EFFECT OF PROTEIN AND ENERGY SUPPLEMENTS ON COWHERD PERFORMANCE AND LOW-QUALITY FORAGE INTAKE AND UTILIZATION

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Format of Dissertation

This dissertation is presented in the Journal of Animal Science style format, as outlined by the Oklahoma Sate University graduate college style manual. The use of this format allows for independent chapters to be suitable for submission to scientific journals. Three papers have been prepared from the data collected for research to partly fulfill the requirements for the Ph. D. degree. Each paper is complete in itself with an abstract, introduction, materials and methods, results and discussion, implications and literature cited section.

CHAPTER I

GENERAL INTRODUCTION

Ruminants have been a major part of the agricultural community. When one thinks of ruminants, usually cows, sheep and goats come to mind, but within the classifications of ruminant are a wide array of species including the tiny mouse deer and the giant giraffe. Ruminants are diverse in size, color, body shape and geographic location. The biggest advantage of ruminants over other species is their ability to utilize cellulose and other fibrous carbohydrates. This unique characteristic gives ruminants an unconquerable advantage over much of the earth's land masses, because most land is not suitable for cultivation.

There are several ways to measure animal performance. One of the easiest methods is to measure weight and skeletal growth. Subjective measurements, like body condition score and conformation scores, can be useful indicators of measurements that are too difficult to directly measure or as an indicator of a threshold needed to maintain normal life functions. Reproduction can also be measured by recording onset of puberty or first estrus after parturition, number of services, conception rate and birthing intervals. Interestingly, reproductive performance has been suggested as being five times more important economically than growth performance and 10 times more important than product quality to beef cow-calf producers (Trenkle and Willham, 1977).

This research was conducted with the goal of providing a better understanding of the effects of protein and energy supplements on beef cowherd performance. The effects of level of supplementation and a combination of low level supplementation followed by feeding of concentrate for a short period in drylot were studied with heifers. With cows the effects of type of supplement and the sequence of supplementation before and after calving were studied.

The information included in this dissertation will be divided into six chapters. Chapter two is a review of literature. Chapter three discusses the 2-year, replacement heifer development study which focuses on the effects of postweaning diets on heifer growth and onset of puberty. The effects of feeding a rumen digestible-fiber or a soybean meal-base supplement, both before and after parturition, to cow herds is included in chapter four. Three years of data were collected covering the economically important traits of: pregnancy rates, calf growth, cow weight and body condition score changes. Chapter five contains data from intake trials performed in two consecutive years. Here, the direct effects of supplement type on low-quality forage intake and digestibility are compared, along with estimates of metabolizable energy and crude protein intake. The last chapter combines and summarizes the results from chapters three, four and five.

CHAPTER II

REVIEW OF LITERATURE

Development of Replacement Beef Heifers

Definition of Puberty

Puberty in heifers is when spontaneous ovulation occurs with estrus (Hafez, 1987). This involves a transition from an inactive ovarian state to regular intervals of ovulations and represents the process by which a female can reproduce itself. Joubert (1963) stated that there is a difference between puberty and sexual maturity in the cow, because puberty is defined as the time at which reproduction first becomes possible, and sexual maturity as the time when the animal reaches its full reproductive power.

Factors Affecting Puberty Age

The age of puberty varies greatly for cattle and is dependent on breed, growth rate, nutrition and environment. Beef breeds commonly reach puberty between 11 and 15 months of age (Hafez, 1987). Puberty studies done prior to the early 60's were reviewed by Joubert (1963), who concluded that dairy breeds generally matured earlier than beef breeds, and that Zebu-influenced cattle are considerably older than other breeds at puberty. There are economic benefits for having heifers calve first near their second birthday as compared to later in life (Lesmeister et al., 1973, Wiltbank et al., 1985). Therefore, age of puberty becomes extremely important within management systems that dictate heifers must calve near two years of age, especially when they are subjected to a restricted breeding season (Ferrell, 1982).

A common, general recommendation has been for producers to breed replacement heifers three weeks prior to the mature cowherd. This allows heifers more time postcalving to rebreed and more salable product to be harvested (Ferrell, 1982) from heifers, since weaning takes place on a given day rather than a given calf age. This practice should increase the number of heifers bred on their pubertal estrus. Byerley et al. (1987) indicated that fertility of heifers bred on their third estrus was 21% greater than heifers bred at the pubertal estrus. Perry et al. (1991b) also reported increases in fertility when heifers were bred on nonpubertal estrus rather than on pubertal estrus.

Nutritional Effects on Puberty Weight and Age

Joubert (1963) stated weight is one of the most influential factors affecting age at puberty. Nutrition controls growth rate, and therefore, nutrition can be used to hasten or delay the onset of puberty. Correlations between age at puberty and daily weight gains have indicated that onset of puberty can be hastened by increasing weight gains (Sorenson et al., 1959; Smith et al. 1976; Oyedipe et al., 1982). Greer et al. (1983) reported no cause-and-effect relationship between weight and age at first estrus. Rather, weight of puberty depends upon age at puberty, and age at puberty does not depend upon weight at puberty when the postweaning diets are known. Therefore, monitoring body weight or feeding to a particular weight within a given genotype can be a practical management tool to ensure optimal fertility levels.

Taylor and Fitzhugh (1971) indicated that heifers will reach puberty at some predetermined size, and Hafez (1987) believes this size or weight is related to a particular point on the growth curve. Critchton et al. (1959) found that heifers reared on different planes of nutrition reach puberty at different ages, but at a similar stage of physical development. Ewe lambs reach puberty from 50 to 60% of their mature weight (Dyrmundsson et al., 1973) and Brahman heifers are 60% of their mature weight and 95% of their mature height (Dale et al., 1959). No study could be found that compared puberty weight or size to mature weight of *Bos taurus* heifers. Yelich et al. (1993) found that *Bos taurus* heifers fed at various rates of gains postweaning had differing amounts of body fat at puberty, but had similar bone and muscle mass at first estrus. This study indicated the percentage or amount of fat heifers possessed at puberty has minimal influence on pubertal onset, and suggested producers should concern themselves with bone and muscle growth more than fat covering or fleshiness.

When weight gains are increased prior to weaning, pubertal age is reduced (Wiltbank et al., 1966; Arije and Wiltbank, 1971). This indicates it may be possible to use several postweaning nutritional programs depending on weaning weight. Moseley et al. (1982) indicated the onset of puberty may be limited by age in heavy weight heifers and by weight in light weight heifers. Comparing British to Brahman influenced heifers, Patterson (1991) found that postweaning nutritional levels emphasized the genotypic differences in age and weight of puberty. Even with this genetic diversity, optimal growth rates have been established on a frame score basis (Fox et al., 1988). Briefly, 5 frame heifers should reach first estrus around 331 kg, have a mature weight of 533 kg and have average daily gains of .47 kg/d from seven to 24 months of age. Because fat deposition is dependent on the amount and nutrient density of the diet, Yelich et al. (1991) has determined that pubertal weight can be quite variable for heifers of similar genetics but differing growth rates.

Short and Bellows (1971) and Granger et al. (1989) found that heifers fed energy-restricted diets during the winter prior to breeding increased the age at the onset of puberty in beef heifers and reduced conception rates. Thus, energy-restricted heifers became pregnant later in the breeding season than heifers fed high-energy diets. Weight gains made during the winter appeared to have a greater influence on fertility than weight gains during the breeding season (Wiltbank et al., 1969; Lemenager et al., 1980). Fleck et al. (1980) also found that rapid growth from weaning to yearling was beneficial for reproduction for beef heifers and young cows.

Altering ruminal fermentation patterns to decrease the acetate:propionate ratio has been shown to hasten the onset of puberty. Rutter et al. (1983) infused propionate via the abomasum and enhanced the ability of prepuberal heifer to respond to a GnRH challenge when compared to controls that received no propionate. Buchanan-Smith et al. (1964) found that feeding an all concentrate diet increased the incidence of estrus over heifers fed a high roughage diet. They could not explain whether the increase was caused by the energy content of the all concentrate diets or because of its biochemical nature. Increasing propionate production in the rumen by feeding monensin increases animal performance and hastens the onset of puberty (Moseley et al., 1977; Moseley et al. 1982). McCartor et al. (1979) increased propionate production in the rumen by increasing the percentage of concentrate in the diet, and by feeding monensin and found that both treatments decreased age of first estrus similarly. Feeding monensin and(or) deworming with an anthelmintic had similar effects and reduced age of first estrus by approximately 30 days when compared to control heifers (Purvis et al., 1993).

Varner et al. (1977) tested the theory of the need to grow heifers to a specific weight before breeding. According to this system, heifers were fed to a body weight that was thought to be the average weight at puberty, with the rationale that the timing of puberty onset was determined by the total amount of growth between weaning and the breeding season. Pregnancy rates increased and age of puberty decreased when heifers were sorted and fed within weaning weight levels. Clanton et al. (1983) tested whether or not growth needed to occur at a specific time postweaning. They grew weaned heifers constantly, rapidly then maintaining body weight and by rapid growth just prior to breeding. Result indicated that age at puberty was similar between the different management regimens.

Summary on Heifer Development

Genotype, level of nutritional intake and growth rate before and after weaning are several factors that affect the sexual maturity of beef heifers. Genotype sets the limits and thresholds that the animal and environment must meet for puberty to occur. Management of heifer growth from weaning to breeding through nutritional programs can vary considerably, but successful management must have heifers reaching puberty early enough in life that they can conceive by 15 months of age.

Supplementation of Beef Cows

Factors Affecting Beef Cow Reproduction

Adequate body energy reserves at calving are a critical factor in determining reproductive performance in beef cows. A number of subjective systems for body condition have been developed to estimate the level or percentage of fat in the body. In the Great Plains region, the system most used has a range of body condition scores from 1 to 9, with 1 being emaciated and 9 being obese. Wagner et al. (1988) reported that live weight, body condition score and weight:height ratio can be successfully used to predict carcass fat and protein of mature, nonpregnant Hereford cows. However, body condition score was the best predictor of energy reserves when expressed on a percentage of body weight basis. Richards et al. (1986) reported that cows calving with a body condition score less than 5 (scale 1 to 9) took longer to return to estrus and conceive than cows with a body condition score greater than 5 at calving. They also determined that body condition score at calving had greater influence on the early return to estrus and pregnancy than postcalving energy intake of cows with body condition score greater than 5, but increasing the energy intake during the postcalving period increased the conception rate of cows under body condition score 4 at calving.

Whitman et al. (1975) determined that body condition at calving accounted for a significant portion of the variation in the likelihood of estrus by 90 days after calving, but when cows showed estrus, fertility was similar regardless of body condition score at calving. Body condition score at calving and body weight during later stages of gestation had a significant influence on pregnancy rate in a five-year trial conducted by Selk et al. (1988). They reported a cubic response would describe the relationship between pregnancy rate and body condition score at calving that ranged from 3 to 7 (9 point scale). They also noted that when body condition scores would increase from calving to breeding, pregnancy rates responded in a positive manner. Diskin et al. (1992) and Laflamme and Connor (1992) also reported a decrease in the postpartum interval to first estrus with increased body condition scores at calving.

Researchers have examined the effect of energy intake both before and after parturition on the return and fertility of the subsequent estrous cycles. Spring-calving heifers fed to lose weight prior to calving had delayed onsets of first estrus after calving, which resulted in later dates of conception when compared to heifers that maintained their weight through the winter (Turman et al., 1964). Since feeding levels after calving had little affect on reproductive performance, they concluded that precalving nutrition was much more important for herd profitability. By restricting energy intake for a 100-day period prepartum, Corah et al. (1975) decreased the number of heifers returning to estrus by 40 days after calving. Calves of energy-deprived heifers were weaker and grew slower than calves of dams adequately fed energy prior to calving. Davis et al. (1977) found earlier conception dates due to feeding greater amounts of energy from grain sorghum fed for 100 days prepartum. Wiltbank et al (1964) agreed that prepartum energy intake will effect the length of the interval of calving to first estrus and added that postpartum energy intake will determine if the estrous cycle will be started and its fertility. In this classical study, they found that the restricting energy during the first 4 weeks after calving delayed the return to first estrus and that feeding greater than recommended levels of energy after calving would increase the conception rate of cows. Dunn et al. (1969) also found that in cows fed restricted levels of energy prepartum, first estrus was delayed after parturition when compared to cows fed to gain weight, and low energy levels feed after calving reduced the number of cows that became pregnant by 100 days postpartum compared to high energy fed cows.

