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INTERACTIONS BETWEEN NUTRITION AND REPRODUCTION IN BEEF COWS

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Nutrition is a primary effecter of reproductive efficiency in beef cows and heifers. The relationship between nutrition and reproduction in cattle is most likely an adaptive mechanism to prevent reproduction in times of limited nutrient availability. Although producers had noticed decreased reproductive rates in undernourished cattle for many years, research into the mechanisms involved in nutritional control of bovine reproduction has only been conducted for the last 40 years.

A preponderance of research has focused on the role of nutrition in the control of the initiation of estrous cycles in postpartum cows or peripuberal heifers. The failure of cows to become pregnant due to nutritional deficiencies is a significant production problem. Several studies have estimated that only 75% to 85% of all US beef cows calve annually (USDA-APHIS, 1994). Over three quarters of this reduction in reproductive efficiency is due to failure to establish pregnancy while the remainder is caused by embryonic loss. A principal factor in failing to establish pregnancy in beef cows is simply a result of cows not cycling during the controlled breeding season.

More recently, advances such as growth factor assays, ultrasound and molecular techniques have enabled researchers to investigate subtle changes in nutrient availability on reproduction. Not only does nutrition affect cyclicity, but it may impact follicular development, oocyte quality and gene expression. In the future, based on this area of research, short-term nutritional manipulations may be designed to enhance pregnancy rates to artificial insemination and embryo transfer or reduce early embryonic mortality.

The purpose of this paper is not an exhaustive review of the literature, but rather a review of the current concepts of the role of nutrition in reproduction of beef cows and heifers.

Energy Availability

Energy intake

Energy is the primary nutrient regulating reproduction in female beef cattle. Undernourished cows and heifers are delayed in the resumption or initiation of estrous cycles. Energy availability appears to control reproduction primarily through pathways that permit or block the release of GnRH from the hypothalamus and LH and FSH from the pituitary. Energy substrates or metabolic responses to energy availability may also act upon the ovary to influence follicular growth, estrogen production, and circulating progesterone levels. In addition to overall energy availability, the timing of energy increase or deprivation appears to be important in determining pregnancy rates.

Restricting energy intake during late gestation increases the length of postpartum anestrus (Bellows et al., 1982) and reduces subsequent pregnancy rate. Contrary to conventional thinking, late gestation reduction in energy does not decrease dystocia or dramatically decrease calf birth weight (Bellows et al., 1982; Rasby et al., 1990). Severe reduction in prepartum nutrition may compromise calf survival especially in heifers (Odde, 1988).

Cows fed high energy diets from calving until breeding have a shorter period of postpartum anestrus and increased pregnancy rates than cows on adequate energy diets (Wiltbank et al., 1964; Dunn et al., 1969). However, a short-term increase in energy intake (flushing) does not necessarily result in improvements in numbers of cows cycling or pregnancy rate. Reduction of energy demands by short-term (48 hour) calf removal combined with flushing can reduce days to estrus and improve conception rates (Nix et al., 1981). Additionally, flushing in combination with progestin-based estrous synchronization increased follicular growth and fertilization rate in undernourished cows (Khireddine et al., 1998; Ponsart et al., 2000).

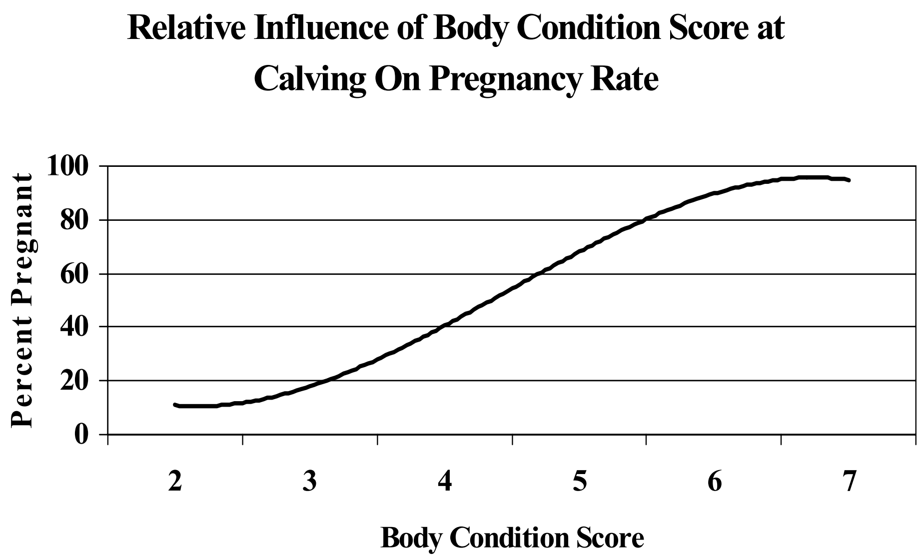
Heifers raised on low energy diets are delayed in reaching puberty and have lower pregnancy rates their first breeding season than heifers raised on a high energy diet (Short and Bellows, 1971). When heifers are developed to reach approximately 65% of their mature weight by 12 to 13 months of age, attainment of puberty is not restricted by nutrition. In contrast, feeding heifers excess energy to reach 65% of mature weight prior to 12 months of age does not initiate puberty (Hall et al., 1997). However, body fat percentage at puberty will be increased in rapidly developed heifers.

