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NUTRITION AND REPRODUCTION INTERACTIONS

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Introduction

Direct reproductive traits, as we are able to measure them currently, tend to be low in heritability, therefore, the environment in which a beef female is produced is of pivotal importance to assure reproductive success. Large cow size and high milk production translate into increased nutrient requirements for the cow. Increased milk production and cow size increase both energy and crude protein requirements. Animals with higher milk production potential have higher maintenance requirements even when not lactating. Excess milk production and cow size can significantly limit the carrying capacity of any ranch. It is important that animal nutrient requirements match feed resources or reproduction will be compromised.

Body Condition Score

Body condition score (BCS) is correlated with several reproductive events such as postpartum interval, services per conception, calving interval, milk production, weaning weight, calving difficulty, and calf survival; greatly affecting net income on a cow/calf operation (Table 1; Kunkle et al., 1994). The most important factor influencing pregnancy rate in beef cattle is body energy reserves at calving (Wettemann et al., 2003). Body condition at calving is the single most important factor determining when beef heifers and cows will resume cycling after calving. Body condition score at calving also influences response to postpartum nutrient intake. Spitzer et al., (1995) fed primiparous cows differing in body condition (BCS 6 vs. 4; 1 = emaciated, 9 = obese) to gain either 1.87 or .97 lb/d. The percentage of BCS 6 cows in estrus during the first 20 days postpartum increased from 40 to 85% when fed to the higher rate of gain, the cows in BCS 4 only increased estrous response from 33 to 50% during the first 20 d postpartum when fed to gain at the higher rate. Cattle should have an optimum body condition score of 5 to 6 at calving through breeding to assure optimal reproductive performance. Body condition score is generally a reflection of nutritional management; however, disease and parasitism can contribute to lower body condition scores even if apparent nutrient requirements are met.

Specific Nutrients and Reproduction

Feeding a balanced diet to beef females in the last trimester of pregnancy through the breeding season is of critical importance. Nutritional demands increase greatly in late gestation and even more in early lactation. Reproduction has low priority among partitioning of nutrients and consequently, cows in thin body condition often don’t rebreed. Plane of nutrition the last 50-60 days before calving has a profound effect on postpartum interval (Table 2, Randel, 1990). The importance of pre- and postpartum protein and energy level on reproductive performance has been consistently demonstrated (Table 2). Positive energy balance postpartum is essential for prompt rebreeding of heifers calving in thin condition (Table 3; Lalman et al., 1997).

Table 1. Relationship of body condition score (BCS) to beef cow performance and income

BCS	Pregnancy rate, %	Calving interval, d	Calf ADG, lb	Calf WW, lb	Calf Price, $/100 lb	$/cow Exposed[a]
3	43	414	1.60	374	96	154
4	61	381	1.75	460	86	241
5	86	364	1.85	514	81	358
6	93	364	1.85	514	81	387

[a] Income per calf x pregnancy rate.

Table 2. Effect of pre- or postpartum dietary energy or protein on pregnancy rates in cows and heifers

Nutrient and time	Adequate	Inadequate	
	Pregnant, %		Difference, %
Energy level pre-calving[a]	73	60	13
Energy level post-calving[b]	92	66	26
Protein level pre-calving[c]	80	55	25
Protein level post-calving[d]	90	69	21

[abcd] Combined data from 2, 4, 9 and 10 studies, respectively.

Table 3. Influence of postpartum diet on weight change, body condition score (BCS) change and postpartum interval (PPI)

	Diet			
Item	Low	Maintenance	Maint./ High	High
Post-calving weight, lb	835	822	826	821
BCS at calving	4.27	4.26	4.18	4.10
PPI, d	134	120	115	114
PPI wt. change, lb	12	40	70	77
PPI BCS change	-.32	.37	1.24	1.50

Bearden and Fuquay (1992) summarized the effects of inadequate and excessive nutrients on reproductive efficiency (Table 4).

