FORAGE UTILIZATION AND PRODUCTIVITY OF LACTATING BEEF COWS FED COTTONSEED MEAL, CORN OR SOYBEAN HULL SUPPLEMENTS DURING THE WINTER

By

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CHAPTER I

INTRODUCTION

Management of fall-calving beef cows on native grass pastures presents a unique challenge to cow-calf producers. Native tallgrass prairie in Oklahoma consists of four primary grass species, big bluestem, little bluestem, indiangrass and switchgrass. These grasses are in abundance in the fall on a well-managed range, yet are of poor quality (approximately 4% CP) during the winter when the grass is dormant (Waller et al., 1972). During the winter, energy requirements of the fall-calving cow are increased due to lactation and environmental stress. Increased nutrient requirements coupled with poor forage quality creates a large nutritional void that must be corrected to maintain productivity. Beef cows in this situation can be energy deficient due to the inability to consume enough energy from the forage to maintain milk production and body condition. Supplementation with a energy supplement (20% CP), such as a corn-based supplement, can be used to increase the energy status of the lactating cow. Negative associative effects due to the starch component of cereal grains result in decreased forage digestibility and intake (Chase and Hibberd, 1987). Under these circumstances, the forage commodity is inefficiently utilized. This approach could be useful when forage quantity is inadequate and the producer wishes to extend forage supply as long as possible.

Energy supplementation with cereal grains substitutes for forage rather than providing a supplement to enhance forage utilization. Supplementation with small quantities (.5 to 1 kg/d) of a high-protein (40% CP) supplement increases forage digestibility and intake which will increase the energy intake from the forage (Gallup and Briggs, 1948). This positive associative effect allows the producer to efficiently utilize the forage resource providing adequate quantities are available.

Modern grain milling practices have increased the availability of grain and milling by-products, for use as feed sources for livestock. By-product feeds such as soybean hulls are moderate in protein, high in fiber, low in lignin, moderate in energy and low in starch (Quicke et al., 1959; Johnson et al., 1962; McDonnell et al., 1982; NRC, 1984; Merrill and Klopfenstein, 1985). The low lignin content coupled with the high NDF and low starch makes soybean hulls a digestible fiber supplement that could complement consumed forage. Thus, soybean hulls could be a logical component of a range supplementation program. The effects of high fiber supplements on the overall energy status and productivity of lactating range cows are unknown. In addition, the effect of high-fiber supplements on forage utilization, forage intake and ruminal function need clarification.

The objectives of this research were to compare soybean hulls to corn or cottonseed meal supplements, on: a) the productivity of fall-calving beef cattle, b) forage digestibility, passage rate and intake, and c) ruminal function.

CHAPTER II

REVIEW OF LITERATURE

Nutritional Status of Fall-Calving Beef Cows

Physiological and Environmental Stress

The fall-calving beef cow maintained on dormant native grass is placed under a great deal of stress, producing peak milk levels when weather conditions and forage quality are less than optimal. The dam often acts as a buffer for her calf by depleting her body reserves in times of high nutritional demand and poor forage supply and restoring these reserves when conditions are more favorable (McDonald et al., 1981). Lactation is the most nutritionally stressful activity for the cow (Lusby et al., 1985). Compared to a dry cow in mid-gestation, a 450 kg, average milking cow (5.0 kg milk/day) requires more TDN (57.5% vs 48.6%) and crude protein (911 g vs 703 g) and a superior milking cow (10 kg milk/day) requires more than twice as much TDN and a 50% increase in crude protein (NRC., 1984). In addition to requirements for lactation, Wiltbank et al. (1962) and Wettemann et al. (1987) observed that a decrease in energy supplied to the cow either before or after calving tended to lengthen the time of uterine involution and significantly increased the postpartum interval (Wettemann et al., 1987).

The environment is a major factor in the efficient production of beef cows. Animals which are acclimated to temperatures between 15 and 25 C (thermoneutral zone) have a maintenance requirement of $NE_m = .077W^{.75}$ (NRC., 1984). For each degree above or below the 20 C, .0007 should be subtracted or added to the coefficient (NRC., 1984).

Rittenhouse et al. (1970) reported decreased forage intake by grazing cattle during short periods of cold weather and snow cover. This decreased intake occurs at a time when added energy is needed to meet increased maintenance requirements (NRC., 1981). At lower temperatures, feed intake tends to increase (Westra and Christopherson, 1976; Kennedy et al., 1977; Kennedy and Milligan, 1978). As a result of increased rate of digesta passage through the rumen, digestibility of dry matter, organic matter, and cell wall constituents decrease (Westra and Christopherson, 1976; Kennedy et al., 1977; Kennedy and Milligan, 1978). Increased feed intake, caused by extreme cold, more than compensates for decreased digestibility so that cattle can consume comparable quantities of digestible energy outdoors during winter as if being housed in a heated barn (Christopherson, 1976).

Westra and Christopherson (1976) noted changes in the ruminal retention time of digesta and reticular motility in sheep with changing ambient temperature. Decreased total retention time and increased ruminal passage of digesta due to cold were associated with increased frequency of reticular contractions.