Perry et al. (1991a) found that increased levels of dietary energy prior to calving caused an increase in concentration and pulse frequency of serum LH after calving and greater appearance rates of large follicles, resulting in a shortened interval to the onset of estrus than energy restricted cows. After calving, dietary energy restriction was shown to decrease the pulse frequency of LH and decrease the appearance rate of small and large follicles resulting in a decrease of the percentage of cows ovulating prior to the 150 days postpartum.

Rutter and Randel (1984) stated when body condition was maintained for the first 20 days after parturition, cows returned to estrus sooner than cows that lost body condition during the same period. Fall-calving cows, in the Rakestraw et al. (1986) study, had increased pregnancy rates if fed greater amounts of energy postpartum even when cows calved at body condition scores that were deemed adequate at calving. Lowman et al. (1979) found only small differences in reproduction between cows that where fed 163 and 89% of their energy maintenance values after calving, but cows in this study were considered extremely fleshy at calving. Somerville et al. (1979) showed that fall-calving cows losing less than 16% of the precalving weight from calving to breeding had reproduction maintained at satisfactory levels while those that lost 21% of their precalving weight had impaired fertility. Pleasants and Barton (1979) also reported no difference in fertility of cows as long as they did not lose more than 15% of the precalving weight prior to mating. Feeding high levels of energy postpartum moved subsequent calving dates three to five weeks forward when compared to feeding maintenance and submaintenance levels of energy during early lactation to spring calving, first calf heifers (Turman et al., 1965). When cows were fed to gain weight after calving, Wettemann et al. (1987) indicated the body condition score of cows can influence pregnancy rates. Cows above body condition score 5 consistently responded to increased postpartum nutrition with less consistent results for thinner cows.

Feeding ionophores increases the amount of propionate in the rumen, thus increasing energy metabolism. Postpartum feeding trials by Turner et al.

(1980), Belcher et al. (1980) and Mason and Randel (1983) have studied the effect of ionophore feeding on the number of days to return to first estrus after calving. Their results indicated that the effect on the postpartum anestrus interval is highly dependent on the length of the ionophore feeding period. Differences in length of the postpartum anestrus period were not affected when ionophores were fed for less than 50 days, showed moderate shortening of the anestrus period from 60 to 85 days of feeding and the greatest shortening of the anestrous period when fed for greater than 90 days. None of the studies indicated fertility was increased by the feeding of an ionophore. Rush et al. (1985) found feeding an ionophore to cows grazing low-quality forages prior to calving did not affect subsequent pregnancy rates. Spring-calving cows fed low levels of protein supplement alone or with an ionophore during the summer breeding season had similar body weight and conditon score gains, milk production, calf performance and pregnancy rates in an Oklahoma study conducted by Fleck et al. (1985).

Total mixed rations were used in most of these studies to control nutrient intake. This allows desired weight and body condition score responses to be more easily accomplished than under normal grazing conditions. However, of particular interest to scientists are the associative and substitution effects of supplemental feeds on the basal forage diet.

Beneficial Effects of Supplementing Low-Quality Forages

Leng (1990) defined low quality forages as those that are less than 55% digestible and are deficient in true protein (less than 8% crude protein). To successfully utilize low quality forages, microbial demands must be met, so in turn they can convert cellulose into usable energy for themselves and the host.

Rumen microbes on a low-quality forage diet need additional nitrogen to improve their performance but only limited evidence exists in the literature to support a bacterial need for either peptides or amino acids (Leng, 1990). McCollum and Horn (1990) noted that diets inadequate in protein suppressed forage digestion and intake as well as reduced the utilization of metabolizable energy. Owens (1986) noted that soybean meal has consistently stimulated rumen microbes to a greater degree than isonitrogenous amounts of other protein sources.

The beneficial effects of supplementing low-quality forages with protein have been well documented with a variety of high protein supplements. Elliott (1967) reported that increasing levels of a groundnut meal supplement fed to heifers on a basal diet of 3.4% CP hay caused hay intake and digestibility to increase in a quadratic manner. Church and Santos (1981) found that increasing supplemental crude protein from 0 to 2 g of crude protein/ kg body weight$^{.75}$ with a soybean meal supplement increased wheat straw intake and digestibility, but greater amounts of soybean meal decreased straw intake. Heifers weighing 219 kg were used by Guthrie and Wagner (1988) to study the effect of increasing levels of soybean meal supplementation. With each addition of soybean meal from 0 to 600 g/d, the native grass hay intake and digestibility was increased. When fed at the greatest level of supplement, heifers were consuming diets of 8.3% crude protein. Steers eating a basal diet of prairie hay had increased hay intakes and digestibility when fed cottonseed meal (McCollum and Galyean, 1985). These researchers accredited a faster particulate dilution rate and shorter rumen retention time as the causes of increased forage intake. Fleck et al. (1988) found greater forage intake and digestibility with the addition of soybean meal or corn gluten feed supplements to a low quality hay diet, and DelCurto et al. (1990) reported similar responses for alfalfa hay supplementation to dormant, tallgrass forage intake and digestibility.

Using Rumen Digestible Fiber as an Energy Source for Beef Cows

Increasing total energy intake of cattle grazing low-quality roughages above that obtained with economically reasonable levels of supplemental protein is difficult. Winter weight changes of winter-calving Hereford cows were not different when cows were supplemented with 1.4 or 2.6 kg of a 30% protein supplement composed of soybean meal and corn (Wyatt et al., 1977). Forage intake studies showed that cows fed the greater amount of supplement were only .1 Mcal of DE closer to meeting energy requirements because of depressions in forage intake by the greater amount of supplement (Lusby et al., 1976). Negative effects of supplements on forage intake and digestibility are especially detrimental when the supplement is high in starch and deficient in protein (Chase and Hibberd, 1987).

Feeds low in starch but high in digestible fiber are equal to or superior to grains as sources of supplemental energy for low-quality roughage diets. Anderson et al. (1988a,b) showed that soybean hulls were similar in energy value to corn when fed at the same daily amount to supplement grazing cattle. Highfill et al. (1987) found similar results when corn-soybean meal supplements were compared to soybean hulls, corn gluten feed or citrus pulp supplements with cattle grazing low quality fescue pastures. Grigsby et al. (1993) reported when corn and soybean hulls were mixed in various proportions and fed as a supplement to a basal diet of low quality brome hay to steers, increasing the percentage of corn in the supplement led to decreasing diet digestibility. Hibberd et al. (1986) showed that lactating, fall-calving cows fed isonitrogenous levels of corn-based supplements lost more weight during winter than cows supplemented with soybean hulls. Likewise, corn gluten feed was shown to be an effective source of supplemental protein and energy for pregnant, spring-calving cows consuming low-quality roughage (Fleck et ., 1987, 1988). Lusby et al. (1989) and Ovenell et al. (1989) reported that wheat middlings, another byproduct feed high in fiber and low in starch, was an effective supplemental energy source for wintering spring-calving beef cows on native range.

Recent studies in which the same energy and protein supplements were fed during the winter to lactating fall-calving cows and to nonlactating spring-calving cows in late gestation, suggest that stage of lactation can affect weight change responses of grazing cows. Ovenell et al. (1989) and Lusby et al. (1989) found that isonitrogenous levels of wheat middlings increased weight and condition precalving compared to soybean meal, but did not increase weight of spring calving cows during the winter. Hibberd et al. (1986) found that soybean hulls compared to isonitrogenous levels of soybean meal decreased winter weight losses of lactating fall calving cows but only after mid-February during late lactation. These studies demonstrate that feeding greater amounts of energy supplements precalving will increase cow weight and body condition at calving. However, improving cow weight and condition of grazing cows after calving with increased energy supplementation is difficult.

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CHAPTER III

EFFECTS OF POST WEANING DIET ON AGE AND WEIGHT AT PUBERTY IN HEIFERS

Abstract

One hundred, 7 mo-old spring-born beef heifers (215 kg) were allotted by breed and weight in November to four treatments to evaluate effects of level of supplementation and short-term concentrate feeding on age and weight at puberty. In each of two years, heifers were individually fed .9 kg/d of a 40% CP supplement (SBM), or 1.8 or 2.7 kg/d of a 20% CP supplement (LOW-20 or HIGH-20, respectively) while grazing dormant native pastures. Supplements were fed until the beginning of a 65-d breeding season, starting May 1. A fourth treatment (DRYLOT) consisted of feeding 1.8 kg/d of SBM until mid-February, then feeding a high-concentrate diet (Ne_g = 1.31 Mcal/kg) in drylot so that DRYLOT heifers weighed the same as HIGH-20 heifers on May 1. From November 1 until mid-February, weight gains were similar for SBM, DRYLOT and LOW-20 (.23, .28 and .31 kg/d) and greatest for High-20 ($P < .01$; .51 kg/d). From mid-February until May 1, SBM and LOW-20 gained the least ($P < .01$; .49 and .54 kg/d), while HIGH-20 and DRYLOT gained .67 and .87 kg/d, respectively. Weights on May 1 were similar for HIGH-20 and DRYLOT (320 and 314 kg, respectively) and were heavier (P< .01) than LOW-20 (289 kg) which was heavier (P< .01) than SBM (278 kg). SBM and LOW-20 had greater gains ($P < .05$) during the breeding season than HIGH-20 and DRYLOT (.85, .79, .69, .48 kg/d, respectively). Pubertal weights, determined by weekly plasma progesterone, were similar for SBM, LOW-20, and DRYLOT (290, 296, 297; respectively) and heaviest for HIGH-20 (*P* < .01, 325 kg). DRYLOT heifers reached puberty 29 d younger (*P* < .05) than the other treatments. Percent of heifers puberal on May 1 were 0, 9, 13, and 72 for SBM, LOW-20, HIGH-20, and DRYLOT, respectively. Pregnancy rates were significantly lower for SBM (67%) than for LOW-20, HIGH-20 and DRYLOT (94, 94, 86%, respectively). Milk production after first parturition, was similar for all treatments. Age and (or) weight of puberty may be altered by short-term feeding of high-concentrate diets. The amount of supplemental energy can alter age and weight at puberty even though body condition score is not affected.

Introduction

Heifers must achieve puberty and conceive by 15 mo of age in order to calve at 24 mo and optimize production (Lesmeister et al., 1973). However, many heifers will not achieve puberty by 15 mo (Ferrell, 1982) because of insufficient growth or for genetic reasons. Joubert (1954), Bellows et al. (1965), Arije and Wiltbank (1971), Short and Bellows (1971) and Lemenager et al. (1980) reported that increasing winter weight gains of spring-born heifers reduced puberal age and therefore age of breeding. When heifers were grown at different rates at specific times prior to first breeding, Clanton et al. (1983) noted the onset of puberty did not differ as long as heifers weighed the same at the initiation of the breeding season. In contrast, dietary changes which decrease the acetate:propionate ratio in the rumen may reduce age at puberty. Dufour (1975) reported a significant reduction in the age of puberty when Holstein heifers were fed a high-concentrate diet for a short period near one yr of age. Feeding monensin (Moseley et al., 1977; Moseley et al., 1982) or concentrates (McCartor et al., 1979) has also been shown to reduce age and weight at puberty.

The objective of this study was determine the effects of level of supplementation and short-term feeding of concentrate diets on age and weight at puberty.

Materials and Methods

Forty-eight Hereford and Hereford × Angus heifers in yr 1 and 52 in yr 2 were used. Heifers were born between February 7 and April 8 and were weaned in October. The trial was conducted 20 km west of Stillwater, Oklahoma. Initial weights were the average of weights recorded on two consecutive days after 16-h withdrawal from feed and water.

Three treatments were established to supplement dormant native forage and a fourth treatment consisted of a combination of forage supplementation and drylot feeding. Treatments (Table 1) were .9 kg/d of a soybean meal-based, 40% CP supplement (SBM); 1.8 kg/d of a soybean hull-based, 20% CP supplement (LOW-20); or 2.7 kg/d of the same 20% CP supplement (HIGH-20). Heifers fed SBM and LOW-20 received isonitrogenous amounts of supplement, with LOW-20 consuming a greater amount of supplemental energy. Heifers fed HIGH-20 treatment received greater amounts of both supplemental protein and energy than SBM or LOW-20. All supplements were prepared as a .48 cm pellet and individually fed in covered stalls with the daily supplement amounts prorated for 5 d/wk feeding. Heifers grazed common native tallgrass pastures during the trial and had free access to a trace mineral, salt mixture (Salt, 63.47; dicalcium phosphate, 33.33; copper sulfate .40; zinc oxide, .43; mineral oil 2.85%). From

January 20 until the end of supplementation, grazing heifers were allowed free access to native grass hay (CP = 4.5%, ADF = 43.9%).