Energy reserves – Body condition

Energy reserves in the form of fat and muscle, body condition, are also an important modulator of postpartum anestrus. Several studies found that body condition score (BCS) at calving and BCS at the beginning of the breeding season were the most important indicators of reproductive performance (Perry et al., 1991; Spitzer et al., 1995). Body condition score at calving has the greatest effect on pregnancy rate during a controlled breeding season (Lalman et al., 1997).

Impact of body condition score at calving

Cows in body condition score BCS 5 (1 = emaciated to 9 = obese; Herd and Sprott, 1986) or better at calving have fewer days to first estrus and increased pregnancy rates (Rasby et al., 1981, Wettemann et al., 1981). Cows calving in BCS ≤ 4 had a 9 % to 29 % lower pregnancy rate compared to cows calving at BCS ≥ 5 (Makarechian and Arthur, 1990; Selk et al., 1988). Based on data from the literature, hypothetical pregnancy rates for cows of various body condition scores are illustrated in figure 1. Research from Oklahoma indicates that changes in BCS between 4 and 6 have a greater impact on pregnancy rate than changes in BCS above 6 or below 4 (Selk et al., 1988). In other words, little improvement in pregnancy rates is seen when cows calve in BCS above 6 while pregnancy rate does not get much worse below BCS 4.



Adapted from Selk et al., 1988

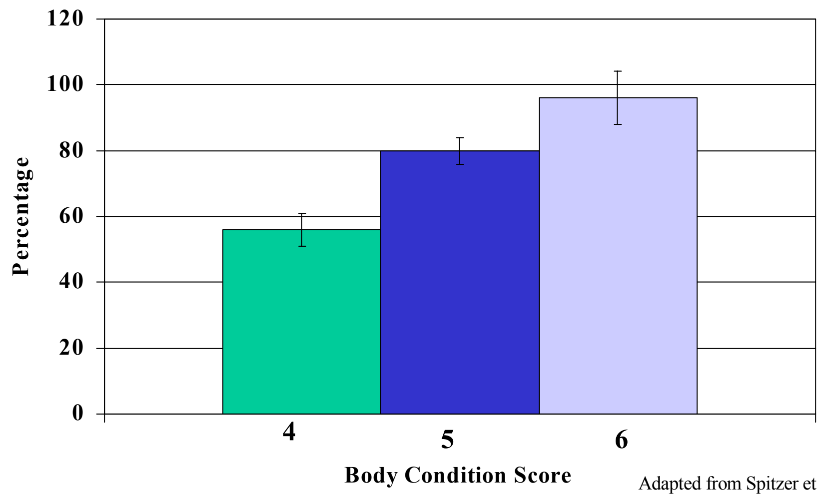
In addition to the overall decrease in pregnancy rates, cows calving at BCS ≤ 4 that conceive become pregnant later in the breeding season (Table 1). As a result, these cows calve later in the calving season the next year. Late calving cows are more likely to fail to conceive during a controlled breeding season. Calves born late in the calving season will be lighter at weaning than calves born early in the calving season. At weaning, calves will be approximately 17 kg (35 lbs) lighter for every 21-day delay in calving (Lesmeister et al., 1973).

Table 1. Effect of Body Condition Score at Calving on Cumulative Pregnancy Rates

		Day of the Breeding Season		
	BCS	20 d	40 d	60 d
Mature Cows (Richards et al., 1986)		Cumulative % Pregnant		
	≤ 4	41	67	84
	≥ 5	51	79	91
First Calf heifers (Spitzer et al., 1995)		Cumulative % Pregnant		
	4	27	43	56
	5	35	65	80
	6	47	90	96

First calf heifers are even more sensitive to the effects of BCS at calving on pregnancy rates. Dramatic decreases of 40 % to 50 % (Figure 2) occur as heifers drop from BCS 6 to BCS 4 (DeRouen et al., 1994; Spitzer et al., 1995). In contrast to mature cows, heifers exhibit a significant decrease of approximately 16 % in pregnancy rate between BCS 6 and BCS 5. Therefore, the optimum BCS at calving is 6 or 7 in heifers.

