MANAGING ENERGY RESERVES TO OPTIMIZE REPRODUCTION

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Introduction

Efficiency in the cow-calf enterprise depends largely on the reproductive performance of the cow herd. It has recently been estimated that reproductive performance in beef is about five times more important economically than growth and product quality. A review by Guilbert (1992), points out that the principal factor influencing reproduction is general under-nutrition due to feed shortage or poor feed quality. If cattlemen are going to maximize return from their resources, they must match feed resources with biological type of cow, take advantage of new advances in technology, and utilize those management tools which optimize cow herd performance.

Diets containing sub-maintenance levels of energy have resulted in delayed onset of puberty (Lamond, 1970; Drymundsson, 1973 a,b), prolonged postpartum anestrus, (Dunn and Kaltenbach, 1980), enhanced effects of suckling on anestrus (Williams, 1990), and an increased onset and duration of seasonal anestrus (Hulet et al., 1985). Inadequate protein intake can also result in reduced pregnancy rates in cows receiving diets containing equal energy (Sasser et al., 1989). Nutrition in the postpartum cow is especially important since several biological events (maximal lactation, uterine involution, return of cyclic functions, conception and early embryonic development) are overlapping and competing for available nutrients. It has been hypothesized (Swanson, 1989) that nutrition during this time dramatically affects reproduction because growth in young females and mammary gland metabolism take priority over the reproductive system in utilizing available nutrients.

The effect of nutrition and energy reserves on reproduction have been reviewed by numerous researchers (Dunn and Kaltenbach, 1980; Dziuk and Bellows, 1993; Entwistle, 1983; Hanzen, 1986 and Randel, 1990). In general, these reviews suggest: 1) failure in reproduction may occur when beef cows receive diets deficient in energy, protein, phosphorus, manganese, copper, cobalt and zinc; 2) most cases of protein, vitamin and mineral deficiencies are confounded with the effects of low energy intake; and 3) under practical management conditions, much of the variation in reproductive performance of beef cows may be accounted for by differences in total energy intake and body condition. Since the common factor among these conclusions is energy intake, this paper will focus primarily on how energy requirements and body condition (energy reserves) relate to reproduction in beef cows.

Energy Reserves and Body Condition Score (BCS)

Estimating Energy Reserves. For years researchers and beef producers have tried to find a fast, noninvasive means of estimating body composition of the beef cow so that an accurate prediction of her energy needs can be made. Estimates of body composition have involved both objective and/or subjective measurements. The most direct means of estimating body

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composition involves carcass measurements and tissue sample analysis.

However, this method involves sacrificing the animal and, therefore, is of little value to th producer as energy reserves of the cow herd are assessed.

Research (Dunn et al., 1983; Houghton et al., 1990a; Wagner et al., 1988) has shown tha body composition (body energy reserves) can be easily and accurately estimated through the us of body condition scores (BCS). Table 1 gives a description of the commonly used 9-poin system. A BCS system should provide a means to group animals that have similar energy reserve and nutritional requirements. Lemenager et al. (1980) reported that weight alone is not a accurate predictor of relative TDN requirements of beef cows. In that study, visual bod condition score (BCS) combined with weight predicted relative TDN requirements of pregnan cows during late gestation more accurately than did weight alone. Body condition score accounted for 16% of the variablility in weight indicating that degree of fatness is an importan consideration in evaluating the weights of beef cows (Northcutt et al., 1992). These researcher also found that condition score was more highly correlated with weight (.48) than with heigh (.10). Body condition score was also superior to live weight and weight:height ratio as a predictor of total carcass energy on a live and hot carcass weight basis and carcass fat on a ho carcass weight basis (Wagner et al., 1988). Recent reviews of the literature (Short et al., 1990; Williams, 1990; Randel, 1990) have emphasized the importance of BCS as a practical indicator o nutritional status and its effect on reproduction in the postpartum cow. Althought subjective, the BCS system is attractive to the producer because cattle do not have to be restrained and excess labor is not necessary to take the measurement (Lemenager and Martin, 1982).