The DRYLOT heifers were managed the same as SBM heifers until mid-February, when they were placed in drylot. While in drylot, daily feed intake was restricted to control growth rate (approximately 1.0 kg/d) so that DRYLOT and HIGH-20 would have similar weights on May 1, the start of the breeding season. Intake adjustments were made at 2-week intervals. DRYLOT heifers were group-fed daily at 0800 in bunks. The adaptation period for DRYLOT heifers to the high concentrate ration lasted approximately one wk. Once adapted, DRYLOT heifers consumed all feed within two hours. During the last week of April, all heifers were gathered into a drylot with free access to native grass hay and were fed 1 kg/d of SBM in order to equalize fill between DRYLOT and pasture supplemented heifers. After five d of the common diet heifers were weighed following 16-h removal from feed and water on two consecutive days. These weights were averaged and used as ending weights for the winter period. Heifers then grazed common summer pastures until November 1.

Intermediate weights were taken at 28-d intervals throughout the winter and breeding season and at the end of summer grazing, following 16 h withdrawal from feed and water. Body condition scores (BCS; scale 1 to 9; 1 = extremely thin, 9 = obese; Wagner et al., 1988) were assigned by two independent evaluators on May 1 and November 1.

Weekly plasma samples were obtained, from January 1 until the end of breeding, by collecting whole blood via tail venipuncture into tubes containing 6.25% oxalate (final concentration of 100 μL/mL). Plasma was harvested and stored at -20°C until progesterone analysis. Concentration and profile of progesterone concentrations was used to determine puberty. Concentrations of progesterone in plasma were determined using a validated RIA procedure

(Bishop and Wetteman, 1993). Puberty was defined as the first day of two consecutive plasma samples with greater than 1 ng/mL of progesterone (an indication of luteal activity). Weight at puberty was determined by regression of intermediate weights. Five heifers failed to achieve puberty by the end of the breeding season (SBM, n = 4; DRYLOT, n = 1) and their data were deleted from the analysis of age and weight at puberty.

On May 1, heifers were exposed for 65-d to at least two bulls that had passed breeding soundness exams (BIF, 1990). Pregnancy was determined by rectal palpation performed by two evaluators in November. Conception date was calculated by subtracting 285 d from the actual calving date. Milk production was estimated during the last week of April following calving. The weigh-suckle-weigh technique used by Drewry et al. (1959) was modified to measure three consecutive 8-hr periods.

Analysis of variance was conducted using the GLM procedure of SAS (1985). Data were analyzed as a randomized complete block design. Dietary treatment, breed and year were the independent sources of variation in the model. Heifer was the experimental unit. All two- and three-way interactions were tested for significance. When the year × treatment interaction was not significant ($P > .20$), treatment means were pooled over years and discussed in that manner. Starting weight was used as a covariate in all models. Julian birthday within year was included as a covariate in models for the percentage of heifers cycling at a given date. Significant ($P < .05$) main effects and interactions were interpreted by comparison of individual means using paired *t*-test, and values are reported as least square means. One DRYLOT heifer data was removed from all analyses because of health reasons.

Results and Discussion

Body weight and ADG reflected the daily amount of energy provided by supplements or the high concentrate ration (Figure 1). From November 1 until February 1, ADG of HIGH-20 heifers was greater ($P < .01$) than for the other heifers. Weight gains from November 1 until February 1 were similar ($P = .23$) between SBM and DRYLOT heifers (22 and 24 kg, respectively), but both treatments gained less weight ($P < .01$) than LOW-20. Rate of gain increased after February for SBM and LOW-20 heifers because of the free access to native grass hay and the increasing quality of early spring forages. Weight gain of DRYLOT heifers from February 1 until May 1 was greater (28.2 kg, $P < .01$) than for other treatments. Weights of DRYLOT and HIGH-20 heifers were similar ($P < .35$) at the beginning of breeding. On May 1, HIGH-20 and DRYLOT heifers weighed 28 kg more than LOW-20 and 39 kg more than SBM heifers. The SBM heifers weighed the least ($P < .01$) at the beginning of the breeding season.

Year had a significant effect on the initial weight of heifers. Heifers used in yr 2 were 11 kg heavier than heifers used in yr 1. Daily weight gain for the entire supplementation period was greater ($P < .01$) in yr 1 than yr 2 (.50 vs .40 kg/d, respectively). The yr × treatment interaction approached significance for the entire supplementation period ($P > .06$) and for the summer grazing period ($P = .13$). Weight gains of heifers in the treatments did not change in rank from yr 1 to yr 2 for the entire supplementation period but they did change in magnitude. Because ADG were greater the first yr, heifers weighed more on May 1 (302 vs 287 kg; $P < .01$) and November 1 (414 vs 398 kg; $P < .01$) when comparing the first to the second yr.

During the breeding season, SBM and LOW-20 heifers compensated for decreased winter ADG and gained .23 kg/d more ($P < .01$) than HIGH-20 and

DRYLOT heifers, in agreement with Short and Bellows (1971). DRYLOT heifers gained the least (.9 kg/d; $P < .01$) during the breeding season. From the end of breeding to November, heifer gains were similar ($P = .49$) for all treatments. Total summer weight gains from May 1 until November 1 for SBM and LOW-20 (.61 and .60 kg/d, respectively) were similar and both were greater ($P < .01$) than either HIGH-20 (.57 kg/d) or DRYLOT (.52 kg/d). Like the heifers studied by Lemenager et al. (1980), the heifers that gained at the smallest rates prior to summer compensated with increased weight gains during the summer. At the end of the summer grazing period, HIGH-20 heifers maintained a 22 kg weight advantage over heifers on the other treatments. SBM heifers weighed 8 kg less ($P = .09$) than LOW-20, whereas DRYLOT heifers were heavier ($P < .01$) than either SBM or LOW-20 heifers at the end of the summer grazing period.

For both years of the study, heifers fed HIGH-20 or DRYLOT had greater ($P < .01$) BCS on May 1 than LOW-20 or SBM heifers (5.7, 5.8, 5.3, 5.2; respectively), but by the end of summer grazing there was no difference ($P > .62$) between treatments (Table 2). Body condition scores on May 1 were greater ($P < .01$) in yr 1 than yr 2. The year × treatment interaction was not significant ($P > .32$).

The DRYLOT heifers reached puberty 29 d younger (P< .05) than heifers in the other treatments (Table 2), with no difference between heifers fed SBM, LOW-20 or HIGH-20. Heifers tended ($P = .16$) to reach puberty at an older age (439 vs 433 d) in yr 2 compared to yr 1. Hereford × Angus heifers were pubescent 11 d younger than Herefords ($P < .03$) and therefore, a greater percent of crossbred heifers had reached puberty by the end of breeding ($P < .07$). Wiltbank et al. (1969), Dow et al. (1982) and Steffan et al. (1985) suggest that heterosis decreases the age of puberty. The 10-d difference in the onset of puberty between crossbred and Hereford heifers was similar to the values reported by Bellows (1968) and Wiltbank et al. (1969). Pubertal ages observed in our study were similar to values reported in the literature (Wiltbank et al., 1969; Arije and Wiltbank, 1971; Short and Bellows, 1971; Varner et al. 1977; Ferrell, 1982; Roberson et al., 1991).

Although average weight at puberty (Table 3) did not differ between yr, the yr x treatment interaction was significant. In yr 1, lightest puberty weights were found for SBM and LOW-20 heifers with DRYLOT intermediate and HIGH-20 heaviest ($P < .05$). In yr 2, HIGH-20 heifers again had the heaviest weights at puberty ($P < .05$). Lemenager (1981) also found that increasing weight gains from weaning to puberty was negatively related to the age at puberty. Because of the increase in daily gain, heifers actually weighed more at puberty when well fed even though they were younger. In yr 2, the lowest puberal weights were observed for SBM and DRYLOT with LOW-20 intermediate ($P < .05$).

At three wk prior to the start of the breeding season (April 10), significantly more DRYLOT heifers had reached puberty than SBM, LOW-20 and HIGH-20 (Figure 2). This pattern continued until three wk into the breeding season (May 21). When compared to the other treatments, fewer SBM heifers achieved puberty ($P < .03$) by the end of the breeding season. There was no yr effect for percentage of heifers cycling three wk prior to the breeding season ($P = .73$), but during the second yr fewer heifers had reached puberty by the start ($P < .04$) or the end ($P < .13$) the breeding season. The importance of having heifers cycling by the beginning of the breeding season was emphasized by Bylerley et al. (1987), who reported significantly more heifers pregnant when bred on their third instead of their puberal estrus.

Pregnancy rates (Table 2) were similar (> 86%) for the LOW-20, HIGH-20 and DRYLOT treatments and greater ($P < .05$) than pregnancy rates for SBM heifers (67%). Heifers fed SBM tended to have the lowest percentage cycling at all times during the breeding season (Figure 2). Greater cycling and pregnancy rates for LOW-20 compared to SBM (P< .05), even with similar body weights and BCS throughout the breeding season suggests that level of supplemental energy may affect reproduction in heifers without significantly increasing weight or body condition. Selk et al. (1987) noted a reduction in fertility for those heifers with BCS less than 5 at the beginning of breeding season, however heifers used in our study may have been fatter than those used by Selk et al. (1987).

Milk production was similar for heifers raised to breeding on the four prebreeding treatments (Table 2). Several studies with young dairy heifers (Swanson, 1960; Sinha and Tucker, 1969; Gardner et al., 1977; Sejrsen, 1978; Little and Kay, 1979) have suggested that high levels of concentrate feeding can reduce subsequent milk production by increased deposition of udder fat. However, our study suggests that limit-feeding a high concentrate diet for about 60 days prior to breeding does not affect subsequent milk producing ability.

Date of first calving was affected by breed, birthday (Julian) and yr (P < .02). Heifers born early in their respective contemporary group (P < .01) and in the first year of the study (P < .002) conceived earliest. Heifers in SBM and HIGH-20 treatments had similar ages at calving (P > .20), while DRYLOT and LOW-20 heifers were 10 d younger (P < .03) than either SBM or HIGH-20 heifers.

The onset of puberty is preceded by increased pulsatile LH secretion beginning about 50 d prior to first ovulation (Schams et al., 1981; Day et al., 1984; Kinder et al., 1987). This time frame coincides closely with the period DRYLOT heifers where consuming high-concentrate ration and their first luteal activity became detectable. A common factor in reducing the age at puberty has been to reduce the acetate:propionate ratio in the rumen (Dufour 1975, Moseley et al., 1977; McCartor et al., 1979, Moseley et al., 1982,). Whether the onset of puberty could be stimulated by less days of concentrate feeding than used in our study is unknown. Sorenson et al. (1959) reported that the growth of the reproductive tract after six months of age was positively correlated to the plane of nutrition of the heifer.

Implications

Reduction in age of puberty can be achieved by short-term feeding of high-concentrate diets compared to feeding protein supplements to low-quality roughages. The amount of supplemental energy fed can alter the age and weight at puberty even though body condition score may not be affected. Feeding high-concentrate diets for up to 60 days just prior to the breeding season does not appear to reduce subsequent milk production.

TABLE 1. COMPOSITION AND NUTRIENT CONTENT OF THE SUPPLEMENTS AND THE DRYLOT RATION FED TO HEIFERS (DM BASIS).

	Supplement or ration		
	40% CP Supplement	20% CP Supplement	DRYLOT Ration
Ingredient			
Soybean meal	91.20	15.00	11.50
Soybean hulls	3.45	81.00	
Molasses	4.00	4.00	3.10
Dicalcium phosphate	1.80	.50	
Vitamin A	.10	.05	.015
Copper sulfate	.01		
Rolled Corn			73.50
Alfalfa Pellets			4.90
Cottonseed hulls			5.40
Limestone			1.30
Salt[a]			.30
Nutrient levels			
Crude protein, %	42.96	19.83	13.52
Ne_m, Mcal/kg[b]	1.86	1.77	2.05
Ne_g, Mcal/kg[b]	1.25	.95	1.31
Calcium, %[b]	.59	.57	.68
Phosphorus, %[b]	1.09	.40	.33
Potassium, %[b]	2.48	1.50	.85
Amount fed, kg/day	.9	LOW/HIGH[c]	See footnote[d]

[a] Heifers had free access to salt, trace mineral when grazing.
[b] Calculated from NRC (1986), except for soybean hulls (NRC, 1988).
[c] Daily supplement intake was LOW (1.8 kg/d) or HIGH (2.7 kg/d) for the 20% CP supplement.
[d] Daily intake was .9 kg/d of the 40% CP supplement from November 1 until February 8, then 6.3 to 7.4 kg/d (as-is basis, adjusted in two week intervals) of the DRYLOT ration until late April.