Figure 2. Effect of Body Condition Score at Calving on Subsequent Pregnancy Rate in First Calf Heifers



Limited data indicates that cows that calve at BCS ≥ 7 and heifers that calve in BCS ≥ 8 may have impaired reproduction during the breeding season (Richards et al., 1986; Houghton et al., 1990). One should be cautious in drawing any conclusions about "fat" cows, as the numbers of cows with BCS ≥ 7 in these studies were limited. In addition, it is not always clear if cows were in high BCS due to nutritional manipulation or physiological factors. Efforts should be made to keep cows in the BCS 5-7 range from an economic standpoint as well as a possible reproductive effect.

Influence of Body Condition Score Changes from Calving to Breeding

Although body condition score at calving has the greatest impact on cow reproduction, changes in body weight and body condition score postpartum will also affect reproductive performance. Change in body condition score postpartum dramatically affect cows that calve at BCS ≤ 4. Low BCS cows that continue to lose weight and BCS after calving are unlikely to become pregnant during the breeding season. Thin cows that continue to lose BCS have a longer interval from calving to first heat (postpartum interval). This means a low percentage of these cows (0-40%) are cycling by the start of the breeding season (Houghton et al., 1990; Perry et al., 1991; Spitzer et al., 1995). Often it may take over 80 to100 days until these cows begin cycling. As a result of delayed cyclicity, thin cows losing BCS postpartum have low pregnancy rates, which are often 30 to 50 % lower than their well-fed counter parts.

Cows that calve in BCS ≥ 5 are less sensitive to the effects of postpartum nutrition, but reproductive ability of cows losing weight after calving may be compromised. Interval from calving to heat is lengthened and pregnancy rate decreased in fleshy cows that lose weight postpartum. For example, researchers in Oklahoma reported an increase of 22 days in postpartum interval and a reduction in pregnancy rate of 14 % in cows that calved at BCS 5.4 but lost 1 BCS before the start of the breeding season (Cantrell et al., 1981).

Producers often hope that feeding thin cows to increase BCS and body weight after calving will solve their reproductive problems. Unfortunately, once a cow has calved her metabolism has shifted to support milk production. Therefore, only a portion of the additional energy fed to postpartum cows is available to combat the effects of low BCS. Cows that calve at BCS ≤ 4 and are fed high energy diets postpartum usually have a 10 to 20 % reduction in cyclicity compared to moderate flesh cows that maintain their weight (Perry et al., 1991). A reduction in the percentage of cows cycling diminishes the chances high pregnancy rates. Occasionally, these refed cows have conception rates equal to cows maintained in better body condition. (Richards et al., 1986; Houghton et al., 1990).

First calf heifers are less responsive to attempts to feed them to gain weight after calving. First, these primiparous cows have a longer postpartum interval and are more sensitive to the negative effects of poor body condition on reproduction. Because they are growing in addition to lactating, enhancing dietary energy intake does not readily enhance reproductive performance. Most studies indicate that thin heifers that are refed during early lactation have lower pregnancy rates at the end of the breeding season compared to heifers that calve at BCS ≥ 5 and maintain their body weight (Spitzer et al., 1995; Lalman et al., 1997). Distribution of conception is also effected, as thin-refed heifers tend to breed later in the breeding season.

Modulating Body Condition

Since BCS of 5-7 is the optimum range for reproductive performance, "keep cows in BCS 5 or better" has been the dogma carried across the industry. In practice, cattle are often below BCS 5 at weaning, but good managers usually have them back to adequate BCS by 60 to 90 days before the calving season. The question is whether it is biologically and economically efficient to maintain cows in optimum BCS year-round.

Changes in environmental conditions and availability of forage often make achieving an optimum BCS by 60 to 90 days before calving difficult. A mild winter may result in most cows being BCS 7 or greater whereas a harsh winter may result in cows calving at BCS < 5. Only a few studies have looked at the effects of making short-term changes in BCS immediately before or after calving (DeRouen et al., 1994; Morrison et al., 1999).