Marchello et al. (1979) evaluated the usefulness of various commerical cuts and their relation to total body composition (specifically bone, fat, and protein). Although these results accurately predict body composition, slaughter of the animal is required. Houghton et al. (1990c) related Marchello's equations to total body energy, empty body weight and BCS. Using Houghton et al. (1990c) prediction equations, carcass energy and total body energy can be determined for a live animal with relative ease and accuracy.

Body condition scores provide a means of describing an animal. For example, a frame size 6 mature cow with a body condition score of 3 would weigh approximately 1100 pounds. Characteristically, she will show little fat cover as previously described (Table 1) and, if slaughtered, she would have approximately 9% carcass fat. If one assumes a 75-80 lb change in weight is required to change one BCS, that same cow in a body condition score of 5 would weigh approximately 1250 pounds with 18% carcass fat. If the cow was a body condition score 7, she would weigh about 1400 pounds with a body fat content of 27%.

Body Condition and Maintenance Requirements. The 1996 NRC now acknowledges that weight alone is not an accurate estimator of the energy requirements (NE_m and NE_p) for beef cows. In past editions (NRC, 1984), empty body weight was the only factor considered in the determination of cow energy needs. Using mature Charolais X Angus rotational cross cows, Houghton et al. (1990a) found that body condition score at calving affected NE_m requirements per Mcal of body energy by 30 and 60 days postpartum. Thinner cows lost less condition, and had a 32.5% greater predicted NE_m ($Mcal/W^{.75}$) requirement than fatter cows. This is consistent with results reported by Klosterman et al. (1968), Russel and Wright (1983) and Thompson et al. (1983a). When energy was expressed as total daily predicted maintenance energy (Mcal/d), however, fatter cows required 21% more energy than moderately conditioned cows (Houghton et al., 1990a). The increased total daily energy requirement for fatter cows could be due to increased weight (Thompson et al., 1983b), which results in a larger $W^{.75}$ (Brody, 1945; Kleiber, 1961). Because of its influence on daily fasting heat production, an increase in $W^{.75}$ can result in an increased NE_m ($Mcal/W^{.75}$) requirement (Lofgreen and Garrett, 1968).

Working with Angus, Hereford, and Simmental cows, Ferrell and Jenkins (1984c) obtained different results. Daily ME intakes were less (55.2 versus 62.4 MJ/day) and daily gains were greater (.88 vs .24 lb/d) for lean versus fat cows. Estimates of ME requirements for maintenance in that study were 452 $kJ/W^{.75}$ for lean cows and 505 $kJ/W^{.75}$ for fat cows. The authors suggest that nutritional manipulation prior to the initiation of studies that estimate NE_m requirements could be a factor contributing to the inconsistency of data regarding the effect of body condition on maintenance requirements.

Wagner et al. (1988) reported that both thin and fat Hereford cows have lower NE_m requirements ($Mcal/W^{.75}$) than moderately conditioned Hereford cows. The lower NE_m requirement of fat cows could be the result of an insulatory effect of the subcutaneous fat cover in cooler environments (Curtis, 1983). Because heat production is more closely related to the synthesis and turnover of protein than body weight (Webster, 1980), the proportion of fat and protein in fleshy cows could also explain the lower maintenance requirements. Estimated maintenance requirements per kg of tissue are lower for fat than protein (Thompson et al., 1983a). The tendency for fatter cows to have a lower NE_m per Mcal of body energy supports the work of Blaxter (1962), Mitchell (1962) and Chester (1975), who suggest that energy required for maintenance is determined primarily by lean body mass.