Table 4. Influence of inadequate and excessive dietary nutrient intake on reproduction in beef cattle

Nutrient Consumption	Reproductive Consequence
Excessive energy intake	Low conception, abortion, dystocia, retained placenta, reduced libido
Inadequate energy intake	Delayed puberty, suppressed estrus and ovulation, suppressed libido and spermatozoa production
Excessive protein intake	Low conception rate
Inadequate protein intake	Suppressed estrus, low conception, fetal reabsorption, premature parturition, weak offspring
Vitamin A deficiency	Impaired spermatogenesis, anestrus, low conception, abortion, weak offspring, retained placenta
Phosphorus deficiency	Anestrus, irregular estrus
Selenium deficiency	Retained placenta
Copper deficiency	Depressed reproduction, impaired immune system, impaired ovarian function
Zinc deficiency	Reduced spermatogenesis

Protein and energy

Inadequate daily energy intake is a primary cause of reduced cattle performance on forage diets. In many instances with warm-season perennial forages (and possibly with cool-season perennial forages at advanced stages of maturity), there is an inadequate supply of crude protein, which will limit energy intake (Mathis, 2000; Paterson et al., 1991). An example of the relationship between crude protein content of forages and forage intake is presented in Figure 1. Dry matter intake declined rapidly as forage crude protein fell below 7%, a result attributed to a deficiency of nitrogen (protein) in the rumen, which decreased microbial activity. If forage contains less than approximately 7% crude protein, feeding a protein supplement generally improves the energy and protein status of cattle by improving forage intake and digestibility. For example (Figure 1), with a crude protein content of 5%, forage intake was about 1.6% of body weight, while at 7% crude protein, forage intake was 44% higher and consumption was 2.3% of body weight.

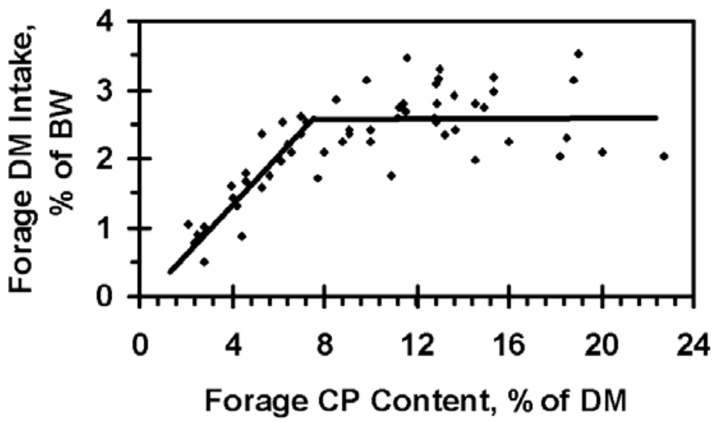

Figure 1. Effect of forage crude protein (CP) on dry matter (DM) intake

Improved forage intake increases total dietary energy intake, and is the reason correcting a protein deficiency is usually the first step in formulating a supplementation program for animals grazing poor quality forage. As suggested, when the crude protein content of forages drops below about 7%, forage intake declines. However, intake of other forages may decline when forage crude protein drops below 10%. Part of the variation can be attributed to differences in nutrient requirements of the cattle, with the remainder of the variation attributed to inherent differences among forages that present different proportions of nutrients to rumen microbes. Response of intake to a single nutrient such as crude protein should not be expected to be similar among all forages (Mathis, 2000).

Livestock producers are often concerned excessive dietary nutrients during the last trimester of pregnancy may negatively influence calf birth weights and dystocia. Selk (2000) summarized the effects of providing either adequate or inadequate amounts of dietary energy and protein on calving difficulty, reproductive performance, and calf growth. These summaries are presented in Tables 5 and 6.

Reducing energy pre-partum had virtually no effect on dystocia rates, even though birth weights were altered in some experiments. Of the nine trials summarized, seven indicated increased energy intakes during the last trimester of gestation did not increase calving difficulty.