In a multi-state study, DeRouen and co-workers (1994) found that it did not matter if first-calf heifers lost weight or gained weight in the last 90 days before calving as long as they achieved a BCS of 6 by calving time. If heifers were BCS 6, then they had a high probability of conceiving during a controlled breeding season. Similarly, cows that calved in ≥BCS 5 had high pregnancy rate regardless if they gained, lost or maintained weight during the last trimester. Several studies indicate that cows that gain a BCS during the last trimester tend to have shorter postpartum intervals compared to those that maintain their body condition. Therefore, the last trimester is not too late to make nutritional adjustments.

Source of calories

Most of the studies discussed to this point have investigated varying levels of dietary energy with little regard to the source of calories. Starch, fiber, and fats all supply energy to ruminants but each of these sources of energy produces different physiological effects in cattle. Isoenergetic diets in which calories come from different energy sources may have different effects on reproduction.

A few studies in developing heifers have examined all three sources of energy in a single experiment. We conducted a two year study examining the effects of source of energy on development of replacement heifers grazing stockpiled fescue and spring growth. Heifers were fed isonitrogenous – isoenergetic supplements constructed with corn/soy (high starch), whole cottonseed (high fat), or soy hulls (high fiber). There was no effect of type of supplement on heifers cycling at the beginning of the breeding season or percentage pregnant to AI or clean-up natural service (Table 2). Extremely high temperatures and drought may have reduced overall percentage pregnant; however supplement did not influence heifer performance. Similarly, Howlett and co-workers (2003) found no advantage to whole soybeans or whole cottonseed compared to soyhulls or a corn/soy supplement. Both experiments had only small numbers of heifers so only drastic changes in reproductive performance would have been detected.

Table 2. Impact of source of energy in supplements for developing heifers on percentage pregnant

Supplement	Percentage pregnant to AI	Overall percentage pregnant
Soyhulls	45.8 % (11/24)	79.2 % (19/24)
Whole Cottonseed	45.8 % (11/24)	75.0 % (18/24)
Corn/soybean meal	54.1 % (13/24)	83.3 % (20/24)

(Wuenschel et al. 2005)

Fats

The impact of fats on reproduction in cattle is a focus of considerable research (See review by Funston, 2004). Because fatty acids and cholesterol are substrates for hormone synthesis, increasing fat in the diet may increase levels of reproductive hormones (progesterone, prostaglandins) or fats may act directly on the reproductive axis. Therefore, the effects of fat may be independent of or additive to those of increased energy availability.

Cattle diets usually contain less than 2 or 3 % fat. Supplementing fat to improve reproduction was initially attempted to increase the energy density in the diet. High fat diets for cattle contain 5% to 8 % fat. Exceeding these dietary fat levels impairs rumen function. Lactating cows are the primary animals to be supplemented because of their increased energy requirements, and the difficulty involved with getting these cows rebred. It is important to note that in all the studies discussed in this section, fat –fed animals and control animals were receiving the same amount of energy!

Early studies (Talavera et al., 1985; Williams, 1989) indicated that feeding high fat diets to cycling heifers and postpartum cows increased progesterone production and the lifespan of the corpus luteum (CL). Higher progesterone levels during the luteal phase generally result in improved fertility.

Increasing dietary fat also results in increased follicular growth. More small and medium follicles are present in cows and heifers fed high fat diets (Thomas et. al, 1997; Ryan et al., 1992; Lammoglia et al., 1997). In addition, this increased follicular growth is often accompanied by increased estrogen and/or progesterone production. These changes in follicular growth and hormone production may enhance reproduction.

Impact on postpartum cows and first calf heifers: Timing may be every thing!

Do the fat-induced physiological changes previously discussed result in increased pregnancy rates? Mature cows fed high fat diets after calving show variable results. A few studies, especially with Brahman cattle, indicated that there was an advantage (DeFries et al., 1998). Other studies showed no effect of added fat on pregnancy rate (Carr et al., 1994; Dietz, 2000).

Interestingly, Montana researchers found that cows supplemented with fat during the last trimester have improved pregnancy rates during the next breeding season. The original objective of the experiment was to increase calf survival by feeding extra fat during gestation when they identified this “carry-over” effect (Table 3). This carry-over effect has been confirmed by researches in Missouri that reported a 7 to 16% increase in pregnancy rate. In addition, the Missouri group identified that the last trimester of gestation may be the important time to feed high-fat diets as feeding these diets after calving or during the breeding season did not increase pregnancy rates (Table 4).