Energy Intake and Maintenance Requirements. Armstrong and Black (1984) suggested that differences observed in energy requirements for maintenance between fat and thin cows may reflect differences in level of feed intake. Maintenance energy requirements are dependent on energy intake (Reid and Robb, 1971; Kromann, 1973) and increase when cattle are fed a high plane of nutrition compared to requirements of cattle fed a low plane of nutrition (Trowbridge et al., 1915; Hogan et al., 1922; Flatt et al., 1969). Cows fed low energy intakes prepartum had reduced daily maintenance energy requirements per $W^{.75}$ by parturition (Houghton et al., 1990a). Data obtained in sheep (Graham, 1969; Ferrell et al., 1983) and cattle (Ferrell et al., 1976; Ledger and Sayers, 1977) suggest that the increased size of metabolically active organs, especially the liver and gastrointestinal tract due to increased nutritional levels, may be responsible for the higher NE_m requirements. Ledger and Sayers (1977) also observed a decrease in the dry matter intake required to maintain steers at a constant live weight. Significant loss of internal organ and empty digestive tract weights occurred even though steers maintained live weight. They concluded that maintenance requirements are reduced because animals utilize energy more efficiently when fed sub-maintenance energy for extended periods of time. Therefore, basal metabolism of the animal may be lowered due to an atrophy of the metabolically active organs during periods of feed restriction (Buskirk, 1989).

Breed, Cow Type and Maintenance Requirements. Approximately 70 to 75% of the tot annual energy requirements of the cow are required for maintenance. The cow's genetic potenti for production (growth rate, milk yield) accounts for most of this variation in maintenanc requirements (Ferrell and Jenkins, 1985a). Lemenager et al. (1980) used Hereford (H), Angus Hereford (AH), Charolais X Hereford (CH) and Brown Swiss X Hereford (SH) cows t determine the effect of breed type on TDN requirements. During lactation the AH, CH and Sl cows required 13%, 14%, and 39% more TDN, respectively, to maintain condition scores equ to the H cows. These researchers found that weight, condition score and estimated mil production appeared to predict relative TDN needs during early lactation better than weight c milk production alone.

Montano-Bermudez et al. (1990) chose three breed types similar in size and growth rat but differing in genetic potential for milk production, to estimate NE_m requirements of crossbre beef cows. These researchers used Hereford X Angus (L), Red Poll X Angus (M) and Milkin Shorthorn X Angus (H) breed types to create cows with the potential for low, moderate and hig milk production, respectively. Their results indicated that the H and M cows required 12% mor energy per unit metabolic weight than the L cows to maintain weight during both gestation an lactation. Steer and heifer calves that were half-sibs and offspring of the cows mentioned abov were evaluated in the feedlot as part of that study. Calves from the H and M dams had an 11% higher energy requirement than calves from the L dams. These results collectively suggest tha NE_m requirements are dependent upon genectic potential for milk production. Similarly, Ferrel and Jenkins (1984) found that cow types with a higher potential for milk production (Jersey and Simmental crosses) had higher daily maintenance requirements (kcal/$W^{.75}$) than cows with moderate to low milk production potential (Angus X Hereford and Charolais crosses). In a different trial, Hereford cattle had lower NE_m requirements than Simmentals and used metabolizable energy with greater efficiency for both maintenance and gain (Ferrell and Jenkins, 1985b). Similarly, Anderson (1980) and Byers (1982) also reported that Simmental or Simmental cross cattle had higher maintenance requirements than either Angus or Hereford cattle.

Increased relative size and metabolic activites of the vital organs explained the 24% increase in maintenance requirements during lactation of rats (Canas et al., 1982). In studies with cattle, although the authors did not indicate the age of the dairy animals, results suggested that the dairy breeds (Holstein and Jersey) had much larger internal organs than first-calf Hereford heifers (Smith and Baldwin, 1974; Ferrell et al., 1976). These results indicate that the higher NE_m requirement associated with an increase in the genetic potential for milk production was closely associated with the size and energy expenditures of the visceral ograns, especially the liver and gastrointestinal tract (Ferrell and Jenkins, 1984a). Montano-Bermudez et al. (1990) found that variation in milk production explained only 23% of the variation in energy requirements for maintenance. These researchers suggested that milk production potential is not the only factor affecting NE_m requirements. Other important factors such as thermoregulation, body composition, behavior and activity may also vary among breeds and contribute to breed differences in NE_m requirements.