Table 5. Summary of studies on supplemental prepartum energy intake on calving difficulty, subsequent reproductive performance and calf growth

Researcher	Supplementation[a]	Summary of Effects
Christenson et al., 1967	HE vs. LE for 140 d prepartum	HE increased birth wt., dystocia, milk & estrus activity
Dunn et al., 1969	ME vs. LE for 120 d prepartum	ME increased birth wt. and dystocia
Bellows et al., 1972	HE vs. LE for 82 d prepartum	HE increased birth wt. but had no effect on dystocia or weaning wt.
Laster & Gregory, 1973	HE vs. ME vs. LE for 90 d prepartum	HE increased birth wt. but had no effect on dystocia
Laster, 1974	HE vs. ME vs. LE for 90 d prepartum	HE increased birth wt. but had no effect on dystocia
Corah et al., 1975	ME vs. LE for 100 d prepartum	ME increased birth wt., estrus activity, calf vigor and weaning wt. but had no effect on dystocia
Bellows and Short, 1978	HE vs. LE for 90 d prepartum	HE increased birth wt., estrus activity, pregnancy rate and decreased post partum interval but had no effect on dystocia
Anderson et al., 1981	HE vs. LE for 90 d prepartum	HE had no effect on birth wt., milk or weaning wt.
Houghton et al., 1986	ME vs. LE for 100 d prepartum	ME increased birth wt. and weaning wt. but had no effect on dystocia

[a]HE = high energy (over 100% NRC or National Research Council's recommended dietary need); ME = moderate energy (approximately 100% NRC); LE = low energy (under 100% NRC)

In addition, producers are often concerned with levels of crude protein and possible effects on calf birth weight. Selk (2000) summarized studies conducted to specifically measure effects of varying protein intake to the prepartum beef female on calving difficulty (Table 6). Reducing dietary crude protein prepartum does not decrease calving difficulty and may compromise calf health and cow reproductive performance.

Table 6. Summary of studies on feeding supplemental protein during gestation on calving difficulty, subsequent reproductive performance and calf growth

Researcher	Supplementation[a]	Summary of Effects
Wallace & Raleigh, 1967	HP[a] vs. LP for 104 - 137 d prepartum	HP increased cow wt., birth wt. and conception rate but decreased dystocia
Bond & Wiltbank, 1970	HP vs. MP throughout gestation	HP had no effect on birth wt. or calf survivability
Bellows et al., 1978	HP vs. LP for 82 d prepartum	HP increased cow wt., cow ADG, birth wt., dystocia, weaning wt. and decreased conception rate
Anthony et al., 1982	HP vs. LP for 67 d prepartum	HP had no effect on birth wt., dystocia or postpartum interval
Bolze et al.,1985	HP vs. MP vs. LP for 112 d prepartum	HP had no effect on birth wt., dystocia, weaning wt., milk or conception rate but decreased the postpartum interval

[a]HP = high protein (over 100% NRC); MP = moderate protein (approximately 100% NRC); LP = low protein (under 100% NRC)

Excess protein and energy

Caution should be used with feeding excessive amounts of nutrients before or after calving. Not only is it costly, but animals with excess body condition (BCS >7) have lower reproductive performance and more calving difficulty than animals in moderate body condition (BCS 5-6). Excessive protein and energy can both have negative effects on reproduction. Overfeeding protein during the breeding season and early gestation, particularly if the rumen receives an inadequate supply of energy may be associated with decreased fertility (Elrod and Butler, 1993). This decrease in fertility may result from decreased uterine pH during the luteal phase of the estrous cycle in cattle fed high levels of degradable protein. The combination of high levels of degradable protein and low energy concentrations in early-season grasses may contribute to lower fertility rates in females placed on such pastures near the time of breeding. Negative effects of excess rumen degradable intake protein on reproduction are well documented in dairy literature (Ferguson, 2001).