Table3. Impact of high fat diets fed to mature cows on reproduction and calf weaning weights

Study	Treatment	No. of cows	Pregnancy rate (%)	Calf Weaning Weight (lbs.)
1 & 2	Control (low fat)	89	56.0	NR
	High Fat	179	70.0	NR
3	Control	47	84	487
	Self-fed high-fat tub	47	86	506
	Hand-fed high-fat block	49	94	494
4	Low fat	93	85	424
	High fat	93	91	428

Adapted from Bellows, 2000

Table 4. Timing of fat supplementation on reproductive responses in mature cows

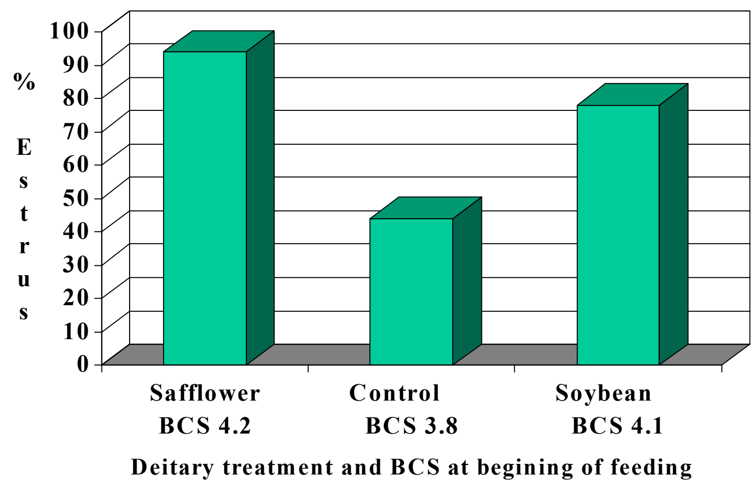
Diet	When Fed	% Cows cycling 2 weeks before breeding	% First Service Conception rate	% Overall Pregnancy rate
High fat	45 d Before calving	75	76	93
Control		56	62	86
High fat	From calving to breeding	50	60	87
Control		46	56	86
High fat	During the breeding season	47	60	90
Control		47	50	89

Zumbrunnen et al., 1999

Primiparous cows appear to derive the most benefit from feeding additional fat. Several studies indicate increased pregnancy rates of 13 to 15 %. This increase is primarily due to more high-fat fed heifers cycling early in the breeding season, which in turn means greater first service conception rates. In addition, calves from these heifers are 15 to 30 lbs. heavier at weaning.

First calf heifers in poor body condition can also benefit from the positive effects of increased dietary fat. Low body condition heifers (< BCS 5) often do not respond as well to additional energy from starch sources as expected. Low BCS heifers on high-fat diets receiving the energy as controls had dramatic increases in the percentage of heifers cycling by the beginning of the breeding season (Figure 3).

Figure 3. Effect of different fat supplements on estrus in thin first calf heifers



Bader et al., 2000

Developing heifers is there an advantage to fat?

The research on developing heifers is less extensive than studies on postpartum cows and heifers. Lammoglia and co-workers (2000) reported a high-fat diet increased pregnancy rates and cyclicity in heifers of a double muscled breed, but it had little effect or a negative effect in other breeds. In contrast, we have preliminary data that indicates an advantage to feeding whole cottonseed (5 % fat diet) to developing beef heifers (Figure 4). The difference between the two studies may be related to the length of time the high fat diet was fed before breeding. Our heifers were fed the high fat diet for 75 days before breeding compared to 162 in the other study. We are continuing further research to determine if short-term feeding of high fat diets, perhaps during synchronization, will improve reproduction in heifers.

Does source of fat matter?

In general, unsaturated fat sources should give better results for all production phases. Linoleic acid serves as a precursor for prostaglandin F2α whereas linolenic, eicosapentanoic (EPA), and docosahexanoic (DHA) acids may inhibit prostaglandin F2α production (Funston, 2004). Oil seeds such as safflower, sunflower, soybeans and cottonseed contain high concentrations of polyunsaturated fatty acids, and all of these oilseeds have given positive results in various studies. These oilseeds should be fed whole or gently cracked as pressed products and meals will not contain sufficient oil to be of benefit. Highly saturated fats such as animal fats and some of the rumen-protected products do not appear to perform as well as oil seeds.

Fish oil or fish meal may also be of benefit, but little beef cattle reproductive research has been complete with this product. A recent study indicates that fish meal reduces the oxcytocin induced increase in prostaglandin F2α in heifers with low progesterone production (Wamsley et al., 2005). However, feeding a 0.45 kg of a supplement (EnerGII, Bioproducts) that was high in EPA and DHA did not influence AI or overall pregnancy rates in heifers (Table 5, Wuenschel, unpublished data).