Forage Quality

Forage quality plays a major role in the acceptability and usefulness of the forage to the cow. Gallup and Briggs (1948) suggested that protein content of native hay is a reliable index of nutritive value. They noted that the TDN of native hay increased from 41% to 56% as crude protein increased from 3% to 6%. McCollum and Galyean (1985) stated that forage intake of blue grama range was regulated by forage quality rather than forage quantity. Forage quality and yield are not constant, however, and vary through the season (Waller et al., 1972; Van Soest, 1982).

Kartchner et al. (1979) suggested that the major factors influencing intake were quality and quantity of forage. McCollum and Galyean (1985) noted a decrease in forage intake due to decreased forage digestibility, increased gastrointestinal tract fill, and longer residence times of particulate and fluid digesta. Intake increased in early dormancy to a level observed in the early growing season due to increased forb consumption. Maintaining a diverse plant community containing not only desirable grasses but also palatable forbs may allow grazing animals to maintain a higher level of nutrient intake during periods of grass dormancy (McCollum and Galyean, 1985).

Forage quality is dependent upon a number of factors; primarily, plant age and quality of the stem (Van Soest, 1982). The nutritive value of plants decreases with maturity due to increased lignification and decreased proportion of leaf to stem. Stem quality is dependent on diameter and whether the stem is hollow or filled with pith.

Forage quality declines from late summer and fall, throughout the winter until the arrival of new growth in the spring (Waller et al. 1972; Van Soest, 1982). This decline could be partly attributed to decreased daylength, since nutrients are metabolized during darkness and not produced (Van Soest, 1982). Declining quality of the forage consumed during the winter may also be due to leaching of nutrients (Waller et al., 1972) and selection of higher quality plant parts (leaves) during early dormancy leaving more stem for grazing in later dormancy (Laredo and Minson, 1973; Minson, 1981; Poppi et al., 1981). Native tallgrass prairie in Oklahoma during the winter (December to March) contains approximately 3% CP, 36% TDN, .4% Ca, and .1% P (Waller et al., 1972; Lusby et al., 1985). Even though this grass is of suboptimal quality, it is an inexpensive feed source which must be utilized efficiently.

Nutritional Deficiencies

According to NRC. (1984), the requirements for 450 kg (1000 lb.) lactating cow of average milking ability in the first 3 to 4 months of lactation are .91 kg CP, 5.3 kg TDN, 26 g Ca and 21 g P. In order for this cow to meet her requirements for CP, TDN, Ca, and P strictly from the grazing of dormant native range, she would have to consume approximately 30.4 kg dry matter, 14.7 kg, 6.5 kg and 21 kg, for each nutrient, respectively. This clearly indicates that crude protein is the first limiting nutrient for cows grazing dormant native range, where forage intake would normally range from 6 to 9 kg per day (1.5 to 2.0% of body weight). Thus, supplementation programs are required to meet the nutritional requirements of lactating cows maintained on dormant native grass.

Production Responses to Supplementation

Cow Performance

Keeping beef cows in good body condition is important to the continued consistent production of the beef herd. Body condition or body energy reserves at calving are the most important factor affecting the length of time beween calving and first postpartum estrus (Richards et al., 1986; Wettemann and Lusby, 1987). If adequate rebreeding performance is expected, the producer must manage the nutritional status of the cow to insure sufficient energy intake to meet the requirements for lactation, body weight maintenance/gain and rebreeding. If body condition or energy intake are inadequate, ovarian function is the most heavily affected (Wiltbank et al., 1962; Dunn et al., 1969; Somerville et al., 1979; Rakestraw et al., 1986). Body condition of fall calving cows should be evaluated at the beginning of summer, at calving, beginning of breeding, and at weaning (Lusby, 1987). Evaluation of body condition at these times provides an indication of the level of management necessary to achieve optimum performance.

Body weight changes have traditionally been used by researchers, to determine the nutritional status of beef cows, although this may be impractical for commercial cattlemen. Body condition scoring provides a precise appraisal of a cow's body energy reserves and may predict maintenance requirements (Wagner et al., 1984, 1985). Body condition scoring serves as a means of determining if the cow is in adequate condition at calving or breeding, and to assess the need for supplementation.

Supplementation decreased winter weight loss (Melton and Riggs, 1964; Wallace and Raleigh, 1964; Harris et al., 1965; Parker et al., 1974) and improved rebreeding performance of lactating beef cows (Kropp et al., 1973; Bellido et al., 1981; Rakestraw et al., 1986). Bellido et al. (1981) and Rakestraw et al. (1986) reported that supplemented cows exhibited a shorter calving interval. The number of days to first postpartum estrus decreases and body condition and conception rate increase as the level of supplementation increases (Kropp et al., 1973) . The pregnancy rate of spring-calving range cows that calve in a body condition score of 5 (1 to 9 scale) can be increased with postpartum supplementation (Wettemann et al., 1987). Rakestraw et al. (1986) concluded that even if fall-calving beef cows have adequate body energy reserves at calving (6+ on 1 to 9 scale), optimum reproductive efficiency can not be insured, especially if body weight loss is excessive prior to breeding.

Milk Production and Calf Performance

To the beef cow/calf producer, calf weight gain is the most important marketable commodity from his livestock enterprise. Calf weight gain is produced indirectly from the forage grazed by the cow for production of milk for the calf. Therefore, efficiency of forage utilization for milk production is a primary concern.

