had 140 control cows and 274 fat supplemented cows. Results revealed an improvement ($P = 0.02$) in pregnancy rates when beef cows were supplemented with fat (91.6%) during late gestation compared to control cows (82.9%). Therefore, it seems reasonable to suggest that feeding fat to beef cows for 59 to 68 d before calving may result in a 10.5% improvement in pregnancy rates in the upcoming breeding season.

Other reports in the non-refereed literature showed similar improvements in reproduction with prepartum supplementation of fat to beef cows. Graham *et al.* (2001) reported that feeding whole soybeans to mature beef cows for either 30 or 45 d before calving increased first service conception rates (62.8 vs 85.7% and 62.5 vs 75%, respectively). In a summarization of data from the two studies where high-linoleate safflower seeds were fed to primiparous beef cows 53 or 55d prepartum (Lammoglia *et al.*, 1999a,b), Bellows (1999) noted that pregnancy rates increased from 56% for the 89 control cows to 70% for 179 fat-supplemented cows. Likewise, feeding high-oleate and high-linoleate safflower seeds primiparous beef cows approximately 55 d prepartum increased subsequent pregnancy rates from 57% to 75 and 77%, respectively (Lammoglia *et al.*, 1997a). Thus, our proposed 10.5% enhancement in pregnancy rates may be a conservative estimate of the potential to improve reproduction by supplementing the diets of beef cows with fat before calving. We conclude that supplementing fat to beef cows during late gestation is an effective means to improve reproductive success in the upcoming breeding season.

The Effects of Feeding Fat to Beef Cows on Their Calf

Focusing on strategies to improve the probability of conception and the production of a healthy calf that experiences minimal dystocia and survives beyond the first 24 h of birth should receive major attention (Bellows *et al.*, 2002). Our previous discussion focused on the potential to improve reproduction by feeding fat to the reproducing beef female. We now intend to focus on how feeding fat to the reproducing beef cow influences production/performance of the calf.

Prepartum supplemental fat for beef cows warrants discussion because birth weight has been identified as the most important factor affecting calving difficulty (Bellows *et al.*, 1971). Increased circulating steroid hormones associated with feeding fat to beef cows late in gestation may influence calf birth weight. Hawkins *et al.* (1995) demonstrated that reduced rate of P_4 clearance from the blood was the major factor contributing to increased serum concentrations of P_4 in cows fed supplemental fat. More recently, Sangsritavong *et al.* (2002) showed that metabolic clearance of P_4 and E_2 was reduced in cows infused with an emulsion of soybean oil. Sangsritavong *et al.* (2002) indicated that this response was related to inhibition of liver cell metabolism of these steroids. Bovine liver slices incubated with P_4 and E_2 in the presence of linoleate increased the half-life of both steroids. Dietary fat-induced changes in circulating concentrations of steroid hormones at the end of pregnancy may influence calf birth weight (Lammoglia *et al.*, 1996). Therefore, we summarized how calf birth weights were affected by supplementing fat in the diet of prepartum beef cows (Table 7). Results of literature published in refereed journals on birth weights of calves from dams that received supplemental fat during late gestation have been inconsistent. Two (Lammoglia *et al.*, 1999b; Bellows *et al.*, 2001) of the 14 prepartum dietary fat treatments increased calf birth weight, two (Lammoglia *et al.*, 1996; Lammoglia *et al.*, 1999b) decreased calf birth weight, and calf birth weight was not affected by 10 of the prepartum fat supplementation programs. Calf genotype (Lammoglia *et al.*, 1996) and sex (Lammoglia *et al.*, 1996; Lammoglia *et al.*, 1999b), calving season (Lammoglia *et al.*, 1996; Bellows *et al.*, 2001), nutritionally induced stress (Lammoglia *et al.*, 1999b), and source of supplemental fat (Lammoglia *et al.*, 1997a) may influence dietary fat effects on calf birth weight. Nonetheless, based on the information in Table 7, we conclude that supplementing fat to beef cows during late gestation does not affect calf birth weight. Likewise, prevalence of calving difficulty is expected to be similar between fat-supplemented cows and cows not supplemented with fat during late gestation (Bellows, 1999; Bellows *et al.*, 2001).