Effects of supplementing feedstuffs high in undegradable intake protein (UIP) on reproduction are inconclusive and appear to be dependent on energy density of the diet (Hawkins et al., 2000). Recent research (Kane et al., 2004) demonstrated negative effects on reproductive hormones when high (.71 lb/d) levels of UIP were supplemented but not at low (.25 lb/d) or moderate (.48 lb/d) levels. Heifers fed additional UIP (.55 lb/d) during development reached puberty at a later age and heavier weight and had fewer serviced in the first 21 d of the breeding season. Fall pregnancy rate was not affected (Lalman et al., 1993). Further research is needed to elucidate potential mechanisms UIP may stimulate or inhibit reproductive processes and under what conditions.

Distillers grains are a co-product from the ethanol industry being utilized in beef cattle diets and are also high (65% of CP content) in UIP. Two research projects were conducted to determine the effects of feeding dried distillers grains to beef heifers during post weaning development and to 2-yr-old cows during the postpartum period (Funston, unpublished data). In both experiments distillers grains were included in a total mixed diet and fed at approximately 2.76 lb DM (3 lb as fed; approximately .55 lb/d UIP). Diets were formulated to be similar in crude protein and total digestible nutrients. Heifers (n = 100) were fed diets with either distillers grains or whole soybeans (3 lb as fed) from late October through early June when they were artificially inseminated after being synchronized with melengestrol acetate (MGA)/$PGF_{2\alpha.}$ There were no differences in cycling activity (98%) before MGA feeding, synchronization rate (86%), AI conception rate (69%) or AI pregnancy rate (59%).

The second experiment utilized 54, 2-yr-old cows, which were assigned to treatment by calving date and fed diets with either distillers grains or wet corn gluten feed as a protein source beginning approximately one week after the last calf was born for a period of 60 d. At 67 d postpartum (based on average calving date), cows were given an injection of GnRH and a CIDR inserted; 7 d later the CIDR was removed and $PGF_{2\alpha}$ injected. Cows were then heat detected and AI'd 12 h later for 96 h, at which time all cows not detected in estrus were inseminated and injected with GnRH. Cow-calf pairs were trucked approximately 225 miles shortly after the last AI and ultrasounded for pregnancy 47 d later. Pregnancy rate (65%) to AI did not differ between treatments.

Shike et al. (2004, and personal communication) also did not observe a negative effect on reproduction when distillers grains were fed to postpartum Simmental cows. One-hundred cows were blocked by age and calving date and fed postpartum diets containing either 13 lb corn gluten feed and 10 lb alfalfa or 12.26 lb dried distillers grains and 10 lb alfalfa (DM basis) until the beginning of the breeding season (approximately 74 d). Pregnancy rate to AI (60 vs. 60.5% for corn gluten and distillers, respectively) and after a 45 d bull breeding (97.1 vs. 90.7 for corn gluten feed and distillers, respectively; $P = 0.13$) period did not differ. Cows fed corn gluten feed lost more weight, had greater milk production, and greater calf average daily gain during the postpartum period. Milk urea nitrogen levels were above levels reported to negatively influence reproduction in other studies (Butler, 1998). Differences may be due to energy balance and lactation potential.

Minerals

Minerals are important for all physiological processes in the beef animal including reproduction. Therefore, the question is not whether minerals are important for reproduction, but rather, when do minerals have to be supplemented in the basal diet.

Salt (NaCl) is the most important mineral in terms of need for the beef animal. Sodium and chloride normally do not appear in feedstuffs in adequate amounts to meet animal requirements and should be provided free choice at all times.

Calcium is generally adequate in forage-based diets but is often included in commercially available mineral supplements because many phosphorus sources also contain calcium. There has been much debate and research conducted on the effects of phosphorus supplementation on reproductive function. Phosphorus and crude protein content generally parallel each other in pasture or rangeland. Mature forages are generally deficient in phosphorus and impaired reproductive function has been associated with phosphorus deficient diets (Dunn and Moss, 1992; Lemenager et al., 1991). Diets should be evaluated for phosphorus content and supplemented accordingly. Caution should be used to not overfeed phosphorus -- it is costly, of potential environmental concern, and does not positively influence reproduction in beef (Dunn and Moss, 1992) or dairy (Lopez et al., 2004) cattle.