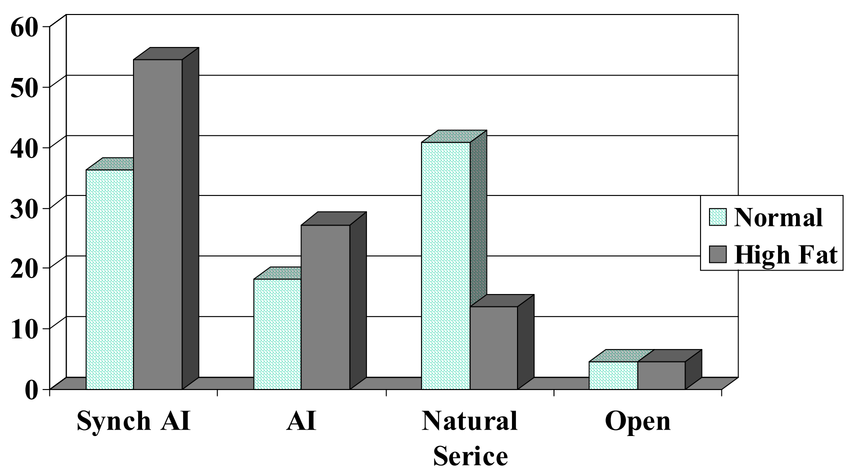
Table 5. Effect of normal or EPA-DHA containing supplements on AI and overall pregnancy percentages in replacement beef heifers.

	Supplement		
Pregnancy status	EnerGII	Corn/Soy	P-value
% Pregnant AI	51.4 (54/105)	49.1 (53/108)	0.73
% Pregnant Overall	87.6 (92/105)	93.5 (101/108)	0.14

Wuenschel, unpublished

In the Eastern US, whole soybeans and whole cottonseed are the preferred and low-fat choices. Fish meal is available, but tends to be expensive as it is valued as a protein source for several classes of livestock. However, recent reports from Missouri and Nebraska (D. Patterson, personal communication and R. Funston, unpublished data) indicate that replacement heifers supplemented with whole soybeans may have impaired reproduction. It is hypothesized that high levels of phytoestrogens may be detrimental to development of the replacement beef heifer.

Figure 4. Effect of High Fat Diet During the Peripuberal Period in Beef Heifers



Cuddy, 2000

Protein Intake

Protein deficiency also delays return to estrus. However, research on protein effects on reproduction is often confounded with energy deficiency or general poor nutrition. Protein supplementation to pregnant or early lactating cows grazing dormant western range forages, which are protein deficient, decreases the postpartum interval and increases pregnancy rates (Vanzant and Cochran, 1994). Similarly, developing replacement heifers grazing protein deficient forages respond to combined protein and energy supplementation with decreased age at puberty and enhanced pregnancy rates. Increasing the amount of digestible intake protein (DIP) enhances digestibility of and energy intake from medium to low quality forages. Therefore, whether protein-induced improvements in reproductive efficiency are a direct effect of protein and/or amino acids or a result of improved energy availability is unclear.

In the East, protein levels are often above adequate to marginal in cool season pastures and high quality hay (i.e. second cutting). Protein deficiencies may be a concern for cows consuming poor quality first cutting hay or mature warm season grass pastures. In addition, heavy milking cows and primiparous cows will have a high protein requirement.

The measurement of protein content in the diet used to balance diets for cows and heifers appears to be important. The commonly used measure of protein in the diet for cattle was crude protein (CP) which is based on the nitrogen content of the feedstuff. Metabolizable protein (MP) is a measure (or estimate) of the protein reaching and absorbed by the small intestine. Using MP designed supplements for pregnant heifers did not alter body weights or body condition of heifers compared to heifer fed supplements based on CP (Patterson et al., 2003). However, heifers consuming supplements based on MP had

5% greater pregnancy rates as 2 year-olds which increased the value of each bred heifer by $13.64.

While a more refined estimate of protein content of the diet, MP cannot be measured directly by chemical analysis and must be estimated from in situ digestion trials of similar feedstuffs. For grains and oilseeds, estimates of MP are fairly accurate; however, estimating MP values of forage is more challenging due to wide variations due to species, soil fertility, and plant maturity.