High correlations have been reported between milk production and calf average daily gain (Furr and Nelson, 1964; Jeffery et al., 1971). From 38 to 66% of the variation in weaning weight is due to differences in milk consumption (Neville, 1962; Rutledge et al., 1971; Robison et al., 1978; Butson et al., 1980). Gleddie and Berg (1968) and Jeffery et al. (1971) reported that milk yield accounted for 71% and 60%, respectively, of the variation in calf average daily gain.

Barnes et al. (1978) studied two biological milk production levels of cows and found calves exposed to the medium level of milk were heavier at weaning than calves suckling low-producing dams. They concluded that as milk intake and average daily gain increased, the apparent efficiency of milk utilization decreased.

Rutledge et al. (1971) concluded that milk quantity was more important than milk quality on 205-day weaning weight. Measurements of milk yield or associated constituent yields, however, serve as good predictors of calf growth (Butson et al., 1980).

Robison et al. (1978) reported that milk supplied sufficient energy to meet requirements for maintenance and gain during the first month of lactation. By the fifth month, however, milk supplied less than 65% of the calf's energy requirement. Boggs et al. (1980) agreed that the cow's milk production had the greatest effect on calf performance but added that the influence of milk production decreased throughout lactation. Milk supplied adequate dry matter and protein to maintain growth to the third month but from then on, calves must have received a large proportion of their nutrients from grass. A one kg increase in average daily milk yield is converted into 7.7 kg to 14.6 kg of additional weaning weight (Jeffery et al., 1971; Butson et al., 1980). Thus, the dam's milk production becomes an important selection criteria to improve calf performance. Average daily gain and weaning weight of the calf have been used as criteria for selection of milk production in the dam (Furr and Nelson, 1964; Totusek et al., 1973).

Supplementation of lactating beef cows grazing dormant native range increases milk yield and calf weaning weight (Howes et al., 1958; Harris et. al, 1965; Huber and Boman, 1966; Kropp et al., 1973; Bellido et al., 1981). Furr and Nelson (1964) observed increased calf gains when lactating beef cows on dormant native range were fed 6.0 kg (22% CP) cottonseed meal/milo compared to 2.3 kg (41% CP) of cottonseed meal. In addition, Harris et al. (1965) fed cows two different planes of nutrition and reported that calves in the restricted group had gained 13.5 kg less by weaning.

Decreased milk intake appears to be associated with increased forage intake in calves (Lusby et al., 1976; Wyatt et al., 1977; Barnes et al., 1978; Boggs et al., 1980; Holloway et al., 1982). Lusby et al. (1976) found that milk intake tended to be negatively correlated with creep intake. Wyatt et al. (1977) used cows with two biological levels of milk production and body size and crossfostered half the calves from each group. They found that larger calves were able to consume more forage without decreasing milk intake. In addition, potential growth rate of the calf had little effect on milk intake. In contrast, Totusek et al. (1973) suggested that milk consumption capacity of the calf was an important factor in determining milk production of the dam.

Holloway et al. (1982) found the correlation between milk digestible energy intake and calf weight and weight gain decreased as calves increased in age, whereas forage digestible energy intake tended to increase with increasing calf age. They noted an apparent gradual shift from dependence on milk to a dependence on forage as the calf grows. But, at a low forage energy density, physical capacity of the calf limited intake of the forage (Holloway et al., 1982).

Nutritional Responses to Supplementation

Ruminal Function

The ruminal microbial population consists of bacteria, protozoa, and anaerobic fungi (Hungate, 1966). Bacteria and protozoa usually comprise equal mass of the ruminal microbial population, but bacteria, being smaller, are most numerous (Hungate, 1966; Orskov, 1982). Ruminal bacteria are not evenly distributed in the rumen. Some will be in the liquid phase although most are attached to particulate matter (Hungate, 1966). In addition, some are attached to the epithelium of the rumen (Cheng and Costerton, 1980; Orskov, 1982).

Ruminal bacteria can be divided into groups according to substrate utilization, primarily cellulolytic or amylolytic (Orskov, 1982). Even though these groups do coexist, they prefer different environments and have different nutritional requirements. Factors that affect the competitive advantage of specific bacteria are maximum growth rates, substrate affinities and preferences, maintenance requirements, growth efficiency and pH tolerance (Russell and Hespell, 1981). Enviromental factors that affect bacterial growth are either physical-chemical or nutritional (Hespell, 1979). The major physical-chemical factors include temperature, pH, oxidation-reduction potential, and osmotic pressure. In contrast, the availability of ammonia, amino acids, peptides, branched chain volatile fatty acids and fermentable energy are nutritional factors.

Cellulolytic bacteria have the ability to grow on poor-quality forage (Orskov, 1982) and therefore are essential to the grazing ruminant. Major species of cellulolytic bacteria include Bacteroides succinogenes, Ruminococcus albus and Ruminococcus flavefaciens. B. succinogenes was the first important cellulolytic bacterium to be isolated (Hungate, 1966) and is more active in the hydrolysis of crystalline cellulose than the ruminococci (Baldwin and Allison, 1983).