TABLE 2. PUBERAL AND REPRODUCTIVE PARAMETERS OF HEIFERS WINTERED ON .9 KG/D OF A 40% CP (SBM); 1.8 (LOW-20) OR 2.7 KG/D (HIGH-20) OF A 20% CP SUPPLEMENT; OR .9 KG/D OF A 40% CP SUPPLEMENT UNTIL MID-FEBRUARY THEN LIMIT-FED A HIGH CONCENTRATE RATION (DRYLOT).

	Treatments				
Item	SBM	LOW-20	HIGH-20	DRYLOT	SEM
Pubertal age, d	447^{b}	443^{b}	441^{b}	414^{c}	3.9
Age of conception, d	453^{bc}	447^{bc}	454^{c}	444^{b}	3.5
Breeding date, Julian	148^{bc}	142^{bc}	150^{b}	140^{c}	3.5
Pregnancy rate, %	67^{b}	94^{c}	94^{c}	86^{c}	6.9
Body condition score[a]					
May 1	5.2^{b}	5.3^{b}	5.7^{c}	5.8^{c}	.05
November 1	5.7	5.7	5.8	5.7	.04
Calving date, Julian	148	142	150	140	3.5
Early milk production, kg/d	5.7	5.2	5.0	5.8	.45

[a]Scale (1 = very thin to 9 = obese).

[b,c]Row means that do not have a common superscript letter differ ($P < .05$), comparison of least square means was used.

TABLE 3. LEAST SQUARE MEANS OF PUBERAL WEIGHT OF HEIFERS WINTERED ON .9 KG/D OF A 40% CP (SBM); 1.8 (LOW-20) OR 2.7 KG/D (HIGH-20) OF A 20% CP SUPPLEMENT; OR .9 KG/D OF A 40% CP SUPPLEMENT UNTIL MID-FEBRUARY THEN LIMIT-FED A HIGH CONCENTRATE RATION (DRYLOT).

	Treatments				
	SBM	LOW-20	HIGH-20	DRYLOT	SEM
Yr 1	293[a]	292[a]	324[c]	306[b]	4.5
Yr 2	288[a]	300[b]	326[c]	288[a]	4.7

[a,b,c]Row means that do not have a common superscript letter differ ($P < .05$), comparison of least square means was used.

FIGURE 1. WEIGHT GAINS OF HEIFERS FED .9 KG/D OF A 40% CP (SBM); 1.8 (LOW-20) OR 2.7 KG/D (HIGH-20) OF A 20% CP SUPPLEMENT; OR .9 KG/D OF A 40% CP SUPPLEMENT UNTIL MID-FEBRUARY THEN LIMIT-FED A HIGH CONCENTRATE RATION (DRYLOT).

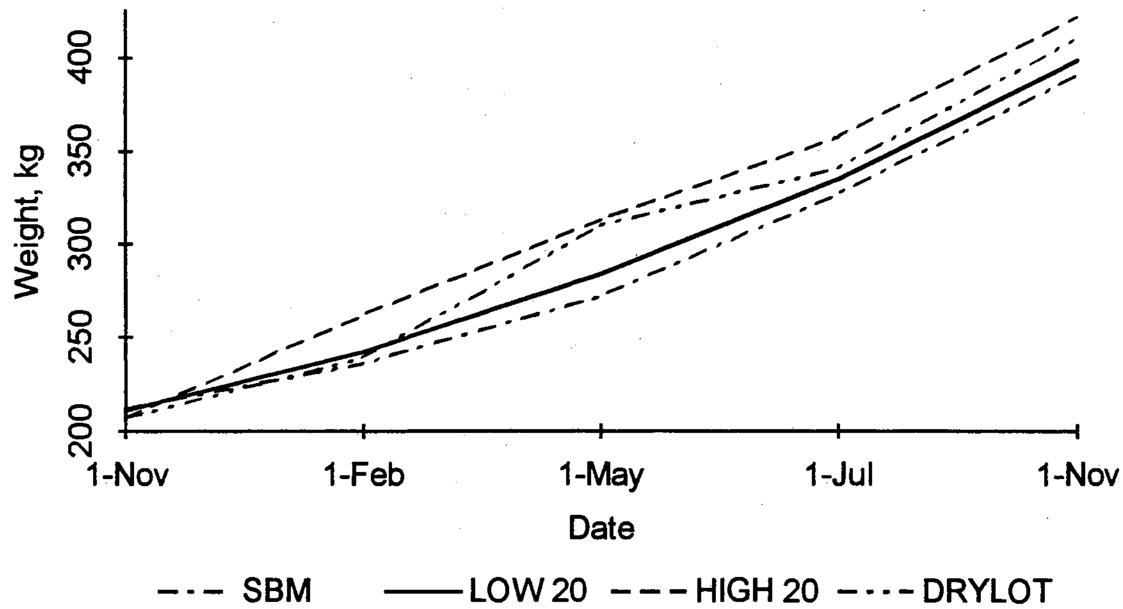
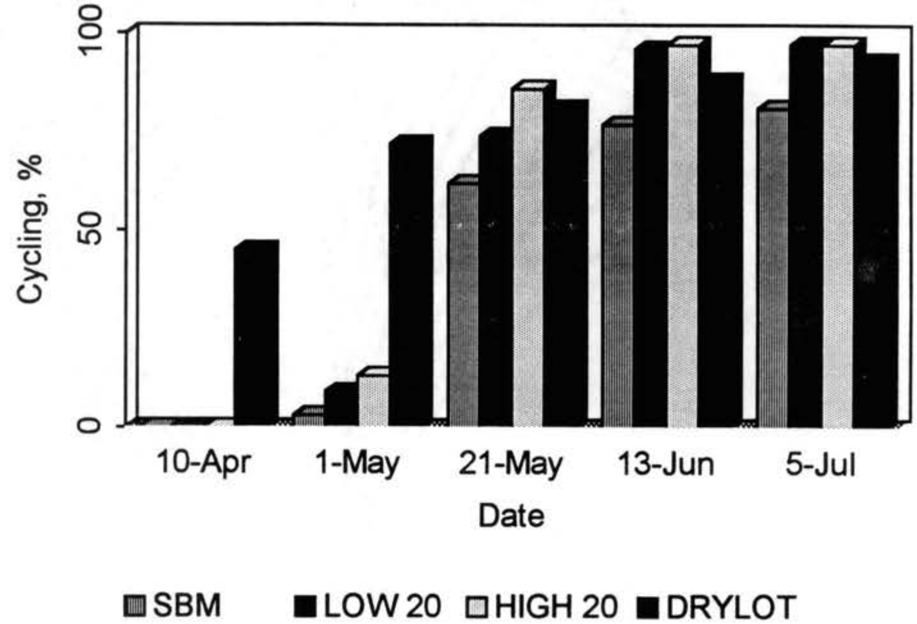


FIGURE 2. CUMULATIVE PERCENTAGE OF HEIFERS WINTERED ON .9 KG/D OF A 40% CP (SBM); 1.8 (LOW-20) OR 2.7 KG/D (HIGH-20) OF A 20% CP SUPPLEMENT; OR .9 KG/D OF A 40% CP SUPPLEMENT UNTIL MID-FEBRUARY THEN LIMIT-FED A HIGH CONCENTRATE RATION (DRYLOT) CYCLING BEFORE AND DURING THE BREEDING SEASON



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CHAPTER IV

PERIPARTURIENT FEEDING OF ENERGY AND PROTEIN SUPPLEMENTS AFFECT ON BEEF COWS GRAZING DORMANT NATIVE RANGE

Abstract

In three consecutive yr, spring-calving, Hereford and Hereford × Angus, primi- and multiparous cows (n = 348) were used to determine if feeding different levels and sources of supplemental energy or protein, before and after calving would affect cowherd performance. Beginning on November 1, cows were individually fed either 1.2 kg/d of a 40% CP (PROTEIN) or 2.5 kg/d of a 20% CP supplement (ENERGY) until calving. After calving, cows either remained on the same supplement, were switched to the other supplement or in yr two and three were fed 2.5 kg/d of a 40% CP supplement (HI PROT). Supplementation ended on April 20, the start of a 65-d breeding season. While grazing native grass pastures, cows and calves were weighed on strategic days after overnight removal from feed and water. Cows fed ENERGY during gestation had greater BW gains and increased body condition scores (BCS) at calving than PROTEIN-fed cows ($P < .01$). No difference in cow weights after calving could be attributed to prepartum supplementation ($P > .10$). Calf birth weight was less for prepartum PROTEIN vs ENERGY-fed cows ($P < .03$), but calf weaning weight was not affected ($P > .24$). Cows fed ENERGY prior to calving had a 11% greater pregnancy rate than the cows fed PROTEIN ($P < .004$). The interaction between supplements fed before and after calving was not significant. After calving, cows fed postpartum PROTEIN or ENERGY had similar BW gains and

BCS changes. Cow fed HI PROT postpartum lost less BW during supplementation ($P < .002$) but had lower summer BW gains than ENERGY-fed cows. Milk production for ENERGY-fed cows tended to be greater than PROTEIN-fed cows ($P < .07$) but similar to HI PROT-fed cows. During postcalving supplementation, calves of HI PROT-fed dams had similar BW gains than ENERGY-fed dams ($P < .16$). After cow supplementation ended, those calves of cows fed HI PROT had lower weight gains than their contemporaries. Pregnancy rates were similar for all postcalving treatments. When the three postcalving supplements were fed to fall-calving cows (n = 48) during lactation, cows on HI PROT gained more weight than PROTEIN and ENERGY ($P < .05$), but BCS and milk production were not affected. Cow gain, milk and BCS were similar for PROTEIN and ENERGY. Reproduction was significantly improved by feeding greater levels of supplemental energy prepartum but not postpartum.

Introduction

Adequate body energy reserves (body condition) at calving are critical in determining reproductive performance of beef cows (Wiltbank et al., 1964; Richards et al. 1986; Selk et al., 1988). Although cows in good body condition at calving can tolerate minimal body weight changes before and after calving (Corah et al., 1975; Dunn and Kaltenbach, 1980), more severe changes in energy intake before and after calving can affect reproductive efficiency (Wiltbank et al., 1962; Wiltbank et al., 1964; Bellows and Short, 1978; and Rakestraw et al., 1986). While effects of weight and condition changes before and after calving have been well documented, controlling such changes under range conditions can be difficult. Recent studies in which the same energy and protein supplements were fed during the winter to lactating fall-calving cows and to nonlactating spring-calving cows in late gestation, strongly suggest that stage of lactation can affect weight change responses of grazing cows (Ovenell et al., 1989; Lusby et al., 1989). The objective of this study was conducted to determine the effects of supplementation with protein and energy before and after calving on cow weight and condition, reproductive performance and calf weight gains.

Material and Methods

Experiment 1: Spring-calving cows

For three successive years, pregnant, primi- and multiparous Hereford and Hereford X Angus cows (1990, n = 96; 1991, n = 126; 1992, n = 126) were blocked by age, breed, body condition and weight and allotted randomly to treatments. Supplementation began on November 8 in each year of the study. Cows were supplemented until calving with a 20% CP soybean hull-based supplement (ENERGY) or a 40% CP soybean meal-based supplement (PROTEIN) fed to provide .51 kg/d of CP. After calving, equal numbers of cows from each precalving treatment were fed the same supplement until the end of supplementation in mid-April or were switched to the other precalving supplement. In yr 2 and 3 a third of the cows were switched to the PROTEIN supplement to provide 1.1 kg/d of CP (HI PROT). Composition of supplements, amounts fed and nutrient percentages are shown in Table 4. The PROTEIN and ENERGY groups received isonitrogenous amounts of supplemental CP, whereas the ENERGY and HI PROT groups received isocaloric amounts of supplemental energy (ME basis).

Supplement was individually fed to cows 6 d/wk at 0800 in covered stalls. All cows grazed together on native tallgrass pastures and had free access to a salt-trace mineral mixture (Salt, 63.47; dicalcium phosphate, 33.33; copper sulfate, .40; zinc oxide, .43; mineral oil, 2.85%) and water at all times. During the summer, tetracycline (10%) was added to the salt mixture. During the first two yr of the trial, cows were provided native grass hay (CP = 4.3%) from March 23 until April 20. In the third year, hay was provided during nine d of inclement weather.