By-Pass or undegradible intake protein

Because forages, especially pasture, contain mostly DIP, there has been interest in the use of undegradible intake protein (UIP) or rumen by-pass protein to enhance beef production. Missouri researchers reported that addition of 0.2 lbs. of blood meal increased average daily gains in stocker steers. Work with gestating or early lactating cows indicates that addition of rumen by-pass protein usually decreases weight loss, slightly increases weight gain, enhances milk production, and alters blood metabolites. Lactation and body weight effects of UIP in postpartum cows may be dependent on amount of UIP added to the diet, parity, and/or protein content of the forage.

The effects on reproduction are less impressive. By feeding a protein supplement that was 30% UIP during the postpartum period, Wiley and coworkers (1991) were able to reduce postpartum interval and increase the number of first-calf heifers rebred during the first 21 days of the breeding season. However, overall pregnancy rates were not affected by feeding UIP. In contrast, increasing UIP content of the diet postpartum did not influence reproductive measures in first calf heifers (Alderton et al, 2000; Anderson et al., 2001). Feeding primiparous cows grazing endophyte-free stockpiled fescue 100g of UIP pre- and postpartum did not reduce postpartum interval (Strauch et al., 2001).

Montana researchers (Dhuyvetter et al., 1993) reported an earlier return to estrus after calving in mature cows receiving 25% of their protein supplement as by-pass compared to 50% by-pass protein. However, overall pregnancy rates were not influenced by UIP level in the diet. The lack of impact of UIP on reproduction in mature cows appears to be independent of forage quality (Sletmoen-Olson et al., 2000; Encinias et al., 2005.)

The situation is also confusing in replacement heifers. In one study, feeding 250 g of UIP to heifers delayed puberty compared to heifers fed monensin, but did not hurt over all conception rates (Lalman et al., 1993). In contrast, feeding 100 g of UIP decreased age at puberty and increased pelvic areas (Graham, 1998; Table6). In addition, UIP supplemented at 216 g or 115 g per heifer per day increased FSH production and/or secretion (Kane et al., 2004). The effects of UIP on replacement heifers appears to depend on UIP supplied as well as UIP in the base diet.

Table 6. Effect of UIP on developing replacement heifers

	UIP (grams per day)	
	0	100
Average Daily Gain	1.86	2.1
Pelvic area (sq. cm)	150.6	162.8
Cycling %	54.0	77.0

Graham, 1998

At present, there are many unanswered questions about the impacts of UIP on reproduction. Producers and clinicians should continue to watch for new developments in UIP feeding. More research is needed to correctly match the level of UIP to the forage and to stage of production of the cow. In addition, the cost/benefit ratios of UIP supplementation must be considered.

Excessive protein

Over-feeding of DIP either as protein or urea has been associated with decreased pregnancy rates in female dairy and beef cattle (Blanchard et al, 1990; Sinclair et al., 2000). It appears that exposure to high levels of ammonia or urea may impair maturation of oocytes and subsequent fertilization or maturation of developing embryos. However, supplying adequate energy for excretion of excess ammonia or urea may prevent decreases in fertility in dry cows or heifers (Garcia-Bojalil et al., 1994). In addition, not all studies have observed negative effects of elevated BUN concentrations on embryo quality or pregnancy rates (Jousan et al., 2002)

Minerals and Vitamins

Although energy and protein are the major nutrients impacting reproduction, minerals and vitamins play an important role in reproductive performance. For this discussion a brief examination of the literature pertaining to mineral and vitamin nutrition of the beef female will be presented. Deficiencies of P, Cu, I, Mn, Se, Zn and vitamin A have been associated with decreased fertility. Recent changes to the Nutrient Requirements of Beef Cattle (NRC, 1996) have adjusted cow requirements for these nutrients and these are the best current guidelines available.

Mineral trials are often extremely complex and confounded with the various combinations of minerals presented in the supplement or primary forage. Most forage in the East is deficient or marginally deficient in calcium (Ca), phosphorus (P), magnesium (Mg), copper (Cu), selenium (Se), and zinc (Zn). In addition, excessive amounts of iron (Fe), molybdenum (Mo) and sulfur (S) can often alter absorption of other minerals particularly Cu. Eastern soils tend to be high in Fe with localities high in S. Dietary levels of Fe, Mo and sulfur S that should cause concern are 400 ppm, 2 ppm and 0.2% respectively. Soil pH and mineral content can have dramatic impacts on mineral content of forages, and actual availability of minerals from different forage sources is still under investigation. In general, availability and absorption of minerals contained in forage or grains are considered to be low. Commonly used fertilizer sources for the East such as poultry litter and biosolids can also change the mineral profile of forages.