Cellulolytic bacteria are very sensitive to pH. Ruminal pH below 6.2 will inhibit growth (Orskov, 1982). Lowering the ruminal pH from 7.0 to 6.0 with HCl almost completely inhibited the attack of cellulolytic microbes on cotton and decreased the titer of filter paper-degrading bacteria (Stewart, 1977). In most cases, the ruminal pH on forage diets will vary from 6.3 to 7.0. The buffering of ruminal contents in cattle fed low-quality forages is due to salivary input from the increased amount of time spent ruminating and reinsalivating the ingesta (Orskov, 1982). Cellulolytic bacteria are strictly anaerobic, most require ammonia as a nitrogen source, and branched-chain fatty acids for growth (Allison et al., 1958; Hungate, 1966).

Amylolytic bacteria are less sensitive to changes in pH than are cellulolytic bacteria, and can survive at pH's of 5.6 to 7.0 and possibly lower (Hungate, 1966; Orskov, 1982). Ruminal pH usually decreases with cereal grain feeding because of lower buffering from saliva due to decreased rumination and the increased fermentability of cereal grains (Orskov, 1982).

Volatile fatty acids are the major end products of microbial fermentation which are used as energy by the host animal (Van Soest, 1982). The major volatile fatty acids produced are acetate, propionate and butyrate. Acetate and butyrate must be used for oxidation while propionate can be used for gluconeogenesis (Van Soest, 1982). The most abundant volatile fatty acid is acetate (Van Soest, 1982; Hungate, 1966). The amount or proportion of propionate, however, is positively associated with animal performance (Blaxter, 1962; Van Soest, 1982).

On a forage diet, typical acetate:propionate ratios range from 4:1 to 3:1 and will decrease with a total concentrate diet to 2:1 (Oldham et al., 1977; Stewart, 1977; Van Soest, 1982). Amylolytic microbes produce more propionate than cellulolytic microbes (Baldwin and Allison, 1983). Thus, propionate production should increase when grains are added to a hay diet due to proliferation of amylolytic bacteria. Esdale and Satter (1972) and Orskov (1982) noted that volatile fatty acid proportions were not greatly affected by changes in ruminal pH, although the proportion of acetate increased slightly as pH approached neutrality.

In addition to the production of volatile fatty acids, microbial cells provide a high-quality protein source (20 - 60% CP) to the host animal (Hungate, 1966; Owens and Zinn, 1987). The quantity of microbial protein which can be synthesized is limited by the amount of energy available for the microbes and the efficiency of substrate use (Owens and Zinn, 1987). Growth of bacteria can only occur once their maintenance requirement is met (Russell and Hespell, 1981).

Ammonia is the major source of nitrogen for bacterial growth but peptides and amino acids are also important, especially on low-quality forage diets where only 40% of the bacterial nitrogen is derived from ammonia (Bryant and Robinson, 1962; Nolan and Stachiw, 1979). Peptides and amino acids are required as precursors to produce branched chain fatty acids which are essential growth or stimulatory factors for many cellulolytic bacteria (Allison et al., 1958). In addition, amino acids stimulate microbial growth in vitro when readily available carbohydrates are being fermented (Maeng and Baldwin, 1976).

Ammonia is produced during the utilization of protein as an energy source (Hungate, 1966). Ammonia is relatively more important for the nutrition of fiber- and starch-digesting bacteria than for those which utilize soluble sugars (Hungate, 1966). Immediately following the feeding of forage, both soluble carbohydrates and proteins are available, while fiber is fermented at a slower rate. Thus, bacteria that utilize soluble carbohydrates can deplete the supply of rapidly available amino acids. Slow-growing cellulolytic bacteria must depend on ammonia as the primary nitrogen source (Hungate, 1966). Consequently, ruminal ammonia concentrations can be used as an index of nitrogen status of ruminal cellulolytic bacteria (Kropp et al., 1977).

Ruminal ammonia concentrations vary with diet fermentability (Erdman et al., 1986). Slyter et al. (1979) noted that dry matter and acid detergent fiber digestibilities decrease when ruminal available nitrogen is limiting. They concluded that a concentration of 2 to 5 mg NH_3-N/dl was sufficient to allow maximum growth of ruminal microbes with a 70% concentrate diet. Erdman et al. (1986) developed an equation to estimate minimum ruminal ammonia required for maximal digestion:

NH3-N (mg/dl) = .452 * fermentability - 15.71

(r^2 = .5, P<.0001).

Based on this equation, the minimum ruminal ammonia concentration required for digestion and probably maximum microbial growth increases with increasing ruminal digestion (fermentability) of the feed dry matter. These authors suggested that variable ammonia concentrations reported in the literature were due to differences in relative fermentability of feeds or diets tested.

Effects of Starch on Ruminal Function

Energy supplements usually contain large quantities (60 to 70%) of cereal grains which are high in starch (Hibberd et al., 1982). The inclusion of starch has been found to have negative effects on forage utilization. Chase and Hibberd (1987) concluded that feeding 2 or 3 kg of a grain-based supplement, formulated only to meet the total protein requirements of the cow, may decrease forage utilization to the extent that overall energy status of the cow is not improved. Calves fed brome hay with 50% corn or 50% corn bran showed negative effects on dry matter digestibility twice as great with 50% corn (Klopfenstein et al., 1985).