Data for precalving variables were not used for cows that failed to calve or were removed because of death or injury (n = 6). For postcalving data cows were removed because of death, injury or illness that affected performance or failure to wean a live calf (n = 22).

Experiment 1: Cow herd management

Cow weights (16-h after removal from feed and water) were taken on November 8 and at 28-d intervals thereafter until the beginning of the calving season (February 1). From the start of the calving season until supplement feeding was terminated (April 20), cows were weighed at 14-d intervals and the closest weight to calving was used as the final pregnant weight. Weight changes during late gestation were calculated from weights before calving and weight changes during early lactation were calculated from weights taken after calving unless specified otherwise.

A 65-d breeding season commenced the day following the end of supplementation using bulls which had passed breeding soundness examinations (BIF, 1990). Cow weights were also recorded at the end of breeding and at weaning on October 1. Body condition scores (BCS; Wagner et al., 1988) were estimated by two independent evaluators at the beginning of the trial, the start of the calving season, the start of breeding, end of the breeding and at weaning. Calves were weighed within 48 h of birth, at the end of supplementation, at the end of the breeding season and at weaning. All calf weights except for birth weight were taken after 16-h withdrawal from feed and water, but were allowed to remain with their dams up to weighing.

In all years, mono- and diparous cows (n = 192) had daily milk production estimated by the weigh-suckle-weigh technique (Drewry et al., 1959) modified for three consecutive 8-hr measurements. In the fall, cows were examined for pregnancy via rectal palpation.

Experiment 1: Statistical analysis

Data were subjected to least-square analysis of variance using PROC GLM of SAS (SAS, 1985). The experimental unit was the individual cow and its calf, because supplements were fed to individual cows. To determine the effects of differing supplemental energy amounts, the data was analyzed with the main effects being the type of supplement fed either before or after calving. Block effects included age, BCS, and breed. Variables and two- and three-way interactions without a marked effect ($P > .20$) on dependent variables were excluded from the model. The final models included the following classification variables: supplement fed before calving and after calving, year, age and breed type. The initial weight of the cow, birth date within year, and starting BCS were included in the model as covariates. When the F-test for treatments was significant ($P < .05$), mean were compared to determine the effects of differing supplemental energy (PROTEIN vs ENERGY) and protein (ENERGY vs HI PROT) amounts. When comparing means for differences caused by the amount of supplemental protein only data from yr two and three were used.

Experiment 2: Fall-calving cows

The effects of PROTEIN, ENERGY and HI PROT supplements on cow and calf performance during lactation were studied using forty-eight fall-calving Hereford and Hereford × Angus multiparous cows. Unless otherwise stated, procedures were identical to those described for Experiment 1 . Cows were allotted randomly to treatment groups by weight, breed and age. All cows calved within a 3-wk period in September and ranged from 3 to 11 years of age. Supplementation began on October 24 and ended on January 9. Cows were exposed to bulls that previously had passed breeding soundness examinations (BIF, 1990) for 65 d beginning on November 25. Calves were early weaned on January 9 for use in another unrelated study. Milk production was estimated at the beginning and end of supplementation. Pregnancy was determined by rectal palpation in May.

Experiment 2: Statistical analysis

Data were subjected to least-square analysis of variance with a statistical model that included supplement type, cow age and breed and all possible two- and three-way interactions. Cow body weight at the start of the supplementation period and calving date were included as covariates. Variables without an important effect ($P > .20$) on dependent variables were excluded from the model. The final model for cow weight performance included the supplement type and breed as class variables and weight at the beginning of the trial as a covariate. The final model for milk production included supplement type, breed, and age with calving date and the first 24-h milk yield estimate as covariates. The final model for calf performance included supplement type, calf sex, birth weight and birthday as independent variables. Means were compared using protected paired *t*-tests.

Results and Discussion

Experiment 1: Supplementation during gestation

ENERGY-fed cows gained more BW during gestation ($P < .004$) than PROTEIN-fed cows (Table 5). Most of the BW gain during gestation took place during the first two months of supplementation. Because of the increased gain, ENERGY cows weighed 9 kg more ($P < .01$) at calving than the PROTEIN-fed cows. Compared to previous wintering studies with spring-calving cows at this station, differences in precalving cow weight gain in our study were less than found by Cox et al. (1989). When supplements provided .5 kg/d CP, Cox et al. (1989) reported that precalving weight gains were 34 kg more for wheat middlings than for soybean meal. Variation in weather conditions between years can affect the magnitude of weight changes.

Weight losses from the birthing process (difference between pre- and postcalving weights) were not different ($P > .48$) for ENERGY and PROTEIN fed prior to calving. Cows lost about 60 kg during calving regardless of which supplement was fed. This is in agreement with Ewing et al. (1966), who reported that about 13% of the precalving weight was lost during the birthing process.

Along with greater weight gain, ENERGY-fed cows had lost less BCS before calving than PROTEIN-fed cows ($P < .001$). This advantage in BCS for cows fed ENERGY prepartum continued throughout the breeding season ($P < .003$) and was measurable at weaning time ($P < .007$).

Cows fed ENERGY during gestation had greater pregnancy rates than cows fed PROTEIN (91 vs 79%, $P < .002$). Dunn et al. (1969), Selk et al. (1988)

and Perry et al. (1991) reported that restriction of nutrient intake during the last trimester could reduce reproductive efficiency. However precalving weight and BCS changes in our study were much less than reported by these authors, suggesting that prepartum nutritional levels can affect reproduction without major changes in BCS or cow weight. Others (Whitman et al., 1975; Laflamme and Connor, 1992, Wallace and Parker, 1992) indicated if cows were allowed to achieve or exceed a threshold BCS and(or) consume a sufficient amount of nutrients, pregnancy rate, return to estrus and calving interval are not affected. The BCS at calving for cows in our study was 5.3 for PROTEIN and 5.4 for ENERGY. Selk et al. (1988) suggested that the threshold for optimal reproductive efficiency occurred at BCS of 5.3.

Calves from cows fed ENERGY during gestation weighed 1 kg more at birth than calves from PROTEIN-fed cows ($P < .01$). These calves also had greater ADG from birth to the end of supplementation ($P <.06$). This increase in weight gain was not a reflection of greater milk production, because 24-h milk production was similar for cows fed PROTEIN or ENERGY to calving ($P > .63$). This increase in weight gain could be caused by increased forage intake of the calves, but calf forage intake was not measured, and can not be confirmed. Precalving supplementation of the cow had no effect on summer calf weight gain.

<u>Experiment 1: Supplementation after calving</u>

The 2-way interaction between supplements fed before and after calving and the 3-way interaction between supplement fed before and after calving and year were not significant for any response variable. Data were pooled over years and least square means of supplements fed in common years are shown in Tables 6 and 7. Differences in supplemental energy amounts compared the ENERGY and PROTEIN supplements fed all three yr, while differences in supplemental CP amounts compared ENERGY and HI PROT supplements in yr two and three.

Cow weight loss from the last weight prior to calving to the end of supplementation on April 20 when expressed as a percentage of precalving BW was similar for cows fed PROTEIN or ENERGY, but cows fed HI PROT lost less BW than cows fed ENERGY ($P< .002$). Turman et al. (1965) and Morris et al. (1978) suggested that cows that lost greater than 15% of precalving weight prior to the breeding season had a greater probability of remaining open than cows which came closer to maintaining their precalving weight at the start of the breeding season.

Cow weight loss from calving to the end of supplementation was similar for ENERGY and PROTEIN and significantly less for cows fed HI PROT than cow fed ENERGY. Weight gains during the breeding season only tended ($P< .15$) to be greater for ENERGY compared to PROTEIN-fed cows but ENERGY-fed cows gained 10 kg more than HI PROT. Cows fed PROTEIN had greater BW gains ($P < .10$) during the later half of the summer grazing period then ENERGY-fed cows. Differences in BCS generally followed the trend of BW changes. Because the large number of cows in this study, small differences in BCS observed were statistically significant, although whether these differences are large enough to be biologically meaningful is not known.

Milk production during early lactation were greater (.5 kg/d) for ENERGY ($P< .09$) than for PROTEIN. Feeding additional CP (HI PROT) did not increase milk production compared to ENERGY. Perry et al. (1991) noted larger increases in milk production by feeding increased levels of energy, but differences in energy intake levels were controlled to a greater degree than in our study.

Pregnancy rates of cows fed ENERGY from calving to start of the breeding season were 4% greater ($P < .27$) than for PROTEIN but no difference was seen between ENERGY and HI PROT-fed cows. Neither level of supplemental energy or protein affected subsequent calving interval ($P > .82$, $P > .64$; respectively). Wiltbank et al., (1964); Dunn et al. (1969); and Rutter and Randel (1984) have shown that energy intake during early lactation and the breeding season increased the likelihood of pregnancy and increasing postpartum energy intake through breeding has been reported to increase the number of cows returning to estrus (Perry et al., 1991). The relatively short postpartum supplementation period in our trial may not have been sufficient in terms of both length and nutrient intake to significantly increase reproduction.

Calf weight gain was not different at any period of lactation for cows fed ENERGY and PROTEIN, in agreement with milk production estimates taken on April 20. Calves of cows fed HI PROT had similar weight gains to calves of cows fed ENERGY while cows were fed supplements postcalving, but gained significantly less during the breeding season and tended to gain less in late summer than for calves of ENERGY-fed cows. Calf weight gains appeared to follow cow weight change patterns. Calf weaning weights were similar for ENERGY and PROTEIN but offspring of HI PROT-fed cows had smaller weaning weights than those of cows fed ENERGY. Although increased energy intake of dams usually results in greater weaning weight (Houghton et al. 1990; Bond and Wiltbank, 1975; Lowman et al. 1979), increased supplemental energy may not result in increases in total energy intake (Marston et al. 1994).

Experiment 2: Fall-calving cows

Cow weight gains were similar for PROTEIN and ENERGY-fed cows throughout the supplementation period ($P > .20$) as shown in Table 8. During the first 53-d of the trial, cows fed HI PROT gained significantly more BW than ENERGY-fed cows, but during the last 24-d of the trial no difference was noted in BW changes ($P > .76$) between the two treatments. Supplements did not affect changes in BCS ($P > .38$). Daily milk yield declined a similar amount (2 kg) from the start to end of the supplementation period for all supplements.

All supplements allowed a high percentage of pregnancy to occur with an acceptable calving interval of 1-yr in length. Kropp et al. (1983) reported an increase in the number of fall-calving cows returning to estrus and a greater pregnancy rate for cows fed an increased level of supplemental energy and Rakestraw et al. (1986) reported increased reproductive efficiency of fall-calving cows by increasing supplemental CP intake. Somerville et al. (1979) reported fall-calving cows, which had lost 21% of their calving weight during lactation from dietary energy restriction, had much lower conception rates and delayed estrus when compared to cows that lost 16 or 8% of their calving weight. As indicated by Morris et al. (1978), cows with sufficient body condition prior to breeding are less dependent on nutrient intake to maintain optimal productivity.

Implications

Feeding greater levels of supplemental energy before calving increased cow BW gains, body condition scores and pregnancy rates, but did not effect weight gains, BCS changes or calf growth after parturition. The interaction between changing of supplements at calving had no effect on cowherd production, indicating cattlemen have the flexibility to make supplemental adjustments at this time. Feeding increased levels of supplemental protein will reduce BW loss during early lactation, but can have a detrimental effect on post supplementation calf growth. Prepartum supplementation had more influence on pregnancy rate than postpartum-supplementation.

TABLE 4. COMPOSITION AND NUTRIENT CONTENT OF SUPPLEMENTS (DM BASIS)

	Supplements[a]		
	PROTEIN	ENERGY	HI PROT
Ingredients, %			
Soybean meal	90.86	15.49	91.72
Soybean hulls	3.28	79.93	3.36
Molasses	3.99	4.02	4.03
Dicalcium phosphate	1.80	.51	.91
Vitamin A	.05	.05	.03
Copper sulfate	.01		.01
Nutrient content, %			
Crude protein[b]	42.66	20.60	42.55
Phosphorus[c]	1.09	.40	.93
Calcium[c]	.59	.57	.39
Potassium[c]	2.48	1.56	2.51
TDN[c]	81.73	77.46	82.50
Amount fed			
Supplement, kg/d	1.22	2.44	2.44
CP, kg/d	.52	.50	1.0
ME, Mcal/d	3.6	7.0	7.4

[a]Abbreviations of supplements correspond to those in the text and are on a percentage of DM.
[b]Kjeldahl N × 6.25.
[c]Calculated from feed composition tables (NRC, 1984), except for the TDN value of soybean hulls (NRC, 1988).