The apparent carry-over effect associated with feeding fat prepartum may serve as an important functional link between calf survivability. Research by USDA-ARS scientists in Miles City, Montana (Lammoglia *et al.*, 1999a,b) investigated effects of prepartum supplementation of dietary fat on cold tolerance of neonatal calves (Table 7). Calves from dams that received supplemental fat during late gestation responded to cold stress by increasing rectal temperature, which was maintained for a longer period of time than calves from dams not fed supplemental fat. This calf response to cold was related to increased availability of glucose for metabolism and heat production. Hence, provision of supplemental fat to beef cattle prepartum appears to be an effective nutritional management strategy to help the neonatal calf combat low ambient temperatures. Nonetheless, prevailing environmental temperatures might influence the supplemental fat-induced response of the neonate. If calves were gestated in less harsh environments and exposed to milder environments after calving, prepartum fat supplementation did not affect apparent cold tolerance (Lammoglia *et al.*, 1999b). This observation may partially explain the lack of prepartum dietary fat effect on calf vigor score (Bellows *et al.*, 2001; Alexander *et al.*, 2002) and rectal temperature (Lammoglia *et al.*, 1999b; Alexander *et al.*, 2002) shortly after birth. Thus, feeding fat to late gestational beef cows may improve the survivability of calves born in cold environments but does not appear to be beneficial in milder environments.

Management of the calf from birth to weaning dramatically affects the profits of the beef cow-calf enterprise (Thomas, 1986). The ability to improve calf weight gain and weaning weight is important because the calf crop represents the major source of salable product and income to the beef cattle producer. Therefore, we evaluated the potential to increase calf weight gain and weaning weight with the provision of fat to beef cows (Table 7). One study (Espinoza *et al.*, 1995) showed increased BW gains by calves from dams fed fat pre- and postpartum. De Fries *et al.* (1998) also reported increased calf BW gain when cows consumed fat for 45 d postpartum. However, BW gain of calves was not affected by feeding fat prepartum (Alexander *et al.*, 2002) or postpartum in three other studies (Tjardes *et al.*, 1998; Webb *et al.*, 2001; Bottger *et al.*, 2002). Although only two experiments (Espinoza *et al.*, 1995; Bellows *et al.*, 2002) showed a statistically significant improvement in weaning weight of calves suckling cows fed fat, numerical trends for weaning weight appeared to favor calves from cows that had been supplemented with fat (Table 7). Hence, we conducted a t-test using the treatment means of weaning weight from data in Table 7 to compare the effects feeding fat to beef cows on calf weaning weight. The data set contained 13 observations in the fat-fed group and 9 observations in the control group. Weaning weight was not different ($P = 0.58$) between treatments, and averaged 212 ± 9 kg for the fat-supplemented group and 204 ± 11 kg for the non-fat-supplemented group. Despite the limited number of observations in this data set, the lack of response in gain by calves to feeding fat to their dam is not surprising considering that milk production was only increased in one (Tjardes *et al.*, 1998) of the three studies (also Alexander *et al.*, 2002 and Bottger *et al.*, 2002). Each of these three studies reported composition changes of milk resulting from consumption of dietary fat. The impact of changing milk composition of beef cows in response supplemental fat is unknown and warrants further investigation. Nevertheless, based on the literature published to date in the *Journal of Animal Science* and *The Professional Animal Scientist*, provision of supplemental fat to beef cows did not affect calf BW gain or weaning weight. Equally important, provision of supplemental fat to beef cows did not have detrimental effects on calf BW gain or weaning weight. Therefore, supplementing beef cows with fat can be used if fat can be incorporated into the diet practically and when this nutritional program is economically feasible.