Thompson et al. (1983a) found that maintenance energy requirements tended to be higher for Angus X Holstein (AHO) than for Angus X Hereford (AHE) cows (140.3 versus 127.6 kcal/BW$^{.75}$). These results are consistant with the research cited above. However, results of this study also indicate a body composition X breed interaction. These researchers found that the NE_m requirements (Mcal/W$^{.75}$) tended to be less for fatter AHE cows and slightly higher for fatter AHO cows when both thin and fat cows were compared within breed type. All cows were reported to have similar amounts of estimated body protein, therefore differences in NE_m requirements between thin and fat cows should have been due to differences in body fat. The researchers suggested that increased body fat did not lower NE_m requirements for AHO cows because they deposit a greater proportion of their fat internally than typical beef cattle (Callow, 1961; Royal Smithfield Club, 1965; Charles and Johnson, 1976). Fatter AHO cows may also have higher NE_m requirements because metabolic activity of internal adipose tissue is expected to be greater than that of more peripheral depots (Thompson et al., 1983a). Therefore, fatter, higher milking cows may not have lower NE_m requirements as would be expected of fatter cows with more typical beef breeding. If Simmental and other beef breeds with potential for high milk yield deposit their fat in a manner similar to the dairy breeds, a higher NE_m requirement for fatter cows relative to breed type is reasonable.

Energy Reserves and Reproductive Performance. Excellent research in recent years has linked the percentage of body fat of beef cows in specific stages of their productive cycle to reproductive performance and overall productivity. Since body condition scores reflect the relative level of fatness of beef cows, it stands to reason that body condition scores are also related to reproductive performance. Some of the original work that made this relationship evident was conducted by Whitman (1975). Data in Table 2 summarizes this work and show that cows in varying body condition at calving differ greatly in how long it took them to resume cycling once they had calved.

Producers also need to consider time of calving when they decide on a target body condition score at calving. For example, early calving cows can be slightly thinner than late calving cows because they have additional time to recycle and rebreed. Recent research at South Dakota State University reinforces this concept and is summarized in Table 3.

These data clearly point out the relationship between body condition score, time of calving and reproductive function. This relationship should encourage producers to sort cattle by body condition so that they might optimize nutritional and reproductive efficiency. Two-year-old, first-calf heifers should be separated from mature cows so the younger females can be fed a higher plane of nutrition to ensure that they rebreed. To further improve the efficiency of this system, some cattlemen are also sorting their mature cows and feeding their thin mature cows with the two-year-old cows. This gives thin, mature cows an opportunity to consume larger quantities of higher quality feedstuffs which will often result in improved reproductive efficiency of the cow herd.

Finally, body condition scores allow producers to formulate diets. For example, if a producer has a set of BCS 4 cows 60 to 90 days prior to the start of calving, a nutritional program needs to be designed that will allow those cows to reach the target body condition by calving (body condition score = 5 to 6). Research data indicate that, on the average, cattlemen should strive for a body condition score of 5 at calving in mature cows, while two-year-old, fir calf heifers may need to have a body condition score of 5.5 to 6.0. This slight increase condition in young cows can help compensate for the additional nutrient demand for growth a increased sensitivity to environmental stress that can affect reproductive performance.

Most research has indicated that a mature cow will need to gain or lose approximately ' to 80 pounds of body weight to change one body condition score. First-calf heifers, howev need to gain approximately 150 pounds to gain one body condition score (Ripberger, 199 Table 4 illustrates this concept and shows the proper weight gain necessary for mature cows varying body condition prior to calving. For example, the weight gain needed by cows moderate condition 120 days before calving is 100 pounds or 0.8 pound gain per day. In contras thin cows 120 days prior to calving must gain 2.2 pounds per day or approximately 260 pounds.

Similar differences are seen in mature cows varying in body condition after calving. I order for thin cows at calving to be in moderate body condition by 80 days postpartum, they mus gain approximately two pounds per day (Table 5). It is important to remember that these cow are also nursing calves at this point. This creates an extra demand for dietary energy and make rapid weight gain difficult for cows after calving without significant amounts of supplementation This further emphasizes the need for cows to be in moderate to near-moderate body condition a calving for optimal reproductive performance.