Other macro minerals include magnesium, potassium, chlorine, and sulfur. Need for supplementation, as with the previously mentioned minerals, is dependent on content in the basal diet and water. Both deficiencies and excesses can contribute to suboptimal reproductive function.

The micro or trace minerals include copper, cobalt, iodine, iron, manganese, and zinc. Inadequate consumption of certain trace elements combined with antagonistic effects of other elements can reduce reproductive efficiency (Greene et al., 1998).

Vitamins

Most of the vitamins (C, D, E, and B complex) are either synthesized by rumen microorganisms, synthesized by the body (vitamin C) or are available in common feeds and are not of concern under normal conditions. Vitamin A deficiency, however, does occur naturally in cattle grazing dry winter range or consuming low quality crop residues and forages (Lemenager, et al., 1991). The role of vitamin A in reproduction and embryo development has been reviewed by Clagett-Dame and Deluca (2002). Supplementation before and after calving can increase conception rates (Hess, 2000).

Water

Water is more essential to life than any other single nutrient. Feed intake is directly related to water intake. Water may also contribute significant macro and micronutrients that may benefit or impair production and reproduction. The contribution of these nutrients from water sources must be considered to accurately design a supplementation program.

Strategies to Enhance Reproduction

Ionophores

Bovatec® and Rumensin® have been shown to influence reproductive performance during the postpartum period. Cows and heifers fed an ionophore exhibit a shorter postpartum interval provided adequate energy is supplied in the diet (Table 7; Randel, 1990). This effect appears to be more evident in less intensely managed herds that generally have a moderate (60-85 d) or longer postpartum interval. Scientists have also demonstrated heifers fed an ionophore reach puberty at an earlier age and a lighter weight (Patterson et al., 1992).

Table 7. Effect of ionophore feeding on postpartum interval (PPI) in beef cows and heifers

Study	Ionophore (PPI, d)	Control (PPI, d)	Difference (d)
1	30	42	-12
2	59	69	-10
3	67	72	-5
4	65	86	-21
5	92	138	-46

Fat supplementation

Inadequate dietary energy intake and poor body condition can negatively affect reproductive function. Supplemental lipids have been used to increase the energy density of the diet and avoid negative associative effects (Coppock and Wilks, 1991) sometimes experienced with cereal grains (Bowman and Sanson, 1996) in high roughage diets.

Supplemental lipids may also have direct positive effects on reproduction in beef cattle independent of the energy contribution. Lipid supplementation has been shown to positively affect reproductive function at several important tissues including the hypothalamus, anterior pituitary, ovary, and uterus. The target tissue and reproductive response appears to be dependent upon the types of fatty acids contained in the fat source. Fat supplementation is a common practice in dairy cattle production, primarily to increase the energy density of the diet. Associated positive and negative effects on reproduction have been reported (Grummer and Carroll, 1991; Staples et al., 1998).

Research with supplemental fat has been conducted on cows that have had one or more calves, and replacement heifers. Fats have been fed before and after calving and during the breeding season. Several response variables have been examined, including body weight and body condition score, age at puberty, postpartum interval, first service conception rates, pregnancy rates, calving interval, calving difficulty, and calf birth and weaning weight. To determine potential mechanisms of action, scientists have investigated changes in follicular and uterine development, hormonal profiles and changes, brain function, and embryonic development.

The effects of fat supplementation on reproduction in beef heifers and cows have recently been reviewed (Funston, 2004). Following is a summary from that review.