TABLE 5. EFFECT OF SUPPLEMENTS FED TO SPRING-CALVING COWS DURING GESTATION ON WEIGHT, BODY CONDITION SCORE, REPRODUCTION AND CALF BIRTH WEIGHT

	Supplement[a]			
	PROTEIN	ENERGY	*P* value	SE[b]
No. of cows	172	170		
Calving date, Julian	60	62		
Initial wt, kg	443	442		
Wt gain, kg				
November 8 to January 1	13	19	.001	1.1
January 1 to calving	2	5	.002	1.0
Calving[c]	-59	-61	.28	1.6
Calving to April 20	-15	-15	.91	1.6
April 20 to July 5	49	53	.10	1.5
July 5 to weaning	8	6	.20	1.4
Initial body condition score[d]	5.8	5.8		
Body condition score change				
November 8 to February 1	-.5	-.3	.001	.03
February 1 to April 20	-.4	-.4	.41	.05
April 20 to July 5	.4	.4	.98	.04
July 5 to weaning	.1	.1	.12	.04
Pregnancy rate, %	79.7	90.5	.004	3.2
Calving interval[e], d	364	363	.45	1.7
Milk yield, kg/d	6	6	.72	.2
Calf birth wt, kg	37	38	.03	.4
Calf wt gains[f], kg				
Birth to April 20	33	31	.05	.8
April 20 to July 5	72	70	.24	1.1
July 5 to weaning	55	53	.12	.9

[a]See Table 1 for description of supplements fed before calving.
[b]SE is the average of the least square means SE in a row.
[c]Difference between last weight prior to and first weight after calving.
[d]Scale: 1 = emaciated, 9 = obese.
[e]Calving interval includes data from first 2-yr of experiment (n = 192).
[f]Weights adjusted for cow age, birthdate and sex of calf.

TABLE 6. EFFECTS OF FEEDING PROTEIN AND ENERGY SUPPLEMENTS TO SPRING-CALVING COWS DURING EARLY LACTATION ON WEIGHT, BODY CONDITION SCORE, REPRODUCTION AND CALF PERFORMANCE (3 YR)

	Supplement[a]			
	PROTEIN	ENERGY	*P* value	SE[b]
No. of cows	123	122		
Calving date, Julian	61	62		
Postcalving wt, kg	405	404		
Wt change, kg				
Calving to April 20	-19	-18	.88	1.9
April 20 to July 5	53	56	.15	1.7
July 5 to weaning	8	5	.10	1.3
Percent BW change				
Precalving wt to April 20	-17.0	-16.5	.30	.38
Body condition score[c]				
February 1	5.4	5.4		
Body condition score change				
February 1 to April 20	-.4	-.4	.91	.04
April 20 to July 5	.4	.5	.21	.04
July 5 to weaning	-.1	-.1	.41	.04
Pregnancy rate, %	83.3	88.1	.27	3.1
Calving interval[d]	362	361	.82	1.5
Milk yield (April 20), kg/d	5.6	6.1	.07	.20
Calf wt gains[e], kg				
Birth to April 20	31	32	.35	.9
April 20 to July 5	72	74	.25	1.0
July 5 to weaning	56	56	.99	.9
Weaning wt[e], kg	198	200	.44	2.6

[a]See Table 1 for description of supplements fed after calving.
[b]SE is the average of the least square means SE in a row.
[c]Scale: 1 = emaciated, 9 = obese.
[d]Calving interval includes data from first 2-yr of experiment (n = 192).
[e]Weights adjusted for cow age, birthdate and sex of calf.

TABLE 7. EFFECTS OF FEEDING ENERGY AND HI PROT SUPPLEMENTS TO SPRING-CALVING COWS DURING EARLY LACTATION ON WEIGHT, BODY CONDITION SCORE, REPRODUCTION AND CALF PERFORMANCE (2 YR)

	Supplement[a]			
	ENERGY	HI PROT	*P* value	SE[b]
No. of cows	72	75		
Calving date, Julian	61	60		
Postcalving wt, kg	407	409		
Wt change, kg				
Calving to April 20	-14	-5	.002	2.2
April 20 to July 5	47	37	.001	1.5
July 5 to weaning	6	8	.36	1.5
Percent BW change				
Precalving wt to April 20	-16.1	-14.5	.0020	.45
Body condition score[c]				
February 1	5.4	5.4		
Body condition score change				
February 1 to April 20	-.6	-.5	.08	.06
April 20 to July 5	.6	.4	.10	.06
July 5 to weaning	-.2	-.1	.23	.05
Pregnancy rate, %	86.0	87.3	.81	3.7
Calving interval[d]	363	362	.64	3.2
Milk yield (April 20), kg/d	5.6	5.8	.65	.25
Calf wt gains[e], kg				
Birth to April 20	28	30	.16	1.1
April 20 to July 5	66	61	.004	1.3
July 5 to weaning	63	61	.17	1.2
Weaning wt[e], kg	196	190	.11	3.2

[a]See Table 1 for description of supplements fed after calving.
[b]SE is the average of the least square means SE in a row.
[c]Scale: 1 = emaciated, 9 = obese.
[d]Calving interval includes data from second yr of experiment (n = 127).
[e]Weights adjusted for cow age, birthdate and sex of calf.

TABLE 8. EFFECTS OF SUPPLEMENTS FED TO FALL-CALVING COWS DURING LACTATION ON WEIGHT, BODY CONDITION SCORE, REPRODUCTION AND CALF PERFORMANCE

	Supplement[a]			Effect (P <)[b]		
	PROTEIN	ENERGY	HI PROT	Energy	Protein	SE[c]
No of cows	16	16	16			
Calving date, Julian	272	269	272			
Initial cow wt, kg	504	504	505			
Cow wt change, kg						
October 24 to November 19	-2	-8	1	.20	.05	3.1
November 19 to December 16	11	7	16	.41	.04	2.9
December 16 to January 9	-39	-38	-39	.70	.76	2.5
Body condition score[d]						
October 24	5.3	5.5	5.5			
Body condition score change[d]						
October 24 to January 1	0	-.1	-.1	.38	.76	.08
Milk yield, kg/day						
October 24	5.6	7.0	6.4	.03	.37	.5
Change October 24 to January 9	-2	-2	-2	.92	.36	.3
Reproductive traits						
Pregnancy rate	94	93	88	.93	.61	7.1
Calving interval	365	365	366	.93	.91	3.3
Initial calf weight[e], kg	69	76	72			
Calf wt gain[e],kg						
October 24 to January 9	30	34	37	.12	.41	2.6

[a]See Table 1 for description of supplements fed after calving.
[b]Energy effect is PROTEIN vs ENERGY; protein effect is ENERGY vs HI PROT.
[c]SE is the average of the least square means SE in a row.
[d]Scale: 1 = emaciated, 9 = obese.
[e]Weights adjusted for cow age, birthdate and sex of calf.

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CHAPTER V

EFFECTS OF LACTATIONAL STATUS AND ENERGY OR PROTEIN SUPPLEMENTS FED TO SPRING-CALVING COWS ON LOW-QUALITY GRASS HAY INTAKE AND DIGESTIBILITY

Abstract

In two consecutive yr, primi- and multiparous, spring-calving Hereford and Hereford × Angus cows (n = 32, yr 1; n = 42, yr 2) were used to determine the effects of supplements and lactational status on forage intake, digestibility and energy intake. Supplement fed during gestation provided equal amounts of CP/d from a 40% CP, soybean meal-based supplement (PROTEIN) or a 20% CP, soybean hull-based supplement (ENERGY). After calving, cows remained on the same supplement or were switched. In yr 2, a 40% CP supplement was also fed postpartum at twice the rate of protein as PROTEIN or ENERGY. Prairie hay DMI was measured directly and DM digestibility estimated for two 7-d periods during late gestation and early lactation. Gestating cows fed PROTEIN consumed 1 kg/d more hay DM and hay DM digestibility was greater ($P < .001$) than for cows fed ENERGY. Lactating cows fed PROTEIN also consumed greater amounts of hay than cows fed ENERGY. Lactating cows fed HI PROT had similar hay DMI as PROTEIN and ENERGY fed cows and no difference was noted in hay DM digestibility among supplement types ($P > .37$). Total ME intake was similar for PROTEIN and ENERGY fed cows in late gestation ($P >$ .35) and after calving cows consumed similar amounts of ME/d ($P < .35$) regardless of supplement fed, within each yr of the study. Results indicated that

ENERGY will decrease low-quality forage digestibility and can decrease forage intake. Increasing the total energy intake of grazing cattle by feeding supplements is difficult once protein requirements are met.

Introduction

The intake and digestibility of low-quality forages has been increased by feeding protein and digestible-fiber based supplements (McCollum and Galyean, 1985; Ovenell et al., 1991). Feeds which are high in digestible fiber, like wheat middlings and soybean hulls, have been shown to cause less substitution of forage intake and to increase forage digestibility more than grain-based energy supplements (Merrill and Klopfenstein, 1985; Ovenell et al., 1991). The additional energy from fiber, along with the corresponding increase in forage intake and utilization, has been shown to increase ADG of steers grazing brome or cornstalks (Anderson et al., 1988a,b). Winter supplements containing wheat middlings (Cox et al., 1989; Lusby et al., 1991) or alfalfa (DelCurto et al., 1990) fed at isonitrogenous levels to soybean meal allowed spring-calving cows to gain more BW and body condition score (BCS) during gestation. However, during lactation, spring- and fall-calving cows did not respond to increased energy supplementation (Lusby and Wettemann, 1988ab; Ovenell et al., 1989), suggesting that responses in BW and BCS changes differ with physiological status.

The objectives of our study were to determine the effect of differing levels of protein and fiber-based energy supplements on low-quality forage intake and digestibility during late gestation and early lactation.

Material and Methods

Thirty-two primi- and multiparous, spring-calving Hereford and Hereford × Angus cows were used in yr 1 and 42 in yr 2 to determine effects of supplement type and stage of lactation on forage intake and digestibility. Cows were randomly selected from herds (n = 96 in yr 1 and 126 in yr 2) that were used to evaluate effects of pre- and postcalving energy and protein levels on cow and calf performance. Cows had been allotted to the different supplement types and regimens in November after being blocked by breed, age, and weight (Marston et al., 1994). Supplements fed precalving (Tables 9 and 10) consisted of a 20% CP soybean hull-based supplement (ENERGY) or a 40% CP soybean meal-based supplement (PROTEIN). After calving, in yr 1 cows remained on the same precalving supplement or were switched to the other supplement. In yr 2, after calving one third of the cows from each precalving treatment were fed the same supplement, one third were switched to the other precalving supplement and one third were switched to a 40% CP supplement fed at a rate to provide 1.1 kg/d of CP (HI PROT). Therefore, it was an imbalanced designed (as HI PROT was not fed the first yr), 2 × 3 factorial experiment with repeated measurements in two periods.

Amounts of supplement fed were reduced in the second yr because cows weighed less (Table 11 and 12). In both yr, cows were fed ENERGY and PROTEIN to provide 1.16 g CP/kg BW during gestation and 1.34 g CP/ kg BW during lactation. In yr 2, HI PROT supplement was fed after calving to provide 2.60 g CP/kg BW. Energy intake was nearly isocaloric for HIGH PROTEIN and ENERGY treatments.

Two 14-d forage intake and digestion studies were conducted each yr, one beginning on January 20 when cows were gestating (mean calving date was

March 6 in yr 1 and February 22 in yr 2) and another conducted to end on April 20 when cows were lactating. Cows were maintained in individual covered stalls (.77 m × 2.5 m) in an open-fronted, barn with free access to native grass hay (Table 10) for two 4-hr sessions beginning at 0800 and 1300 daily. Supplement was fed individually once daily at 0800. Hay was placed in feeders twice daily prior to cow placement and orts removed nightly. When not in their stalls, cows were maintained in an open drylot (30 m × 18 m) and provided water only. During the lactation phase, calves remained in the drylot while cows were being fed hay and were allowed to suckle at will when dams were in the drylot.

Between intake trials, cows were returned to dormant, native grass pastures and were managed with the remainder of the cows used for the performance study. Cows not suckling a calf (yr 1, n = 2; yr 2, n = 3) were eliminated from the lactation phase.