Conclusions and Recommendations

Nutritional programs are undoubtedly one of the most important facets involved in dictating biological efficiency and sustainability of beef cattle production systems. The ideal nutritional program to be implemented is confined by the resources of each beef cattle operation and therefore depends largely on each producer's capabilities. In the ever-endless search to discover new methods to improve efficiency of beef cattle production, beef cattle researchers have directed modest attention on high-fat supplements for the reproducing beef cow. From the literature reviewed herein we cannot suggest that fat supplements possess the magical powers often sought to be the cure-all for improving production efficiency of replacement heifers and cow-calf units. There are instances, however, where provision of supplemental fat may afford beef cattle producers the opportunity to increase efficiency of beef cattle production. The ensuing list provides anticipated responses of beef cattle to dietary fat, in addition to our recommendations for including fat in the reproducing beef cow's diet.

1. A 15.4% improvement in pregnancy rate may be expected when developing prepubertal beef heifers are fed supplemental fat. Levels of cholesterol in circulation plateau between 55 and 88 d after supplementation has been initiated. Therefore, we recommend feeding fat to developing prepubertal beef heifers for 60 to 90 d before the breeding season. Feeding fat to beef heifers for either half or twice our recommended length of time has resulted in no improvement in pregnancy rate.
2. Ovarian follicular growth and development will be enhanced in pubertal beef heifers fed supplemental fat; however, pregnancy rates have not been improved when fat has been fed to pubertal beef heifers. One report in the literature indicated that beef heifers fed fat had a greater percentage of heifers give birth to calves, but the potential to affect embryonic mortality or survivability requires further investigation. Although we cannot recommend feeding fat to pubertal beef heifers as a method to improve reproduction, inclusion of dietary fat should not impair reproduction and fat may be added to the diet when it is economically feasible.
3. Like pubertal beef heifers, cycling beef cows fed fat postpartum will exhibit increased ovarian follicular growth and development. There may be instances where this nutritional strategy enhances luteal activity, but studies designed specifically to evaluate luteal function have proven that supplemental fat does affect luteal growth and physiology. Therefore, it was no surprise to find an equivocal response on reproduction of beef cows to provision of supplemental fat postpartum. We cannot recommend feeding fat to postpartum beef cows as a method to improve reproduction unless the intended use of supplemental fat is to increase dietary energy of beef cows that may have low conception rates. The decision to include fat in the diet of postpartum beef cows should be based on whether or not this nutritional regimen is economically feasible.
4. Feeding fat pre- and postpartum appears to improve reproduction of beef cows. However, we hesitate to draw definitive conclusion and provide a recommendation based on the limited information available in the literature. The effects of feeding fat to beef cows pre- and postpartum should receive greater attention by beef cattle researchers in the future.
5. Supplementing the beef cow's diet with fat for approximately 60 d before parturition resulted in a 10.5% improvement in pregnancy rates during the subsequent breeding season. This response appeared to result from a carry-over effect of the supplemental fat because the cows were not bred until at least 40 d after they had consumed the fat. Calf birth weight and incidence of dystocia are not affected by feeding fat to beef cows during late gestation. Calves born to cows fed fat prepartum were more cold tolerant when born in and exposed to colder environments, suggesting that calf survivability may be

improved if beef cows maintained in harsh winter environments are fed fat prepartum. Thus, we recommend feeding fat to beef cows for approximately 60 d before calving as a method to assist calves combat cold stress and improve beef cow reproduction in the upcoming breeding season.

6. Feeding fat to beef cows altered milk composition, but may not affect total milk production. Calf BW gain and weaning weight does not seem to be influenced by changing milk composition; however, additional research is required to determine how the calf responds to changing the composition of its dam's milk through provision of supplemental fat.

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Table 1. A summary of responses elicited by peripubertal beef heifers to consumption of dietary fat.