If cows are in good to moderate body condition at parturition, they can lose some weigh and condition after calving without significantly affecting the postpartum interval (Corah et al., 1975; Whitman, 1975; Richards et al., 1986; Hougton et al., 1990b). When cows are thin at calving, however, increased postpartum energy is needed to increase the percentage of females that will exhibit estrus during the breeding season (Dunn and Kaltenbach, 1980; Richards et al., 1986). Research by Wiltbank (1982) has shown that thin cows brought to moderate body condition from precalving through early lactation responded by showing estrus activity 20 to 40 days earlier than moderately conditioned cows that were maintained at moderate to borderline condition. Likewise, it has been shown that when first-calf heifers calved in a BCS of 4 (scale 1 to 9) and were fed to maintain weight after calving, they had reduced ovarian activity and lower pregnancy rates compared to heifers that calved in similar body condition and gained weight after parturition (Weltemann et al., 1986). Work at Purdue involved an integrated energy x reproduction approach with all other nutrients fed to meet NRC (1984) recommendations. In the Houghton et al. (1990b) study, energy-deficient, thin cows had a longer postpartum anestrous interval (Table 6); but if they cycled, first-service conception rate was extremely high (Table 7). Also, cows in thin, moderate or fleshy condition at calving had improved pregnancy rates when energy was manipulated to move cows toward moderate BCS before the breeding season compared to cows moving away from moderate BCS (Table 8). This research suggested that mature cows should be between a BCS 4.6 (scale =1 to 9) and 5.7 at breeding (carcass lipid level of 15.8 to 20% and total empty body lipid of 13.3 to 17.8%) to optimize return to estrus and pregnancy rate.

It has been proposed that a minimum amount of body fat may be necessary in females before they can exhibit estrus. This relationship exists in numerous species, including rats (Frisch et al., 1975, 1977) and humans (Frisch et al., 1973). Amenhorrhea began in women when body fat decreased to less than 13%. Additionally, a delayed return to estrus (Reese et al., 1984) and a suppression of LH release was observed when ewes obtained a BCS of ≤ 2 (1-9 scale; Tatman et al., 1990). Hougton et al. (1990b) reported that cows fed to maintain moderate to borderline BCS from precalving through breeding should posses no less than 15.8% carcass lipid, or 13.3% total empty body lipid (BCS ≈ 4.5 on 1-9 scale), at parturition to obtain an acceptable postpartum interval of approximately 60 days. In addition, cows can possess as little as 14.7% carcass lipid, or 12.4% total empty body lipid (BCS ≈ 4.0% on 1-9 scale) at parturition and still obtain an acceptable PPI (≤ 60 days) and pregnancy rate (>90%) if they are provided 130% of NRC (1984) energy recommendations for 60 days postpartum. Furthermore, cows should not be allowed to exceed 20% carcass lipid, or 17.8% total empty body lipid (BCS ≈ 6.33), at breeding to optimize pregnancy rate.

Protein and Reproduction. Many cattle are wintered in the United States on forages that are marginal to deficient in crude protein. The response to supplemental protein under grazing conditions is variable and dependent on forage availability, forage quality and environment (Rittenhouse et al., 1970; Kartcher, 1980). In general, positive responses to protein supplementation (rumen digestion and animal performance) are expected with forages containing less than 6% crude protein (Campling, 1970; Kartchner, 1980). The effect of protein supplementation on reproduction, however, is variable. Some studies have reported minimal effects of protein restriction on postpartum reproduction (Davis et al., 1977; Anthony et al., 1986; DelCurto et al., 1990) while others have suggested that supplementation may increase reproductive efficiency (Clanton, 1982; Wallace, 1987; Sasser et al., 1988). Sasser et al., (1988) reported that when diets were equal in energy, protein deprivation did not affect calving difficulty, uterus involution or presence of the first ovarian follicle. However, a deficiency of protein tended to lengthen the postpartum anestrous interval and decreased the number of females exhibiting estrus, first service conception rate and overall pregnancy rate by 110 days postpartum.