One day prior to trial periods, cows were weighed following 16-h overnight withdrawal from feed and water. This weight was used to express forage DM intake. Voluntary forage intake was measured directly for 7-d following a 7-d adaptation period to the hay, supplement feeding schedule and indigestible marker intake. On April 21, milk production was estimated using the weigh-suckle-weigh technique (Drewry et al., 1959) modified for consecutive, 8-h periods.

Fecal output was estimated by feeding each cow 10g/d of chromic oxide as an indigestible marker. Chromium recovery in the feces was assumed to be 100% (Vogel et al., 1985; Ovenell et al., 1991). The chromic oxide was mixed with dry rolled corn (10 g Cr_2O_3/113.5 g corn) and fed at 0800 daily with the supplement to assure rapid and complete consumption. Rectal grab samples were taken at 0800 and 1700 on days 8 through 14. Samples were thoroughly mixed, and equal aliquots were taken and composited. Fecal samples were then dried in a forced-air furnace at 60°C for 48 h, ground through a 2 mm screen, placed in plastic bags and stored at -20°C until chromium analysis. Fecal Cr concentrations were analyzed by atomic spectrophotometry (Williams et al., 1962) using a air-acetylene flame.

Samples of hay, orts, and supplements were collected daily and composited after each period. Feedstuff samples were ground through a 2 mm screen, placed in plastic bags and stored at -20°C. Crude protein of hay and supplement samples was determined as Kjeldahl N (AOAC, 1980) $\times$ 6.25. Neutral detergent fiber and ADF concentrations of feed samples were determined by the nonsequential procedure of Goering and Van Soest (1970), except that decalin and sodium sulfite were omitted from the neutral detergent reagent (Robertson and Van Soest, 1981). Total diet digestibility was determined by the measured intake of total diet and the estimated total fecal output. Digestibility of the supplements was assumed to be the TDN values reported in NRC (1984) for their various ingredients, except for soybean hulls (NRC, 1988). Fecal output from hay was determined by subtracting estimated fecal output of the supplement from total fecal output. Digestibility of the hay was calculated from the measured hay intake and the estimated hay fecal output. Daily ME intake was determined using the formula: .82(forage digestible DMI $\times$ 2) + (supplement TDN $\times$ 3.62 Mcal/kg) (NRC, 1984).

A linear model was fit to the data for each response variable by least squares using the GLM procedure of SAS (1985). The initial model contained yr, treatment, period, breed and age, all two and three way interactions among these factors, and the covariables of BW and birthday within yr; also included was a random effect for cow within treatment $\times$ yr, which was used as the error term for testing treatment. All other sources of variation were tested against the residual error term. In the initial models, neither breed or age, nor any of the interactions except treatment × period were significant (*P* > .20). Thus, the final model contained yr, treatment, period, the treatment × period interaction and the random cow effect. When the *F*-test for treatments was significant (*P* < .05), comparisons among treatments were made using orthogonal contrasts that compared PROTEIN vs ENERGY and ENERGY vs HI PROT. Data were pooled for the gestation period between years, but because of the missing cell for HI PROT the first yr, data are reported on a yearly basis for the lactation period.

Results and Discussion

Gestation

Cows weighed about 485 kg at the start of the gestation phase. The supplement × yr interaction was not significant (*P* > .31) for any response variables so data were pooled across yr (Table 11.). Cows fed PROTEIN consumed significantly greater amounts of hay DM than ENERGY-fed cows. The decrease in daily hay DM intake was less than the difference in the amount of supplements fed, indicating that the ENERGY supplement did not entirely substitute for hay. Hay intake in our study was similar to intake reported for similar low-quality grasses or hays fed by Rittenhouse et al. (1970), Kartchner (1981), Vanzant et al. (1991) and Stanley et al. (1993), who fed gestating beef cows supplements of soybean meal and corn; cottonseed meal, soybean meal or cracked barley; dehydrated alfalfa; or alfalfa, respectively. When expressed on a BW basis, PROTEIN-fed cows consumed .2% more DM than cows fed ENERGY. Similar results were reported by Fleck et al. (1988) and Ovenell et al. (1991) who compared energy supplements composed of corn gluten meal and wheat middlings, respectively.

Fecal DM output values were within the range of normal estimates (.8 to 1% of BW) for dairy and beef cattle (Conrad et al., 1964; Owens et al., 1991). Sampling times similar to our study have also been used by Smith and Reid (1955), Davis et al. (1958) and Ovenell et al. (1991).

Hay DM digestibility was about 6 percentage units greater ($P < .001$) for gestating cows fed PROTEIN compared to ENERGY. Ovenell et al. (1991) noted that DM digestibility of native grass hay (4.9% CP) for gestating and lactating cows was 5 and 8% greater for cows supplemented with soybean meal than cows supplemented with wheat middlings or a corn-soybean meal supplement, respectively. This decrease in hay digestibility was reportedly caused by the starch component of the wheat middlings and corn-soybean meal supplements. Fleck et al. (1988) reported gestating cows supplemented with corn gluten feed (another rumen degradable fiber) and soybean meal had similar low-quality hay DM digestibility when fed at isonitrogenous levels. Hsu et al. (1987) indicated that soybean hulls contain no starch. Owens (1986) reveiwed the effects of soybean meal supplementation on rumen fiber digestion and indicated that soybean meal consistently increases ruminal ADF digestion about 5% over a variety of other supplement types. He accredited this to increased microbial activity, but the exact mechanisms of microbial stimulation are still unclear. Reasons for the decrease in hay DM digestibility for cows fed the soybean hull-based energy supplement compared to soybean meal in our study are not clear.

The ME intake of gestating cows was similar for PROTEIN and ENERGY, in agreement with similar weight gains observed with PROTEIN and ENERGY-fed cows during late gestation in the companion study (Marston, 1994). Cow weight gains measured during the last two months appeared to indicate cows were consuming near maintenance requirements of energy. NRC (1984) indicates the ME requirement of 470 kg, dry, pregnant mature cows and 430 kg pregnant yearling heifers (.9 kg/d BW gain) is similar to the ME intake of the cows in our study. In the companion study, significant BW and BCS changes were reported for a 60-d period that ended about 30 d prior to the digestion trials. Whether the difference is caused by cows closer to mid-gestation being more responsive to increased supplemental energy or whether this was caused by declines in forage quality as cows advanced in gestation during January is unknown. Vanzant et al. (1991) reported that forage intake was similar but NDF digestion increased for cows grazing dormant native grass pastures and supplemented with dehydrated alfalfa at 55 and 12 d prior to parturition.

Gestating cows fed PROTEIN consumed similar amounts of CP as ENERGY-fed cows ($P < .70$). On a percentage basis, cows fed PROTEIN consumed a diet that was significantly greater ($P < .002$) in CP than cows fed ENERGY (10.1 vs 9.3). According to NRC (1984), PROTEIN and ENERGY-fed cows consumed 124 and 120% of the daily requirements of CP, with supplements providing 60 to 65% of the total CP intake.

<u>Lactation</u>

The precalving × postcalving supplement interaction did not contribute to variation ($P > .81$) in hay DM intake of lactating cows. Because HI PROT was not fed during the first yr and the postcalving supplement × yr interaction approached significance ($P < .20$), data are presented by yr (Table 12).

Hay DM intake was greater for PROTEIN than ENERGY-fed cows in yr 1 ($P < .001$), but in yr 2 hay DM intake was only slightly greater for PROTEIN than for ENERGY-fed cows ($P < .13$). Cows fed ENERGY and HI PROT (yr 2) had similar hay DM intake ($P > .93$). In yr 2, cows fed ENERGY and HI PROT ate significantly more total diet DM than PROTEIN-fed cows (10.3, 10.5, 9.5 kg/d; respectively). During both yr, when hay DM intake was expressed as a percentage of BW, PROTEIN-fed cows ate significantly more hay than did cows fed ENERGY (2.17 vs 1.99%, yr 1; 1.99 vs 1.88%, yr 2). In yr 2, ENERGY and HI PROT-fed cows consumed similar amounts of hay DM expressed as a percentage of BW. The second yr hay DM intakes were significantly lower than the first year, regardless if hay DM intake was expressed as kg/d or as a percentage of BW. In our study, a decrease was observed in hay DM intake between PROTEIN and HI PROT (total DM, $P < .17$; percentage of BW, $P < .06$). Other studies (McCollum and Galyean, 1985; Guthrie and Wagner, 1988) have also shown that increasing the amount of a protein-type supplement fed with low-quality forage will increase forage intake but dietary CP levels in our study were near maximums reported by these authors. Elliott (1967) reported that forage DM intake responded in a quadratic manner as ground nut meal was added to a diet of low-quality Rhode grass.

Fecal outputs were consistently between 1.2 and 1.3% of BW for all lactating cows in both years. This is greater than values generally recorded for cattle (Conrad et al., 1964; Owens et al., 1991). The elevated level of fecal output during lactation could be caused by underestimation of Cr concentration in the fecal samples, by differences in physiological status or by the changes in BW and BCS of the cows between gestation and lactation. If the cow BW measured for gestating phase was used to express percent of fecal DM output, values were .8 to 1.0% of BW range within the range reported by Owens et al. (1991).

Hay DM digestibility was 2 percentage units greater for lactating cows fed PROTEIN than ENERGY-fed cows in yr 1, less than the to hay DM digestibility difference for the two supplements reported for gestating cows. In yr 2, hay DM digestibility was again greater (4 percentage units, $P < .08$) for cows fed PROTEIN compared to ENERGY. Hay DM digestibility was similar for ENERGY and HI PROT-fed cows.

The calculated ME intake was similar between the PROTEIN and ENERGY-fed cows ($P = .66$, yr 1; $P = .70$, yr 2). These findings agree with cow BW gains in the companion performance study (Marston et al., 1994) and cows fed isonitrogenous amounts of wheat middlings and soybean meal (Lusby et al., 1991). ME intake was similar ($P < .35$) for lactating cows fed HI PROT versus PROTEIN-fed cows. The daily ME intakes calculated in yr 1 are sufficient to maintain a 454 kg beef cow producing 4.5 kg milk/d, but the cows in yr 2 were consuming less than the requirements of a 410 kg cow producing the same amount of milk (NRC, 1984).

Cows consumed equivalent amounts of CP in yr 1 ($P < .42$), but in yr 2, PROTEIN-fed cows consumed more CP than cows fed ENERGY($P < .06$). By design, HI PROT-fed cows consumed more CP than cows fed either PROTEIN or ENERGY ($P < .001$). According to NRC (1984) the CP intake (expressed as total CP or a percentage of diet DM) for cows fed PROTEIN or ENERGY supplements was deficient, especially in yr 2. HI PROT was the only supplement that resulted in adequate daily CP intake (NRC, 1984). Daily milk production was similar (about 6.7 kg) for all supplements fed during lactation ($P > .50$).

Physiological status

Forage DM intake increased (2 kg/d, .38% of BW) as cows advanced from late gestation to lactation (Table 13). Forbes (1986), Ovenell et al. (1991), Vanzant et. al. (1991) and Stanley et al. (1993) reported increases in diet intake after parturition of ewes and beef cows. Low levels of intake during late gestation have been associated with the fetus displacing the rumen (especially with multiple-birth ewes) and hormonal concentrations (Forbes, 1986). Bines (1976) and Forbes (1986) indicated dairy cows are in negative energy balance during the first wk of lactation because forage intake does not increase enough to compensate for increased energy demands. However, immediate increases in forage intake after beef cows calve have been reported by Vanzant et al. (1991) and Stanley et al. (1993). Our study indicates that forage intake will increase by six wk after calving. The intake of forage-based diets with DM digestibility below 67% are believed to be regulated by body weight (a reflection of roughage capacity), fecal output and DM digestibility (Conrad et al., 1964). Our measurements of diet DM intake during gestation and lactation agree with the regression equation developed by Conrad et al. (1964) for estimating intake of milking cows fed rations between 52.1 and 66.7% DM digestibility.

Native grass hay DM digestibility was not affected by lactational status ($P > .52$). Gunter (1989) noted no difference in DM digestibility between pregnant and nonpregnant ewes, as did Ovenell et al. (1991) with gestating or lactating beef cows. By combining increased forage intake with similar forage digestibility, fecal output was elevated after parturition ($P < .001$). Increased forage intake accounted for the increase in daily ME consumed from late gestation to early lactation. It appears that greater nutrient demand by lactating cows drives the increase in energy intake, especially with the low-quality hay used in our study.