					Response[a]							
Reference	Breed type	Feeding period	Basal diet	Supplements[b]	Breeding weight	ADG	Gain efficiency	BCS	Fat depots	% &/or age at puberty	1st service conception rate	Overall pregnancy/ calving rate
Rhodes *et al.* (1978)	Brahman × Hereford	108d prebreeding + 60d into breeding	Bermudagrass hay	Milo+cottonseed meal	328	0.47	16.3			80%	Not reported	30%
				Microencapsulated tallow	346↑	0.52	14.1↓	↑	↑	33%↓	(NR)	30%
Pate *et al.* (1995)	<50% Brahman	Yr 1: 132d prebreeding + 60d into breeding	Bahiagrass pasture + stargrass hay	Molasses + urea	245	-0.14	NR	NR	NR	NR	NR	9.5%
				Molasses + urea + feather meal	261↑	0.01↑						24.6%↑
				Molasses + urea + feather meal + catfish meal	259↑	-0.02↑						38.1%↑
				Molasses + urea + feather meal + catfish meal + catfish oil	269↑↑	0.06↑						47.6%↑
		Yr2: 133d prebreeding + 61d into breeding	Bahiagrass pasture + stargrass hay	Molasses + urea	267	0.12	NR	NR	NR	NR	NR	42.9%
				Molasses + urea + feather meal	283↑	0.24↑						71.4%↑
				Molasses + urea + feather meal + catfish meal	286↑	0.27↑						66.7%↑
				Molasses + urea + feather meal + catfish meal + catfish oil	298↑	0.34↑						80%↑
Lammoglia *et al.* (2000)	Crossbred × Hereford, Limousin, or Piedmontese	162d prebreeding	Corn silage + alfalfa hay	Barley + soybean meal	348	0.77	NR	6.2		73.4% 389	NR	75.5%
				High-linoleate safflower seeds + barley	349	0.78		6.4	↑	78.1%↑ 389		72.7%
Whitney *et al.* (2000)	Angus × Gelbveih rotational cross	Exp. 1: 98d prebreeding + 6d into breeding	Bromegrass hay	Corn + soybean meal	346	0.81	10.1	NR	NR	NR	67%	91.7%
				3% dietary soybean oil	354	0.91↑	11.7↑				50%	90.9%
				6% dietary soybean oil	346	0.79	10.7				50%	100%
		Exp. 2: 90d prebreeding	Bromegrass hay	Corn + soybean meal	352	0.72	NR	NR	NR	NR	65%	92.9%
				3% dietary soybean oil	350	0.69					73%↑	100%
				6% dietary soybean oil	354	0.71					54%	92.9%

[a] Response variables with ↑ or ↓ beside them were greater or less than the value reported for the other treatment(s) within each study.

Table 1. continued

Brokaw *et al.* (2002)	Angus × Gelbveih rotational cross	Yr. 1: 90d prebreeding	Bromegrass hay	Corn + soybean meal	344	0.89	10.3	NR	NR	NR	NR	93.1%
				3% soybean oil hand-fed	346	0.90	10.7					93.3%
				Self-fed tub w/soapstocks	330	0.74↓	9.0↓					72.4%↓
		Yr. 2: 98d prebreeding	Bromegrass hay	Corn + soybean meal	368	0.92	9.7	NR	NR	NR	NR	93.7%
				3% soybean oil hand-fed	368	1.03↑	11.0↑					89.4%
				Self-fed tub w/soapstocks	353	0.79↓	8.5↓					100%
Lloyd *et al.* (2002)	Angus	123d prebreeding	Tall fescue pasture + hay	Corn	NR	1.46	NR	NR	NR	NR	58.3%	85%/70.6%
				Corn + Ca-fatty acids		1.39					61.5%	70%/92.2%↑

[a] Response variables with ↑ or ↓ beside them were greater or less than the value reported for the other treatment(s) within each study.

Table 2. Responses of ovaries collected from postpubertal beef heifers consuming fat.