The effect of protein deficiency also appears to be related to BCS in much the same way as energy deficiency with properly supplemented cows maintaining more of their initial weight and BCS. DelCurto et al. (1990) speculated that the increased production observed with protein supplementation is mediated through increased forage intake, which is in turn correlated with increased forage digestibility, rate of digestion and digesta flow through the GI tract.

Managing Energy Reserves

Although Tables 5 and 6 indicate the weight gain needed by cows to reach moderate body condition during the pre- and postcalving periods, they do not take into account the energetic efficiency of thin versus fleshy cows. Recent research conducted at Purdue University has examined the role of energy in cow diets to change cow body condition score. This system takes into account the initial body condition of cows and is based on the net energy system currently used in growing and finishing cattle. In this system, the energy requirements of cattle are expressed in megacalories (Mcal). These energy units are usually expressed in two ways - first, as Mcal of net energy for maintenance (NE_m) and secondly, as Mcal of net energy for weight change (NE_ρ). These measurements are valuable tools in determining required energy levels but, unfortunately, little has been done until recently to apply these concepts to nutritional progra for cows.

Net energy for maintenance (NE_m) has classically been defined as 77 kcal/$W^{.75}$ for b cattle and was confirmed by Buskirk et al. (1992) and Graffam (1992) for mature beef cows a gestating first-calf heifers. Lactating first-calf heifers, however, responded differently in both t Graffam (1992) and Ripberger (1997) studies. Ripberger (1997) determined the N requirements of Angus and Simmental first-calf heifers to be 97.2 kcal/$W^{.75}$ (23% increase) a 106.9 kcal/$W^{.75}$ (38.8% increase), respectively, compared to the classical definition. Research Blaxter et al. (1966), Graham et al. (1974) and Graham (1980) also support this higher N requirements in first-calf heifers. It has been postulated that the growing first-calf heifer's high protein deposition and protein turnover rates, compared to the mature cow, maybe responsible f the higher NE_m requirements. Recognizing the impact of protein synthesis on basal ener expenditures, Smith (1970) and Ferrell and Jenkins (1985) also contend that a relatively lar proportion of NE_m expenditures can be attributed to energy expenditures of the visceral orga especially the liver and the gastrointestinal tract. Therefore, it is suggested that the componen of growth, age, lactation and rate of protein synthesis and turnover combine to exert an increas energy demand from the metabolically active organs.

The additional 12.5% increase in the NE_m requirements for Simmental first-calf heife above that obtained for Angus heifers (Ripberger, 1997) is supported by many researchers (1: 15% increase) working with cows differing in milk production potential (Montano-Bermudez al., 1990; Lemenager et al., 1980). Canas et al. (1982) reported that increases in relative size ar metabolic activities of the liver, heart and kidney explained the 24% increase in maintenan requirements observed with lactating rats..

Therefore, an objective of the Purdue study was to identify and recommend specif energy supplementation programs that will achieve a specific amount of gain over time in matu beef cows and lactating first-calf heifers. These data provided estimates of net energ requirements necessary to change weight of beef females that vary in body condition. Fc example, thin mature cows (BCS = 3) only need 1.64 Mcal of energy per pound of weight gai whereas fleshy cows (BCS - 7) need 2.97 Mcal of energy per pound of weight gain (Buskirk, e al., 1992). Ripberger (1997) reported slightly higher, but similar, values for first-calf heifers. I that study, thin heifers (BCS=3) required 2.06 Mcal while fleshy heifers (BCS=7) required 3.0 Mcal per pound of weight gain. The reason for differences between thin and fleshy females is th a pound of gain on a thin animal is primarily protein and water, whereas a pound of gain on fatter animal contains proportionally more fat. Since it takes 2.25 times more energy to put on pound of fat than a pound of protein, it stands to reason that the net energy for gain is higher fc fleshy cows than for thin cows. Requirements for other condition scores are shown in Table 9.

Implications

Table 10 summarizes data from the Buskirk et al. (1992) study and permits producers t calculate the energy needed to meet a targeted weight gain and BCS in mature cows. In addition the table takes into account the energy needed for fetal growth during the last trimester o gestation and the energy needed for average to superior milk production during lactation. A similar table could be constructed for lactating first-calf heifers using the 25-40% higher maintenance energy values and NE_p values determined by Ripberger (1977).