Cellulose digestion in vitro has been increased with small quantities (1 g/ 9 g cellulose) of readily available carbohydrate, but large quantities (2 to 3 g/ 9 g cellulose) inhibited cellulose digestion (Arias et al., 1951). Similiarly, when 1 g starch was added to 2 g cellulose, partial inhibition of cellulose digestion was observed (el-Shazly et al., 1961). Adding 2 g starch to 2 g cellulose, inhibited cellulose digestion completely. Aitchison et al. (1986) found that feeding 175 g of maize starch per kg hay dry matter increased volatile fatty acid concentrations and decreased ruminal pH. This response was rapid and short resulting in longer lag times for fiber digestion in animals receiving the starch supplement.

Mertens and Loften (1980) developed four hypotheses of digestion kinetics to explain the decrease of fiber digestion with addition of starch: 1. increased lag time of digestion, 2. decreased rate of digestion, 3. decreased potential extent of digestion, or 4. combination of all three. They found the addition of starch increased the lag time associated with fiber digestion in vitro, but that this did not explain the large decrease in fiber digestion in vivo when starch is fed. Differences in fiber digestion, due to starch, among different forages may be related to plant morphology and the type of bacteria associated with fiber digestion of each forage (Mertens and Loften, 1980).

B. succinogenes digests both starch and cellulose but prefers starch (Hungate, 1966). Mertens and Loften (1980) speculated that bacteria, such as B. succinogenes, that prefer starch, would be more susceptible to starch inhibition than bacteria, such as Ruminococcus, which degrade only cellulose. Amylolytic bacteria grow quickly and deplete the rumen of available nutrients, thereby creating a nutrient deficiency for slower-growing cellulolytic bacteria. Burroughs et al. (1949) suggested that the attack on starch either precedes or takes place at a faster rate immediately after feeding than does the action on roughages.

Stewart (1977) reported that in vitro cellulose digestion decreased with low ruminal pH because cellulolytic bacteria are more sensitive to low pH. el-Shazly et al. (1961) offered four theories to explain decreased cellulose digestion with starch supplementation: 1. starch-digesting microorganisms produce an inhibitor, 2. decreased pH due to acid production from starch fermentation, 3. competition for essential nutrients, or 4. predominance of starch-digesting microorganisms in the rumen of an animal on a high-starch ration. The production of an inhibitor was not a major factor in decreasing cellulose digestion and pH, in their system, was controlled by a continuous flow system. When a nutrient solution or autoclaved ruminal fluid supernatant were administered, the inhibition of cellulolysis was partially or completely alleviated. They concluded that nitrogen was a major factor although other nutrients may be beneficial. Chase et al. (1986) and Hibberd et al. (1987) suggest that negative effects of supplementing large quantities of corn to low-quality native hay diets may be overcome by providing a soluble source of nitrogen to meet microbial demands for ammonia. Burroughs et al. (1949) observed that four pounds of starch decreased the dry matter digestibility of corncobs or corncobs with limited alfalfa hay diets, yet only minor reductions in dry matter digestibility of high-quality alfalfa hay diets were observed. They concluded that alfalfa contained more of the essential nutrients required by ruminal microorganisms. The problem with starch-digesting microorganisms is unlikely since el-Shazly et al. (1961) found cellulose to be efficiently digested in ruminal fluid of animals whose diet contained large quantities of starch. Burroughs et al. (1950), however, found that when starch was added to a diet of corncobs, the number of bacteria decreased from 49.6 billion to 24.8 billion per gram of wet solid digesta suggesting negative effects of starch on the microbial population.

Forage Digestion

Van Soest (1982) defined the rate of digestion as the quantity of feed digested per unit time. This is a function of the diet composition plus quality and availablity of nutrients (Mertens, 1977; Van Soest (1982). Soluble feed components are fermented more rapidly and less soluble components attacked more slowly (Van Soest, 1982). Therefore, structural carbohydrates, such as cellulose, are fermented more slowly than storage carbohydrates like starch.

Low-quality roughages are unable to support optimal ruminal conditions for microbial activity mainly due to the lack of nitrogen, readily fermentable carbohydrates and branched-chain volatile fatty acids (Bryant, 1973; Allden, 1981; Ndlovu and Buchanan-Smith, 1985). Ruminants consuming low-quality forages may be energy deficient due to decreased digestibility (Allden, 1981). Supplementation of low-quality roughages with the necessary nutrients for microbial fermentation should increase digestion of fiber components.

Pritchard and Males (1985) increased total tract dry matter digestibility (49.7% to 53.2%) when crude protein of the diet was increased from 10% to 12%. Increased crude protein, dry matter and acid detergent fiber digestibilities of wheat straw were observed when increased levels of crude protein were supplied through either soybean meal or a liquid (NPN) supplement (Church and Santos, 1981). Gallup and Briggs (1948) found that cottonseed meal increased digestibility of dry matter (46% to 60%), crude protein (negative to 41.2%), and crude fiber (56% to 60%) of prairie hay. They suggested that the dry matter digestibility of a high-protein hay would be equal to that of a low-protein hay with 2 pounds of added cottonseed meal. Ndlovu and Buchanan-Smith (1985) observed that alfalfa hay supplementation increased in situ rates of fiber digestion for barley straw (4.63 to 5.85%/h), bromegrass hay (4.73 to 6.18%/h) and corncobs (3.78 to 4.57%/h).

Corn starch (2.7 kg/d) decreased crude protein, nitrogen-free extract and dry matter digestibilities of alfalfa hay when no acclimation was allowed (Kane et al., 1959). With a 20-day preliminary period, however, the starch had no effect on dry matter digestibility of alfalfa hay.