					Ovarian response[a]			
Reference	Breed type	Feeding period	Basal diet	Supplements	Follicular numbers	Follicular fluid	Granulosa cells	Ovulation rate
Wehrman *et al.* (1991)	Brahman × cycling heifers	53-55d	Kleingrass hay + cottonseed hulls	Grain sorghum + cottonseed meal				NR
				Whole cottonseeds	↑M (NS)	↑HDL-CH	↑P_4, ↑P_5	
Ryan *et al.* (1992)	Postpubertal beef heifers	44-51d	Kleingrass hay + cottonseed hulls	Grain sorghum + cottonseed meal				
				5.3% soybean oil	↑M	↑HDL-CH, ↑P_4	↑P_4, ↓E_2	NS
Thomas and Williams (1996)	½ Angus, ¼ Brahman & Hereford cycling heifers	35-45d	Cottonseed hulls	Grain sorghum + cottonseed meal		NR	NR	
				4% tallow	↑M			NS
				4% soybean oil	↑M			NS

[a]NR = not reported, M = medium-sized, NS = not statistically significant, HDL-CH = high-density lipoprotein cholesterol, P_4 = progesterone, P_5 = pregnenolone, E_2 = estradiol-17β. Response variables with ↑ or ↓ beside them were greater or less than the value reported for the other treatment(s) within each study.

Table 3. Responses of ovarian follicles or corpora lutea collected from beef cows consuming fat postpartum.

					Ovarian response[a]			
Reference	Breed type	Feeding period	Basal diet	Supplements	Follicular numbers	Follicular fluid	Granulosa cells	Luteal cells
Wehrman *et al.*	Brahman ×	19-21d	Kleingrass hay +	Cottonseed meal			NR	NR
(1991)	pluriparous cows		Bermudagrass hay +	Whole cottonseeds	↑M	↑HDL-CH, ↑A_4		
Ryan *et al.*	Hereford ×	17d	Kleingrass hay +	Soybean oil @ 0.44 kg/550 kg BW	↑L w/↑BCS			NR
(1994)	Brahman cows		2 kg grain sorghum	BCS 3, 4, 6, and 8	d15 BCS3↓, others =	=HDL-CH	BCS6 ↑E_2	
Hawkins *et al.*	Primiparous	100d prepartum	Corn silage +	Whole corn	NR	NR	NR	=P_4
(1995)	beef cows	~90d postpartum	alfalfa hay (TMR)	Ca-fatty acids				=wt.
Ryan *et al.*	Brahman ×	28d	Cottonseed hulls +	Cottonseed meal	NR	NR	NS	↑IGF-I, =P_4 & wt.
(1995)	Hereford cows		grain sorghum	Whole cottonseeds				
Thomas *et al.*	Brahman ×	35-45d	Total mixed rations	No fat			NR	NR
(1997)	Hereford cows			4% tallow	↑M	↑HDL-CH, ↑IGF-I		
				4% soybean oil	↑↑M	↑HDL-CH, ↑↑IGF-I		
				4% fish oil	↑M	↑HDL-CH, ↑IGF-I		
Lammoglia *et al.*	Brahman cows	25-28d	Bermudagrass hay	Corn + soybean meal				
(1997b)				Corn + soybean meal + rice bran	↑M	only ↓E_2:P_4	=# viable, E_2 & P_4	=wt.

[a] NR = not reported, M = medium-sized, HDL-CH = high-density lipoprotein cholesterol, A_4 = androstenedione, L= large, E_2 = estradiol-17β, P_4 = progesterone, IGF-I = insulin-like growth factor-I. Response variables with ↑ or ↓ beside them were greater or less than the value reported for the other treatment(s) within each study.

Table 4. Ovarian follicular dynamics, apparent luteal function, and reproductive performance of beef cows consuming fat-supplemented diets during the postpartum period.