Although trace minerals may be important for early embryonic survival (Hostetler et al., 2003), research indicates positive (Kropp, 1990; Swenson et al., 1998) or no reproductive response (DiCostanzo et al, 1986) to trace mineral supplementation. Positive effects of mineral supplementation, if any, tend to be subtle, year dependent, or age dependent. Organic trace mineral supplementation increased AI or 30 d pregnancy rates in some years, but not others (Muehlenbein et al., 2001; Ahola et al., 2004). Furthermore, mineral supplementation did not impact final pregnancy rates in those studies. Arthington and Swenson (2004) found supplementation with organic minerals enhanced reproduction in young but not mature Braford cows. A report of excessive supplementation (2x NRC levels) of Cu, Co, Mn, and Zn reducing reproductive performance is more disturbing (Olson et al., 1999).

Minerals are stored in the animal in bone (Ca, P) or liver (Co, Cu), and can be recycled within the body (Fe). In addition, uptake of minerals is tightly controlled with absorption of increasing in times of deficiency. Producers and clinicians should be cautious about attributing decreased reproductive performance solely to mineral deficiencies or imbalances without performing the appropriate review of diets accompanied by diagnostic tests and biopsies. Consultation with extension veterinarians, toxicologists and nutritionists is strongly encouraged.

It appears that most standard mineral mixes recommended by Extension Specialists or nutritionist for your area should support adequate reproduction. An example of recommended mineral concentrations for beef cows in Virginia are shown in table 7. Similar levels are most likely appropriate for most of the Eastern US but localities will vary (i.e. Florida), so producers and clinicians should use mineral mixes formulated for their state.

Table 7. Recommended concentrations of minerals in mineral mixes for brood cows in Virginia*

Macro Mineral	Percentage (%)	Micro Mineral	Parts/million (ppm)
Salt	15-30	Copper	1000-2500
Calcium	0-12	Iodine	26-52
Phosphorus	0-12	Manganese	1800-3600
Magnesium	8-14	Selenium	26-60
Sulfur	0-3	Zinc	1800-3600

* Rate variations based on forage mineral content and daily mineral consumption

Winter hay based diets can become deficient in Vitamin A. However, cattle grazing green forage generally are not deficient in vitamin A, D, or E. Supplementing beta-carotene to dairy cow diets improved reproduction (Iwanska and Strusinska, 1997). Due to consumption of stored forages and high milk production, dairy cows are more likely to need additional beta-carotene.

Ionophores

Rumensin® and Bovatec® act by altering the types of microbes in the rumen, thereby enhancing digestion and growth rate. Addition of ionophores to replacement heifer diets can reduce age at puberty by 15 to 30 days while increasing growth rate (Moseley et al., 1982). Although some of the reproductive effect may be due to ionophores action in the rumen, evidence indicates there may be systemic actions as well. Response to ionophores appears to be less dramatic in light-weight or poorly fed heifers.

Feeding ionophores decreases postpartum interval in mature cows and first-calf heifers (Randal, 1990). However, this reduction in postpartum interval does not always increase pregnancy rates at the end of the breeding season. Benefits of using ionophores in postpartum cows may be greater in herds that have long postpartum intervals.

Nutritional Management for Successful Reproduction

Based on what we have discussed today, it is apparent that there are no nutritional supplements or technologies currently available that will greatly enhance reproduction in nutritionally mismanaged cattle. Therefore, nutritional management should focus on maintaining cattle in proper nutritional status or achieving that status by critical reproductive events (i.e. calving, breeding).

Key management strategies are:

1. **Ensure sufficient energy is available to support reproduction**
    a. Body condition score cows and achieve BCS 5 in cows and BCS 6 in heifers by calving (latest) or 60 days before calving (preferred).
    b. Maintain cow body condition from calving through breeding for cows in proper body condition, and increase body condition in cows that are below optimal BCS at calving.
    c. Feed thin cows and 1st calf heifers in a separate group(s) from main herd.
    d. Provide energy supplementation from the most economical local source.
    e. If fats are an economical source of energy, include oil seeds or fats to increase dietary fat up to 5% of total diet dry matter.
2. **Provide optimum level of dietary protein**
    a. Balance diets on MP if possible
    b. Provide sufficient DIP for adequate rumen function
    c. Avoid over supplementation of protein
    d. Inclusion of UIP in diets may not be effective
3. **Include ionophores in diets when possible**
4. **Base mineral supplementation on forage mineral content and local deficiencies**
    a. Supplement P only when needed
    b. Pay attention to trace mineral levels especially Cu, Se, Mn, and Zn
    c. Be aware of mineral antagonisms

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