Rittenhouse et al. (1970) found only a small positive influence of protein supplementation on digestibility and intake of dormant shortgrass pastures. Factors such as the presence of highly lignified material in the rumen rather than nitrogen, limited intake. Supplemental energy above .041 Mcal/kg $BW^{.75}$ decreased forage intake but had no influence on forage dry matter digestibility. They concluded that total dietary intake and digestibility were increased by successive increments of increased energy supplement.

Chase and Hibberd (1987) provided 0, 1, 2 or 3 kg of ground corn supplements, formulated to provide 256 g/d of CP, to mature beef cows fed low-quality hay. Cellulose digestion and ruminal ammonia concentrations decreased linearly as the amount of supplemental corn increased. Ruminal NH_3-N concentration remained below 1 mg/dl throughout the day when cows were fed 3 kg corn/d, indicating a deficiency of ruminal degradable protein. They suggested that feeding 2 or 3 kg of grain-based supplements formulated only to meet the total protein requirement of the cow may decrease forage utilization to the extent that overall energy status is not improved. Hibberd et al. (1987) fed cows low-quality native hay supplemented with 1.8 kg corn plus graded levels of cottonseed meal ranging from 0 to .8 kg. Organic matter and NDF digestibilities increased with increasing cottonseed meal. They suggested additional cottonseed meal may be useful in alleviating ruminal degradable protein deficiencies when supplementing large quantities of cereal grains.

The adverse effects on forage utilization noted when feeding starch supplements has prompted the use of low starch, high fiber byproduct feeds as energy supplements. Soybean hulls, a byproduct of soybean meal production, are an example of a high-fiber feed. Soybean hulls are practically devoid of starch and the high neutral detergent fiber content coupled with low lignin, suggests that the fiber should be available to the ruminal microbes (Quicke et al., 1959; McDonnell et al., 1982; NRC., 1984; Hsu et al., 1987). Therefore, highly digestible, low-starch feeds may provide a means of supplementing low-quality forages without the negative associative effects that occur with cereal grain supplementation (Johnson et al., 1962; Merrill and Klopfenstein, 1985; Highfill et al., 1987).

Sudweeks (1977) compared the digestibilities of diets containing citrus pulp, corn and soybean mill feed at levels of 10, 40 and 70% of diet dry matter, with basal diets consisting of either corn silage, sorghum silage or bermudagrass hay and reported increased dry matter and nitrogen-free extract digestibilities with added concentrate. Crude fiber digestibility was greatest for soybean mill feed, although diets containing soybean mill feed averaged 29.5% crude fiber compared to citrus pulp (23.2%) and corn (18.9%). Crude protein digestibility was greater for citrus pulp and corn (69 and 70%, respectively) than soybean mill feed (66%), perhaps related to the amount of crude protein in the diet. Sudweeks (1977) concluded that citrus pulp and soybean mill feed promoted digestion of fiber.

Merrill and Klopfenstein (1985) found that supplemental soyhulls had no effect on fiber digestibility unlike supplemental corn. In growth trials, both soyhulls and corn increased average daily gain of bromegrass diets although soyhulls increased average daily gain over corn when calves grazed cornstalks.

Passage Rate

Ingested feed and water disappear from the rumen in two ways, through digestion and absorption or by passage (Mertens, 1977; Van Soest, 1982). The digestion of feeds has been discussed previously. The rate of passage refers to the escape of undigested material from the rumen. Removal of undigested material from the rumen is an important physical factor in the regulation of intake of bulky, fibrous feeds (Van Soest, 1982; Allison, 1985). Increased passage (dilution) rates should increase the efficiency of microbial growth (Owens and Isaacson, 1977; Hespell, 1979; Van Soest, 1982). The mean age of the microbial population is decreased at higher dilution rates resulting in younger cells that have a higher growth potential than mature cells (Van Soest, 1982). As dilution rate increased from 2 to 12%/h, maintenance needs of the bacteria decreased from 50 to 15% of the energy supply (Owens and Isaacson, 1977). With increased ruminal turnover, however, forage fiber digestion usually decreases (Owens and Isaacson, 1977; Bull et al., 1979).

Ruminal contents are separated into two major pools, liquid and particulate. Fluid dilution influences particulate and bacterial outflow (Owens and Isaacson, 1977). In addition, increased liquid passage usually occurs in conjunction with changes in ruminal fermentation toward more acetate, butyrate, methane and less propionate (Owens and Isaacson, 1977; Bull et al., 1979; Crawford et al., 1980).

Liquid flow rate is determined by fluid and salivary input, while particulate turnover is affected by particle size and shape, density and wettability as well as total fluid turnover (Owens and Isaacson, 1977; Bull et al., 1979; Ehle and Stern, 1986). Individual components of a mixed diet are retained for times characteristic of each component, but are probably influenced by the remainder of the diet (Warner, 1981). Ellis et al. (1979) stated that particulate turnover is of primary interest since this provides a source of digestible energy for microbial growth and the turnover of undigested particles establishes intake of less digestible forages.