					Response[a]					
Reference	Breed type	Feeding period	Basal diet	Supplements	Ovarian follicles	Luteal activity & postpartum interval	Reproductive hormones	Normal estrus	1st service conception	Pregnancy rate
Williams (1989)	Primiparous & multiparous cows	~48d	Kleingrass hay	Whole corn	NR	38%		36%	NR	NR
				Whole cottonseeds		81%↑	↑P_4	↑		
Hightshoe *et al.* (1991)	Multiparous Simmental	~45d	Priarie hay + soybean meal	Grain sorghum	0.25 @ 10-15mm	NS		33%	NR	NR
				Ca-fatty acids	0.92 @ 10-15mm↑		↑LH & P_4, ↓E_2	67%		
Wehrman *et al.* (1991)	Primiparous & multiparous cows	30d	Native range + cottonseed meal	Corn + milo grain	NR	44%	NR	NR	NR	NR
				Whole cottonseeds		62%↑				
Carr *et al.* (1994)	Multiparous Angus	100d	Corn silage + cottonseed meal	Exp. 1: Corn	NR	100% & 61d	=P_4	67%	NR	NR
				Whole cottonseeds (4.3% fat)		100% & 63d		67%		
				Whole cottonseeds (5.3% fat)		92% & 56d		67%		
				Whole cottonseeds (6.3% fat)		100% & 57d		75%		
			Corn silage	Exp. 2: Cottonseed meal	NR	86% & 54d	=P_4	82%	NR	NR
				Whole cottonseeds (5.5% fat)		77% & 56d		82%		
				Whole cottonseeds (8.3% fat)		86% & 54d		64%		
Ryan *et al.* (1995)	Pluriparous Brahman × Hereford	28d	Cottonseed hulls + cottonseed meal	Grain sorghum	NR	53%	NR	NR	NR	NR
				Whole cottonseeds		80%↑				
De Fries *et al.* (1998)	Multiparous Brahman	45d	Bermudagrass hay + soybean meal	Corn	58%w/L	NS	=P_4	NS	NR	71%
				Rice bran	80%w/L↑, ↑M&L					91%↑
Tjardes *et al.* (1998)	Angus × Hereford reciprocal cross	79d	Corn + red clover hay + soybean meal		NR	NR	NR	NR	NR	91%
				Yellow grease replaced a portion of corn						75%
Filley *et al.* (1999)	Primiparous Hereford × Angus	d 7-11 postpartum	Meadow hay + alfalfa hay	1L saline i.v.	NR	133d		NS	NS	100%
				1L 20% soybean oil i.v.		130d	↑PGFM d-7&11			75%
				1L 50% dextrose i.v.		126d				80%
				0.5 L 20% soybean oil i.v.		120d				100%
Filley *et al.* (2000)	Primiparous Hereford × Angus	30d	Meadow hay + alfalfa hay	Barley	NR	115d		NS	NR	68%
				Ca-fatty acids		111d	↑PGFM d-7&9			72%
Webb *et al.* (2001)	Multiparous Brahman	~48d	Coastal bermudagrass hay	Corn soybean meal	2.5 M↑	54d	NS for P_4 & PGFM	82%↑	71%	76%
				Rice bran	1.88M=	44d↓		65%=	60%	75%
				Corn + lasalocid	1.41M↓	42d↓		65%=	50%	81%
				Rice bran + lasalocid	1.38M↓	52d		38%↓	73%	67%

[a] Response variables with ↑ or ↓ beside them were greater or less than the value reported for the other treatment(s) within each study; PGFM = prostaglandin $F_{2\alpha}$ metabolite.

Table 4 continued.

Bottger *et al.* (2002)	Angus × Gelbvieh rotational cross	90d	Native grass hay	Corn + soybean meal	NR	NS	NR	NR	NS	100%
				High-linoleate safflower seeds						92%
				High-oleate safflower seeds						100%
Lloyd *et al.* (2002)	Primiparous & multiparous Angus	54d	Tall fescue pasture + hay	Corn + inorganic minerals	NR	NR	NR	NR	76%	94%
				Corn + chelated minerals					86%	88%
				Ca-fatty acids + inorganic minerals					71%	92%
				Ca-fatty acids + chelated minerals					85%	90%

Table 5. Ovarian follicular dynamics, apparent luteal function, and reproductive performance of beef cows consuming fat-supplemented diets pre- and postpartum.