Implications

Increasing the total energy intake of grazing cattle by feeding supplements is difficult once protein requirements are met. Beef cows consume about 28% more total DM when lactating than when in late gestation but the substitution of supplement for forage DM is not changed. Increasing total ME intake during lactation may require more CP than is economically feasible.

TABLE 9. SUPPLEMENT COMPOSITION, NUTRIENT CONTENT AND AMOUNTS FED (DM BASIS)

	Supplements[a]		
	PROTEIN	ENERGY	HI PROT
Ingredients, %			
Soybean meal	90.86	15.49	91.72
Soybean hulls	3.28	79.93	3.36
Molasses	3.99	4.02	4.03
Dicalcium phosphate	1.80	.51	.91
Vitamin A	.05	.05	.03
Copper sulfate	.01		.01
Nutrient content[b], %			
Phosphorus	1.09	.40	.93
Calcium	.59	.57	.39
Potassium	2.48	1.56	2.51
TDN	81.73	77.46	82.50
Amount fed, kg DM/day			
Gestation			
Yr 1	1.35	3.21	
Yr 2	1.23	2.44	
Lactation			
Yr 1	1.36	3.24	
Yr 2	1.22	2.44	2.44

[a]Abbreviations of supplements correspond to those in text.
[b]Calculated from feed composition tables (NRC, 1984), except soybean hulls (NRC, 1988).

TABLE 10. CHEMICAL COMPOSITION OF NATIVE GRASS HAY AND SUPPLEMENTS (DM BASIS)

		Supplements[a]		
Item[b]	Hay	PROTEIN	ENERGY	HI PROT
DM, %				
Yr 1	94.26	92.12	93.09	
Yr 2	92.45	90.02	89.66	89.82
Ash, % DM				
Yr 1	6.89	8.81	7.39	
Yr 2	7.22	9.70	7.31	10.09
CP[c], % DM				
Yr 1	4.80	42.36	20.13	
Yr 2	4.40	42.95	21.06	42.55
NDF, % DM				
Yr 1	77.6	20.0	47.3	
Yr 2	78.7	22.4	46.1	15.4
ADF, % DM				
Yr 1	42.6	10.69	34.5	
Yr 2	44.8	12.10	32.55	11.8

[a]Abbreviations of supplements correspond to those in text.
[b]Chemical analysis.
[c]CP = Kjeldahl N × 6.25.

TABLE 11. LEAST SQUARE MEANS FOR HAY INTAKE, HAY DIGESTIBILITY, ME AND CP INTAKE AND FECAL OUTPUT OF COWS DURING GESTATION

	Supplement[a]			
Item	PROTEIN	ENERGY	*P* value	SE
No. of cows	37	37		
Cow BW, kg	478	492	.10	.2
Hay intake, kg/d	7.7	6.8	.001	.10
Hay intake, % BW/d	1.74	1.51	.001	.028
Diet DM digestibility, %	49.7	49.5	.88	.91
Hay DM digestibility, %	44.2	37.8	.001	1.22
ME intake, Mcal/d[b]	16.1	16.7	.35	.42
CP intake, kg/d	.91	.89	.70	.022
CP intake, % diet	10.1	9.3	.002	.19
Total fecal output, kg/d	4.5	4.8	.005	.08
Hay fecal output, kg/d	4.2	4.2	.58	.08

[a]Abbreviations of supplements correspond to those in text.
[b]ME = .82(forage DDMI × 2 Mcal/kg) + (supplement TDN × 3.62); DDMI = digestible DMI (NRC, 1984).

TABLE 12. LEAST SQUARE MEANS FOR HAY INTAKE, HAY DIGESTIBILITY, ME INTAKE, FECAL OUTPUT AND MILK YIELD OF COWS IN EARLY LACTATION

Item	Supplement[a]			P value[b]		
	PROT	ENERGY	HI PROT	Energy	Protein	SE
No. of cows						
Yr 1	15	15				
Yr 2	14	13	12			
Cow BW, kg						
Yr 1	432	448				
Yr 2	394	408	406			
Hay intake, kg/d						
Yr 1	9.5	8.8		.001		.11
Yr 2	7.7	7.5	7.5	.13	.93	.12
Hay intake, % BW/d						
Yr 1	2.17	1.99		.001		.028
Yr 2	1.99	1.88	1.90	.01	.57	.031
Diet DM digestibility, %						
Yr 1	53.7	54.3		.66		1.01
Yr 2	44.9	43.9	45.3	.52	.37	1.07
Hay DM digestibility, %						
Yr 1	48.1	46.7		.49		1.41
Yr 2	37.5	33.8	34.9	.08	.62	1.49
ME intake, Mcal/d[b]						
Yr 1	21.6	21.9		.66		.47
Yr 2	14.5	14.8	15.2	.70	.58	.50
CP intake, kg/d						
Yr 1	1.05	1.05		.42		.005
Yr 2	.86	.85	1.12	.06	.001	.006
CP intake, % diet						
Yr 1	9.4	9.2		.26		.09
Yr 2	9.4	8.9	11.4	.001	.001	.10
Total fecal output, kg						
Yr 1	5.2	5.3		.67		.09
Yr 2	5.1	5.3	5.2	.08	.42	.10
Hay fecal output, kg						
Yr 1	4.9	4.7		.18		.09
Yr 2	4.6	4.9	4.8	.52	.67	.10
Milk, kg/d						
Yr 1	6.8	7.5		.15		.34
Yr 2	6.5	6.2	6.6	.59	.48	.36

[a]Abbreviations of supplements correspond to those in text.
[b]Energy effect is PROTEIN vs ENERGY; protein effect is ENERGY vs HI PROT.
[c]ME = .82(forage DDMI × 2 Mcal/kg) + (supplement TDN × 3.62); DDMI = hay digestible DMI (NRC, 1984).

TABLE 13. VOLUNTARY HAY INTAKE AND DIGESTIBILITY, FECAL OUTPUT AND ME AND CP INTAKE OF COWS FED PROTEIN AND ENERGY[a] SUPPLEMENTS DURING GESTATION AND LACTATION

Item	Gestation	Lactation	*P* value	SE
No. of cows	60	57		
Hay DMI				
Kg/d	7.3	9.4	.001	.12
Kg/100 kg BW	1.64	2.01	.001	.030
DM digestibility				
Total diet	49.6	49.1	.63	.71
Hay	41.0	41.9	.52	1.02
Fecal DM output, kg/d				
Total	4.6	5.8	.001	.07
Hay	4.2	5.4	.001	.07
ME intake, Mcal/d	16.4	17.9	.001	.37

[a]Abbreviations of supplements correspond to those in text.

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CHAPTER VI

SUMMARY OF ENERGY OR PROTEIN SUPPLEMENTS FED TO CATTLE GRAZING DORMANT, LOW-QUALITY NATIVE GRASS

Cow-Calf Study

For cowherds to maintain high reproductive performance, cows must achieve adequate body condition scores at calving. However body weights and condition scores of range cows are dependent upon many variables including weather, physiological stage of production, cow age, quality and quantity of the forage, supplements fed, and the associative effects between supplements and forages. Many of these factors are beyond the control of the producer and as a result, many cows calve in less than desirable body condition. Understanding how nutritional management interacts with these factors could permit producers to minimize the risks of poor reproductive rates and improve profitability.

To determine when energy and protein supplementation would be the most beneficial, we designed a large scale, 3-year study using spring-calving cows. Energy (20% CP) and protein supplements (40%) were fed to provide .55 kg/d of CP. At calving, cows either remained on their precalving supplement or were switched to the other, creating a 2 x 2 factorial arrangement. After calving, an additional 40% CP supplement was fed at the same daily rate as the energy supplement during the final two years. Feeding additional energy prior to calving caused slight and variable increases in cow body weight and condition scores, but increased pregnancy rate by 10% over the 3-year study.

Body weight and condition responses to energy supplementation were greater during earlier stages of gestation. After calving, feeding the energy or protein supplements at isonitrogenous or isocaloric levels had similar effects on cow body weight, condition score and milk production. Our data suggest little effect of changing between a protein or an energy supplement at calving. Feeding the greater amount of 40% CP supplement (2.7 kg/d) during lactation reduced cow weight loss after calving when compared to feeding 2.7 kg/d of the energy supplement or 1.4 kg/d of the 40% CP supplement but did not change pregnancy rates or calf weaning weights. Therefore, producers should strive to increase cow body weight and condition during gestation rather than early lactation.

Intake and digestion trials performed during late gestation and early lactation indicated that energy intake is not increased by feeding greater quantities of supplemental energy. Even though research with sheep and young cattle has shown that supplements composed of energy sources low in starch do not substitute for low-quality forage intake or lower its digestibility, our studies indicated that cows in late gestation and early lactation, did use energy supplements as a substitute for low quality forage and had depressed low-quality forage digestibility. Cows increased forage intake nearly 28% as they progressed from gestation to lactation, presumably to meet increased metabolic needs. However, energy and protein intakes were not sufficient to prevent the use of body reserves.

Combining our results with other findings, cattlemen can expect energy supplements to enhance weight gains of growing stock, but not necessarily improve body weight gains or condition scores of cows late in gestation and early lactation. Because a forage intake and digestibility trial was not performed near the beginning of our trial, we can only speculate that the advantages in body weight and condition score gains experienced during this period in the companion feeding trial were due to the cows ability to consume sufficient amounts of forage to increase energy intake.

General recommendations for winter supplementation programs for cows grazing dormant native grasses derived from our study indicate that cows in moderate body condition should be fed an energy supplement until calving. This may not have a large effect on body weight or condition scores, but should ensure a satisfactory or profitable rebreeding rate. At calving, producers have several options. Feeding either a protein or an energy supplement to provide .55 kg of CP/d, will not allow cows to consume energy or protein amounts sufficient to met requirements during lactation, but these supplementation rates should be adequate to allow a timely return to estrus and acceptable reproductive efficiency.

Replacement Heifer Study

Advantages in hastening the onset of puberty are magnified in production systems that demand heifers calve near two years of age. Genetics determine the thresholds of age and mass necessary for puberty to occur in heifers, but nutrition determines when the threshold level of mass will be met. This theory is solidified by research that has shown that increased prepubertal weight gain is accompanied by decreased age at puberty. Work with dairy heifers has shown that increasing growth prior to puberty can increase fat deposition in the udder and damage milk production, causing beef producers to have concerns about developing heifers at the proper rate to ensure high lifetime productivity, especially with diets containing concentrates. However, reducing the acetate:propionate ratio by altering rumen fermentation has reduced pubertal age in heifers. High concentrate diets alter rumen fermentation and decrease the acetate:propionate ratio, as has ionophore feeding.

The importance of having heifers cycling prior to the beginning of the breeding season has been demonstrated by others because fertility increases as heifers advance from pubertal estrus. Also, having heifers cycling regularly prior to the breeding season allows producers to take advantage of heat synchronization programs.

A 2-year study evaluated the effects of supplementation and a combination of supplementation and limited-feeding of a high concentrate diet on replacement heifer development. Utilizing dormant, low-quality native grass pastures, a low starch supplement was compared to a high protein supplement and to a limit-fed high concentrate diet fed 60 to 80 days just prior to a restricted breeding season. Results indicated weight gains were greater for heifers receiving 2.7 kg/d of a 20% CP, energy supplement than for heifers fed 1.8 of the same supplement or .9 kg/d of a 40% CP supplement. However, no differences was found in pubertal age between these supplementation programs. Heifers fed .9 kg/d of the 40% CP supplement experienced a significantly reduced pregnancy rate compared with heifers fed either 2.7 or 1.8 kg/d of the 20% CP supplement. Feeding a high concentrate diet prior to the breeding season caused a reduction of nearly three weeks in the age of puberty compared with all other treatments. At three weeks prior to the breeding season, a significantly greater percentage of the heifers fed high concentrate had reached puberty than heifers developed solely on native grass pastures. Heifers fed the high concentrate ration had pregnancy rates and subsequent milk production estimates similar to those heifers developed on low-quality forage and the 20% CP supplement fed at high and low amounts, and significantly greater than heifers developed with .9 kg/d of high protein supplement.

To minimize costs, producers could feed a 40% CP supplement until approximately 60 days prior to the breeding season, then switch heifers to a high concentrate diet; or they could utilize a supplement with a low starch component throughout the postweaning phase. Our results indicate there will be no detrimental effects on subsequent milk production from the high concentrate diet, contrary to popular belief.

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Doctor of Philosophy

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