A question that often gets asked is whether or not it is efficient for cows to gain or lose body energy reserves (BCS) and then realign to moderate condition by calving? The answer is not an easy one. First, from an economic perspective, if cows gain body condition above what is considered ideal during the grazing season without supplementation, the extra body energy reserves can be used as a cheap source of supplement later in the production cycle. This would allow producers to utilize cheaper feed resources such as crop residues, stockpiled forage, and low quality winter range grasses to minimize feed cost. Second, from an energetic perspective, the literature would indicate that thin cows have a lower maintenance energy requirement and utilize energy more efficiently because visceral organ weights (liver, kidney, GI tract) are reduced. The data also suggest that thin cows have a long postpartum interval, but if they return to estrus after calving, their fertility is very good. Our challenge, then, is to get thin cows to return to estrus within 60 days after calving. The literature also indicates that thin cows gain weight more efficiently than moderate or fleshy cows. Using this information, producers could allow forages to increase cow BCS during the grazing season, use the extra body energy reserves that have accumulated as a source of cheap supplement during the second trimester of gestation, and then use the NE_{Δ} system to design a strategic supplementation program during the last trimester of gestation to obtain moderate body condition by calving. The environment is a variable that can add significantly to the energy requirements and must be considered in any production system when cows are border line in body condition. Maintaining cows in moderate body condition provides producers some insurance against environmental stresses that can reduce energy reserves beyond what is desired.

Diets containing deficiencies of energy, and to a lesser extent protein, significantly affect reproductive efficiency when energy reserves of the animal are less than optimal. When discrete amounts of energy reserves have been catabolized, reproductive function appears to be selectively suppressed through mechanisms that control higher neural centers (Lemenager et al., 1991). The complexity of interrelationships between factors controlling reproduction make it unlikely that a sole factor will be identified as being the messenger responsible for mediating nutritional effects on reproduction. Lemenager et al. (1991) postulated that when all metabolic reactions necessary for reproduction are considered, the net effect of positive and negative inputs must be large enough to induce a threshold potential for neural depolarization that causes the release of GnRH to drive the system. On the practical side, however, the use of body condition scores provides an accurate method of categorizing body energy reserves that impact reproductive efficiency. The combined use of cow weight, BCS and stage/level of production can be used to determine energy requirements and formulate diets that will allow producers to manage energy reserves, minimize supplementation cost, and optimize reproductive performance.

TABLE 1. WHAT ARE BODY CONDITION SCORES?

Body condition scores are numbers used to suggest the relative fatness or body condition of the beef cow. The most commonly used system in the United States is one that ranges from one to nine with a score of one representing very thin body condition and nine extreme fatness. A cow with a body condition score of five should be in average flesh and represent a target that many cattlemen strive for. The nine-point body condition scoring system is described below.

Nine-Point Body Condition Scoring System

1) **Emaciated.** Bone structure of shoulder, rib, back, hooks and pins are sharp to the touch and easily visible. Little evidence of fat deposits or muscling.

2) **Very Thin.** Little evidence of fat deposition, but some muscling in the hindquarters. The spinous processes feel sharp to the touch and are easily seen with space between them.

3) **Thin.** Beginning of fat cover over the loin, back and foreribs. The backbone is still highly visible. Processes of the spine can be identified individually by touch and may still be visible. Spaces between the processes are less pronounced. Carcass fat ≈ 9%.

4) **Moderately Thin.** Foreribs are not noticeable but the 12th and 13th ribs are still noticeable to the eye, particularly in cattle with a big spring of rib and width between ribs. The transverse spinous processes can be identified only by palpation (with slight pressure) and feel rounded rather than sharp. Full but straight muscling in the hindquarters.

5) **Moderate.** The 12th and 13th ribs are not visible to the eye unless the animal has been shrunk. The transverse spinous processes can only be felt with firm pressure and feel rounded but are not noticeable to the eye. Spaces between the processes are not visible and are only distinguishable with firm pressure. Areas on each side of the tail head are fairly well filled but not mounded. Carcass fat ≈ 18%.