					Response					
Reference	Breed type	Feeding period	Basal diet	Supplements	Ovarian follicles	Luteal activity & postpartum interval	Reproductive hormones	Normal estrus	Early[a] conception	Pregnancy rate
Hawkins *et al.* (1995)	Primiparous beef cows	100d prepartum ~90d postpartum	Corn silage + alfalfa hay (TMR)	Whole corn Ca-fatty acids	NR	NR	↑P_4	NR	NR	NR
Espinoza *et al.* (1995)	Multiparous Angus & Angus × Hereford	61d prepartum 44d postpartum	Range forage	Milo + meat meal + urea	NR	22% <90d, 72% > 90d	NR	NR	38%	85%
				Control + Ca-fatty acids		38% <90d↑, 61% > 90d			63%↑	91%
Lammoglia *et al.* (1996)	Brahman	2wk prepartum 21d postpartum	Bermudagrass + soybean meal	Corn	↓ all classes	90d		55%	NR	NR
				Corn + rice bran (5.2% fat)	↑	84d	↑PGFM	75%	gestation length was	
				Corn + rice bran (6.6% fat)	NR	80d		55%	greatest for 6.6% fat	

[a] Percentage of cows pregnant at the first half of a 190d breeding season.

Table 6. Effects of feeding supplemental fat to beef cows during gestation on subsequent cow reproduction.

					Response			
Reference	Breed type	Feeding period	Basal diet	Supplements	Postpartum interval	Detected estrus	1st service conception	Pregnancy rate
Bellows *et al.* (2001)	Exp.1: primiparous 50% Angus	65d prepartum	Corn silage + grass hay soybean meal	Barley	NR	68%	NR	79%
				High-linoleate safflower seeds		85%		97%↑
				Soybean seeds		76%		93%↑
				Sunflower seeds		76%		92%↑
	Exp.2: primiparous crossbred	68d prepartum	Corn silage + alfalfa hay soybean meal	Barley	NR	66%	NR	90%
				Sunflower seeds		55%		80%
Alexander *et al.* (2002)	Exp.1: primiparous Angus × Gelbveih rotational cross	62d prepartum	Bromegrass hay	Corn + soybean meal	NS	83%	55%	73%
				Sunflower seeds & soybeans	avg. 66d	50%	38%	100%
				Soapstocks		60%	71%	100%
	Exp.2: multiparous Angus × Gelbveih rotational cross	59d preparutm	Bromegrass hay	Corn + soybean meal	NR	NR	60%	88%
				Sunflower seeds & soybeans			67%	91%
				Soapstocks			71%	92%

Table 7. Effects of supplementing fat in the diet of beef cows on the calf, milk production, and milk composition.