Fat Supplementation to Replacement Heifers. Studies are limited on the use of fat supplements in replacement heifer diets. In general, heifers in the studies cited were on a positive plane of nutrition and developed to optimum weight and age at breeding. There may have been a positive response to fat supplementation had heifers been nutritionally challenged. It appears from the studies cited here, there is limited benefit of fat supplementation in well-developed replacement females and is probably only warranted when supplements are priced comparable to other protein and energy sources.

Fat Supplementation Prepartum. Results from feeding supplemental fat prepartum are inconclusive. However, response to supplementation appears to be dependent on postpartum diet. Beef animals apparently have the ability to store certain fatty acids, supported by studies in which fat supplementation was discontinued at calving but resulted in a positive effect on reproduction. Postpartum diets containing significant levels of fatty acids may mask any beneficial effect of fat supplementation. There appears to be no benefit and in some cases, a negative effect of feeding supplemental fat postpartum, particularly when supplemental fat was also fed prepartum. Fat supplementation has been reported to both suppress and increase $PGF_{2\alpha}$ synthesis. In situations in which dietary fat is fed at high levels for extended periods of time, $PGF_{2\alpha}$ synthesis may be increased and compromise early embryo survival. Hess (2003) summarized research on supplementing fat during late gestation and concluded that feeding fat to beef cows for approximately 60 d before calving may result in a 6.4% improvement in pregnancy rate in the upcoming breeding season.

Fat Supplementation Postpartum. Supplementing fat postpartum appears to be of limited benefit from studies reported here. The majority of the studies reported approximately 5% fat in the diet supplemented with fat. It is not known if more or less fat would have elicited a different response (either positive or negative). If supplementing fat can either increase or decrease $PGF_{2\alpha}$ production, it seems reasonable the amount of fat supplemented might affect which response is elicited. Recent research (Hess, 2003) demonstrated a decrease in first service conception rates (50 vs. 29%) when young beef cows were fed high linoleate safflower seeds (5% DMI) postpartum. The same laboratory has also reported (Grant et al., 2002) an increase in $PGF_{2\alpha}$ metabolite (PGFM) when high linoleate safflower seeds are fed postpartum and a decrease in several hormones important for normal reproductive function (Scholljegerdes et al., 2003 and 2004).

Feeding Considerations. The amount of supplemental fat needed to elicit a positive or, in some cases, a negative effect on reproductive function is largely unknown and titration studies are needed in all situations in which supplemental fat has been fed. Dose response studies indicate the amount of added plant oil necessary to maximize positive ovarian effects is not less than 4% (Stanko et al., 1997; Thomas et al., 1997). Staples et al. (1998) indicated 3% added dietary fat (DM basis) has often positively influenced the reproductive status of the dairy cow. Lower levels of added dietary fat (2%) have also been shown to elicit a positive reproductive response (Bellows et al., 2001) and in studies with fishmeal less than 1% added fat (Burns et al., 2002) produced a positive reproductive response, indicating both the amount and types of fatty acids are important. Feeding of large quantities of fat (> 5% of total DMI) has not been recommended due to potential negative effects on fiber digestibility and reduction in DMI (Coppock and Wilks, 1991). The duration and time (pre or postpartum) of supplement feeding needed to elicit a positive response is not precisely known, many of the studies have supplemented fat at least 30 d. The period of supplementation has varied from different times before breeding in heifer development, pre-calving, post-calving, and/or pre-breeding periods. The young, growing cow appears to be the most likely to respond to supplemental nutrients. An appropriate situation for fat supplementation may be when pasture or range conditions are limiting or are likely to be limiting before and during the breeding season. Feeding supplemental fat to well-developed heifers or cows in adequate body condition on adequate pasture or range resources may not provide any benefit beyond energy contribution to the diet.

The majority of fat supplementation in beef cattle diets has been in the form of oilseeds added to a total mixed diet or fed as a supplement. A challenge has been making a supplement high in fat that can be pelleted or blocked and fed on the ground. Levels above 8% fat have resulted in pellets and blocks that are soft and of poor quality (Bellows, personal communication). Whole soybeans, sunflower, and cottonseeds have been fed without processing;

it appears safflower seeds need to be processed to improve digestibility. Seeds should be processed (rolled) with enough pressure to crack about 90% of the seed hulls without extracting the oil (Lammoglia et al., 1999).