In vitro experiments have shown increased pH with increased liquid dilution rate at low particulate retention times, although this effect was not evident at high retention times (Crawford et al., 1980). Dry matter and fiber digestibilities tended to increase with increased solid retention time and liquid dilution rate, to a plateau at 22 hours and liquid dilution rates of 11 to 15%/h.

Liquid rate of passage decreased and ruminal digesta retention time increased with increasing maturity of blue grama pasture from early growing season to early dormancy (McCollum and Galyean, 1985). Passage rates ranged from 14.9 and 4.6%/h in early growing season to 10.5 and 3.5%/h in early dormancy, for fluid and particulate, respectively.

Protein supplementation increases intake due to increased digestion rate and increased passage of undigested material (Ellis, 1978). Ndlovu and Buchanan-Smith (1985) found that alfalfa hay supplementation of a corncob diet increased the passage rate of indigestible material from 1.87%/h to 3.06%/h.

Aitchison et al. (1986) fed two levels of perennial ryegrass hay (11 and 16.5 g DM/kg $BW^{.75}$) and found that starch (175g DM/kg hay DM) had no effect on digesta passage rate. Increased intake, however, increased particulate passage rate from 3.18 to 4%/h, while neutral detergent fiber digestibility decreased from 75.5 to 72.4%. Chase and Hibberd (1987) fed a low-quality native prairie hay with increasing levels of a corn-based supplement to beef cows and found that particulate passage rate decreased linearly from 3.90 to 3.68%/h with increased corn supplementation.

Protein supplementation (800 g cottonseed meal) increased fluid dilution rate (8.8 to 10.5%/h) and particulate passage rate (2.9 to 4.5%/h) of steers fed prairie hay, although ruminal fluid volume did not change (McCollum and Galyean, 1985). Increased passage rate was mainly associated with increased intake (16.9 to 21.5 g/kg BW) of the low-quality hay.

Supplementation of steers grazing dormant blue grama range with either 1.7 kg cottonseed meal, 3.6 kg alfalfa pellets or no supplement did not alter rate of particulate passage, fluid dilution rate, or ruminal volume (Judkins et al., 1987).

Hespell (1979) suggested that feeding and management practices should be developed in ways that increase the ruminal turnover rate as this will probably lead to greater net microbial protein synthesis, particularly with low-quality, high-forage rations.

Forage Intake

Range ruminant productivity and efficiency is relatively low, due, in part, to limitations on voluntary intake (Allison, 1985). Ellis (1978) suggested that rate of passage, rate of digestion and feed intake are related. Aitchison et al. (1986) observed that increased feed intake increased the rate of passage and decreased overall feed digestibility. In animals whose gut normally contains substantial quantities of digesta, such as the grazing ruminant, increased feed intake results in decreased ruminal retention time as well as increased ruminal volume and rate of passage (Warner, 1981).

Digestibility decreases with increased feed intake (Van Soest, 1982; Faichney and Gherardi, 1986). McCollum and Galyean (1985) concluded that the decreased forage intake of grazing steers was due to decreased forage digestibility, increased gut fill and increased residence time of particulate and fluid digesta. Cows grazing fescue-legume pastures consumed 1.7 kg/d more dry matter that was 4.6% more digestible than cows grazing fescue pastures (Holloway and Butts, 1983). The depression in digestibility is a function of competition between rates of digestion and passage (Van Soest, 1982). Digestion and ruminal efflux are means by which ruminal fill is alleviated. Taking this into account, Van Soest (1982) concluded that rate of passage is more important than rate of digestion in accounting for intake of animals of similar appetites. Warner (1981) stated that any treatment which alters feed intake can be expected to alter ruminal retention time.

Many factors such as humoral factors, neural transmitters, chemical and hormonal mechanisms, ruminal fill and rate of passage, regulate feed intake (Allison, 1985). The most important factors for the range ruminant are physical; ruminal fill and rate of passage (Van Soest, 1982; Allison, 1985; Grovum, 1987). This is due to the bulky, fibrous nature of the feeds which are relatively low in digestible energy (Allison, 1985). Intake is partially dependent on the cell wall content of the feed (Van Soest, 1982). This is due to the slow rate of digestion and water holding capacity of cell walls brought about by a relationship between surface area and increased intracellular space.

Level of intake may influence ruminal liquid turnover rate to a greater extent than solid turnover (Varga and Prigge, 1982; Adams and Kartchner, 1984). Mudgal et al. (1982) found that increasing the intake of sheep consuming alfalfa pellets increased fluid dilution rate 54% and decreased particulate retention time 25%. Merchen et al. (1986) found that increasing the intake of 25% or 75% alfalfa diets in sheep decreased OMD, increased efficiency of bacterial protein synthesis as well as duodenal flows of total, essential and nonessential amino acids, although the amino acid profile was unchanged.

Allison (1985) suggested that variation in feed intake is the major dietary factor determining the level and efficiency of ruminant production. Therefore, management considerations should attempt to increase intake. Allden (1981) noted that energy intake of grazing livestock is impaired by low digestibility, low protein or low forage availability. Supplementation is one way of controlling low-quality forage intake by grazing ruminants.

Gallup and Briggs (1948) found marked increases in feed intake with as little as 220 g of supplemental cottonseed meal. Intake of wheat straw was increased with the addition of soybean meal (1 g/kg $BW^{.75}$) but not with the addition of NPN (Church and Santos, 1981).