6) **Moderately Fleshy.** Ribs are fully covered and are not noticeable to the eye. Hindquarters are plump and full. Noticeable sponginess over the foreribs and on each side of the tail head. Firm pressure is now required to feel the transverse processes.

7) **Fleshy.** Ends of the spinous processes can only be felt with very firm pressure. Spaces between processes can barely be distinguished. Abundant fat cover on either side of the tail head with evident patchiness. Carcass fat ≈ 27%.

8) **Very fleshy.** Animal takes on a smooth, blocky appearance. Bone structure disappears from sight. Fat cover is thick and spongy, and patchiness is likely.

9) **Obese.** Bone structure is not seen or easily felt. The tail head is buried in fat. The animal's mobility may actually be impaired by excessive fat.

TABLE 2. BODY CONDITIONS AT CALVING AND PERCENT SHOWING ESTRUS AFTER CALVING[a]

Body Condition at Calving	No. Cows	% in Showing Estrus - Days Postcalving 60	90
Thin (1-4)	272	46	66
Moderate (5-6)	364	61	92
Good (7-9)	50	91	100

[a]Whitman, Colorado State University, 1975.

TABLE 3. EFFECT OF BODY CONDITION SCORE ON PERCENTAGE OF COWS CYCLING[a]

Body Condition Score	No. of Cows	% Cycling May	June	July
		Early Calving Cows		
March condition score (prior to calving)				
≤ 4	45	10.0	28.2	70.5
5	84	17.8	43.5	85.6
6	43	41.9	77.5	97.5
≥ 7	25	45.9	76.6	94.7
		Late Calving Cows		
March condition score (prior to calving)				
≤ 4	14	0.0	0.0	44.7
5	41	7.5	26.0	74.4
6	22	0.0	35.3	98.5
≥ 7	6	0.0	65.8	99.1

[a]Pruitt and Momont, South Dakota State University, 1988.

TABLE 4. NEEDED WEIGHT GAINS IN MATURE PREGNANT COWS IN DIFFERENT BODY CONDITIONS[a]

		Weight Gain Needed to Calving, lbs.				
At Weaning	Needed at Calving	Calf Fluids And Membranes	Body Weight	Total	Days to Calving	ADG
Thin	Moderate	100	160	260	120	2.2
Borderline	Moderate	100	80	180	120	1.5
Moderate	Moderate	100	0	100	120	.8
Thin	Moderate	100	160	260	200	1.3
Thin	Moderate	100	160	260	100	2.6

[a] Wiltbank, 1982.

TABLE 5. NEEDED WEIGHT GAIN IN MATURE, LACTATING COWS IN DIFFERENT BODY CONDITIONS[a]

Body Condition		Weight Gain Needed to Breeding, lbs.		
At Calving	Needed at Breeding	Body Weight	Days to Breeding	ADG
Thin	Moderate	160	80	2.0
Borderline	Moderate	80	80	1.0
Moderate	Moderate	0	80	0.0
Thin	Moderate	160	60	2.7
Thin	Moderate	160	40	4.0

[a] Wiltbank, 1982.

TABLE 6. EFFECT OF BODY CONDITION SCORE (BCS) AT PARTURITION ON POSTPARTUM INTERVAL (PPI)[A]

BCS	PPI, days
3	88.5
4	69.7
5	59.4
6	51.7
7	30.6

[a] Adapted from Houghton et al., Purdue University, 1990.

TABLE 7. EFFECT OF BODY CONDITION SCORE (BCS) AT BREEDING ON FIRST SERVICE CONCEPTION RATE[a,b]

BCS	Conception Rate, %
3^{+}	100^{c}
4	100^{c}
4.5	94^{c}
5	80^{cd}
5.5	70^{d}
6^{+}	67^{d}

[a] Cows exposed to A.I. breeding when they individually reached 60 days postpartum.
[b] Adapted from Houghton et al., Purdue University, 1990.
[c,d] Means with unlike superscripts differ ($P < .05$).