Additional Compounds in Oilseeds. Gossypol levels may be a concern when high levels of whole cottonseed are fed. However, levels of gossypol present in typically fed quantities of whole cottonseed for protein or fat supplementation provide only a fraction of the amount of gossypol fed in studies in which gossypol toxicity has been reported (Williams and Stanko, 1999). Other factors such as phytoestrogens may be present in some oilseeds (legumes in particular) and have been shown to negatively affect reproduction in cattle (Adams, 1995). The precise effect of these factors and possibly others on reproductive function has not been fully elucidated and is probably dependent on level of inclusion, basal diet, and stage of physiological maturity of the female being supplemented.

In a recent study (Funston, unpublished data), beef heifers (n = 106; approximately 10 mo of age; 660 lb) were fed 3 lb/d (4% added fat) whole soybeans or wet corn gluten feed as a protein source in a total mixed diet approximately 110 d before AI. There was no difference in cycling activity (98%) before heifers were synchronized with MGA/ $PGF_{2\alpha}$. Fewer (81 vs 96% for soybean and control, respectively) heifers fed soybeans were detected in estrus through 120 h after $PGF_{2\alpha}$. Estrous response (time after $PGF_{2\alpha}$) was also delayed (3.2 vs 2.9 d for soybean and control, respectively) in the heifers fed soybeans. Neither AI conception rates (81 vs 72% for soybean and control, respectively) nor AI pregnancy rates (65 and 69% for soybean and control, respectively) were affected by treatment. Overall pregnancy rates (90 and 94% for soybean and control, respectively) were also not different after the breeding season. The reason for the delayed estrous response and delayed time of estrus is not known. However, analysis of the extracted soybeans indicated the presence of three different phytoestrogens, which may have affected estrous response, and time of estrus.

In a subsequent heifer development study utilizing whole soybeans (3 lb/d), discussed previously, distillers grains were used as the protein source in the control diet. Heifers (n = 100) were approximately 500 lb and 7 months of age when placed on experimental diets. There were no differences in cycling activity (98%) before MGA feeding, synchronization rate (86%), time of estrus (2.9 d) after $PGF_{2\alpha}$, AI conception rate (69%) or AI pregnancy rate (59%). It is not understood why there was not a difference in estrous response or delay in time of estrus in this experiment. Only 16% of heifers were cycling when feeding of experimental diets initiated compared to 81% the previous year. Soybeans were also fed longer (230 d) than the previous year (110 d). Differences in physiological maturity and duration of feeding may have contributed to the inconsistencies between years.

An additional study was conducted to determine if time of feeding whole soybeans before AI had an effect on estrous response or pregnancy rates. Heifers (n=100) were synchronized with MGA/PGF and fed 3 lb/d whole soybeans for approximately 120 or 210 d before PGF injection. Heifers weighed approximately 570 and 730 lb at initiation of soybean feeding. There was no difference in synchronization rate (77%), time of estrus (78h) after PGF, AI conception rate (57%), AI pregnancy rate (44%) or final pregnancy rate (90%). Serum samples will be analyzed to determine cyclic activity before each treatment was initiated.

Howlett et al. (2003) also fed whole soybeans, whole cottonseed, or pelleted soybean hulls for 112 d in a total mixed diet to replacement heifers. Soybeans and cottonseeds contributed approximately 2% added fat to the diet. Heifers were synchronized with MGA/$PGF_{2\alpha}$ and experimental diets were discontinued approximately one week before the first MGA feeding.

Treatment did not affect the proportion of heifers pubertal before beginning MGA feeding. First service conception rates were also not affected by treatment. However, there was a 20% increase ($P = 0.27$) in first service conception rates in the soybean fed group (57%) compared to controls (37%). In this study 96 heifers were split into three treatments and a control group. Neither estrous response nor time of estrus was reported.