				Response							
Reference	Feeding period	Basal diet	Supplements	Birth wt.	Calving difficulty	Vigor score	Calf rectal temperature	Cold tolerance	Milk production	Calf ADG	Weaning wt.
Miner *et al.* (1990)	Exp.1: 76d prepartum Exp.2: 81d prepartum	Native range	None	38	NR	NR	NR	NR	NR	NR	NR
			Soybean meal	38							
			Soybean meal + urea + blood meal	39							
			Soybean meal + urea + corn gluten meal	38							
			Soybean meal + tallow	39							
Espinoza *et al.* (1995)	61d prepartum 44d postpartum	Range forage	Milo + meat meal + urea	31	NR	NR	NR	NR	NR	0.68	173
			Control + Ca-fatty acids	32						0.74↑	186↑
				During the fall only							
Lammoglia *et al.* (1996)	2wk prepartum 21d postpartum	Bermudagrass + soybean meal	Corn	32	NR	NR	NR	NR	NR	NR	NR
			Corn + rice bran (5.2% fat)	24↓							
			Corn + rice bran (6.6% fat)								
De Fries *et al.* (1998)	45d postpartum	Bermudagrass hay + soybean meal	Corn	33	NR	NR	NR	NR	NR	0.90	215
			Rice bran	33						0.99↑	220
Tjardes *et al.* (1998)	79d postpartum	Corn + red clover hay + soybean meal		NR	NR	NR	NR	NR	@ 90d 5 kg, 6.9% fat	0.65	187
		Yellow grease replaced a portion of corn							8.2 kg↑, 4.7% fat↓	0.64	186
Lammoglia *et al.* (1999a)	55d prepartum	Corn silage + crested wheat hay + soybean meal	Barley	32	NR	NR	39.1		NR	NR	NR
			High-linoleate safflower seeds	34			39.4↑	↑ rectal temp. & glucose,↓ cortisol in cold			
Lammoglia *et al.* (1999b)	Exp.1: 53d prepartum	Alfalfa hay + corn silage + soybean meal	Corn	33	NR	NR	39.1		NR	NR	NR
			High-linoleate safflower seeds	35↑			38.9↑	maintained↑ rectal temp., ↑ glucose, = cortisol in cold			
	Exp.2:50d prepartum	Wheatgrass hay + corn silage + soybean meal		37=	NR	NR	38.9	lack of dietary effect to cold exposure			
		Control + Ponderosa pine needles (28d)		30=							
		Basal forage + high-linoleate safflower seeds		38=			39.1				
		Safflower diet + Ponderosa pine needles (28d)		30↓							
Filley *et al.* (2000)	30d postpartum	Meadow hay + alfalfa hay	Barley	35↑[a]	16%[a]	NR	NR	NR	NR	NR	125 @ 150d
			Ca-fatty acids	33	30%						123 @ 150d

[a] Data were collected before treatments were initiated.

Table 7. continued.

Bellows *et al.* (2001)	Exp.1: 65d prepartum	Corn silage + grass hay soybean meal	Barley	37	28%	1.3	NR	NR	NR	NR	182
			High-linoleate safflower seeds	38	36%	1.1					194↑
			Soybean seeds	39	26%	1.1					198↑
			Sunflower seeds	39	38%	1.1					197↑
	Exp.2: 68d prepartum	Corn silage + alfalfa hay + soybean meal	Barley	34	12%	1.0	NR	NR	NR	NR	212
			Sunflower seeds	36↑	21%	1.1					215
Webb *et al.* (2001)	~48d postpartum	Coastal bermudagrass hay + soybean meal	Corn	NR	NR	NR	NR	NR	NR	0.96	190
			Rice bran							0.89	191
			Lasalocid							0.94	193
			Rice bran + lasalocid							0.86	195
Alexander *et al.* (2002)	Exp.1: 62d prepartum	Bromegrass hay	Corn + soybean meal	NS	NS	NS	NS	NR	6.8 kg, 3.6%Pro↑	0.77	NR
			Sunflower & soybeans						8.0 kg, 3.2%Pro↓	0.84	
			Soapstocks						7.6 kg, 3.4%Pro=	0.82	
	Exp.2: 59d preparutm	Bromegrass hay	Corn + soybean meal	NS	NS	NS	NS	NR	NR	NS	284
			Sunflower & soybeans							avg. = 0.95	283
			Soapstocks								287
									% fat @ 60 & 90d		
Bottger *et al.* (2002)	90d postpartum	Native grass hay	Corn + soybean meal	NR	NR	NR	NR	NR	8.1kg, 3.5= & 3.9	1.0	200
			High-linoleate safflower seeds						8.4kg, 3.3↓ & 3.5↓	1.0	199
			High-oleate safflower seeds						8.3kg, 3.7↑ & 3.8	1.1	208