Five hundred-sixty Angus x Simmental cows were utilized to evaluate the effects of supplemental fat on performance, lactation, and reproduction (Shike et al., 2004). Cows were fed one of four dietary supplements: whole raw soybeans, flaxseed, tallow, and corn-soybean meal (control). Flaxseed and tallow were added to the control supplement to provide similar fat levels as supplied by whole soybeans. Supplements (4 lb/d) were fed for 105 d after calving and ended at breeding. Cows grazed endophyte infected tall fescue and red and white clover pastures. There were no differences in cow or calf ADG or milk production. Soybean supplemented cows had greater milk fat and milk urea nitrogen than flaxseed supplemented cows. There were no differences in AI conception rates. However, conception rates to bulls were lower in cows fed soybeans (65%) compared to flaxseed (79%) or tallow (76%). Overall pregnancy rates were lower in cows fed soybeans (83%), compared to cows fed flaxseed (91%) or tallow (89%). It was stated the flaxseed, tallow, and control supplements were isonitrogenous but apparently not the soybean supplement. It is not clear why there would be a reduction in bull, but not AI, pregnancy rates. Apparently protein levels were higher in the soybean supplement as demonstrated by higher milk urea nitrogen levels. Overall dietary protein may have been in excess throughout the supplementation period, depending on forage quality. Artificial insemination pregnancy rates were also apparently quite low. Cessation of supplement feeding may have actually benefited reproduction. This also appears to be a high supplementation rate of soybeans. Compounding this apparent problem may have been endophyte from tall fescue and phytoestrogens from clover (Adams, 1995).

Summary of Fat Supplementation. Currently, research is inconclusive on exactly how to supplement fat to improve reproductive performance beyond the energy contribution. Most studies have tried to achieve isocaloric and isonitrogenous diets. However, this can be challenging. Some studies only have sufficient animal numbers to detect very large differences in reproductive parameters such as conception and pregnancy rate. Research on feeding supplemental fat has resulted in varied and inconsistent results as it relates to reproductive efficiency including positive, negative, and no apparent effect.

Elucidating mechanisms of action of how supplemental fat can influence reproductive function has been a difficult process. Animal response appears to be dependent on body condition score, age (parity), nutrients available in the basal diet, and type of fat supplement. The complexity of the reproductive system and makeup of fat supplements are often confounded by management conditions and forage quality both in research and in commercial feeding situations. This has contributed to inconsistencies in research findings.

Improvements in reproduction reported in some studies may be a result of added energy in the diet or direct effects of specific fatty acids on reproductive processes. As is the case for any technology or management strategy that improves specific aspects of ovarian physiology and cyclic activity, actual improvements in pregnancy rates, weaned calf crop, or total weight of calf produced are dependent on an array of interactive management practices and environmental conditions. Until these interrelationships are better understood, producers are advised to strive for low cost and balanced rations. If a source of supplemental fat can be added with little or no change in the ration cost, producers would be advised to do so. Research investigating the role of fat supplementation on reproductive responses has been variable. Therefore, adding fat when significantly increasing ration cost would be advised when the risk of low reproduction is greatest. Postpartum fat supplementation appears to be of limited benefit and adding a fat source high in linoleic acid postpartum may actually have a negative effect on reproduction.

Summary

Nutrition has a profound effect on reproductive potential in all living species. Body condition is a useful indicator of nutritional status and when used in conjunction with body weight change can provide a useful method to assess reproductive potential. Energy and protein are the nutrients required in the greatest amounts and should be first priority in developing nutritional programs to optimize reproduction. Minerals and vitamins must be balanced in the diet to optimize reproductive performance. Consider water quantity and quality when balancing diets. Caution should be taken not to overfeed nutrients or reproductive processes may be adversely affected. There does not appear to be any magic feed ingredient that will compensate for a diet greatly deficient in any of the nutrients or poor body condition score.

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