Duodenal casein infusion immediately increased intake of chaffed oat hay by sheep but urea infusion provided a next day response (Egan and Moir, 1965). They suggested that urea increased the digestion of cotton thread on the day of infusion through increased nitrogen recycling to the rumen, therefore increasing feed intake by stimulating the rate of cellulose digestion. In contrast, casein appeared to act independently of digestion rate, by improving the nitrogen status of the animal as a chemoregulatory mechanism to enhance feed intake.

McCollum and Galyean (1985) noted that intake of a low-quality hay was increased with the supplementation of 800 g cottonseed meal. Others have found similar responses in feed intake with protein supplementation (Elliot, 1967; Cook and Harris, 1968; Andrews et al., 1972; Kartchner, 1980). McCollum and Galyean (1985) concluded that the increased rate of particulate passage was the major factor associated with increased intake.

The effects of protein supplementation, however, are dependent upon forage quality (Rittenhouse et al., 1970; Lusby et al., 1976; Van Soest, 1982; Judkins et al., 1985). When the crude protein content of forage is sufficient (above 6 to 8% CP), forage intake may not be improved by protein supplementation (Rittenhouse et al., 1970; Van

Soest, 1982; Judkins et al., 1985). Lusby et al. (1976) added that roughage palatability may also be an important factor in determining the usefulness of protein supplementation. They reported when cows were grazing a less palatable, less available, mature winter forage, forage intake was decreased with increased protein supplementation.

Since performance of livestock grazing low-quality forages is often limited by digestible energy intake (Cook and Harris, 1968; Rittenhouse et al., 1970; Allden, 1981), supplementation with a low protein, high energy feedstuff would be logical. These supplements are usually composed of cereal grains that contain high amounts of starch.

Up to 6 kg of concentrate had little effect on hay intake and a slight increase in barley straw intake, but feeding of 6 and 8 kg of concentrate decreased intake (Campling and Murdoch, 1966). Decreased cellulolytic activity of ruminal microbes and the decreased rate of digesta disappearence from the tract may explain their responses (Campling and Murdoch, 1966; Rittenhouse et al., 1970). Chase and Hibberd (1987) found a linear decrease in low-quality hay intake as supplement level increased, but suggested that 1 kg of supplement increased the energy intake of the cows. Kartchner (1980) compared protein to energy supplementation, feeding barley at isocaloric levels with either .75 kg cottonseed meal or .7 kg soybean meal and found that both total and forage dry matter intake was increased with protein supplementation. Digestible energy intake increased 45% for animals fed the protein supplement (16.87 Mcal/d) versus the control (11.74 Mcal/d) or the barley (11.52 Mcal/d) groups. Elliot (1967) found that feed intake increased with supplemental protein and decreased with concentrate. Depressed feed intake was due to decreased pH and fiber digestion in animals fed the concentrate supplement.

CHAPTER III

SOYBEAN HULL VS CORN SUPPLEMENTS FOR LACTATING BEEF COWS GRAZING DORMANT NATIVE GRASS IN WINTER

Abstract

Two trials were conducted to evaluate soybean hulls as a component of range supplements for lactating Hereford X Angus beef cows grazing dormant, native tallgrass prairie during the winter (December through March). In trial 1, cows were individually fed 1.48 kg/d cottonseed meal (CSM), 2.62 kg/d corn/cottonseed meal blend (CORN/CSM) or 3.45 kg/d soybean hulls (SBH). In trial 2, a fourth supplement consisting of 2.63 kg/d soybean hull/cottonseed meal blend (SBH/CSM) was added. All supplements provided approximately 610 g crude protein/d while CORN/CSM and SBH supplied 2.2 kg TDN/d, twice that of CSM. The SBH/CSM and CORN/CSM supplements were fed at similar levels of intake (2.6 kg DM/d). Cows receiving energy supplements (CORN/CSM, SBH/CSM or SBH) lost less weight and body condition and supported increased calf gains over the CSM (control) cows in both years. In trial 1, cows supplemented with SBH lost less weight and body condition than cows fed CORN/CSM. In trial 2, source of supplemental energy (CORN/CSM vs SBH/CSM vs

SBH) had little effect on cow performance. Cows receiving SBH produced more milk than cows fed CORN/CSM or SBH/CSM although calf performance was not affected. These studies suggest that soybean hulls perform similarly to corn when fed either at equal levels of dry matter or TDN. Therefore, soybean hulls are a useful substitute for corn as a component of range supplements.

(Key Words: Beef Cattle, Corn, Soybean Hulls, Supplements)

Introduction

Fall-calving beef cows are subjected to increased physiological and environmental stress during the winter (NRC., 1981). Thus, energy requirements are increased at a time when the nutritional quality of dormant, native grass pastures is extremely low (Waller et al., 1972; NRC., 1984).

Commercial energy supplements (20% CP) frequently contain large quantities of cereal grains. Cereal grains fed at levels of 1 to 2 kg may decrease forage digestibility and intake due to the starch component of the grains (Hennessy et al., 1983; Chase and Hibberd, 1987). Thus, feedstuffs containing little or no starch may be more effective energy supplements than cereal grains (McDonnell et al., 1982; Merrill and Klopfenstein, 1985).

Soybean hulls, a byproduct of the soybean milling industry, are moderate in both crude protein (McDonnell et al., 1982) and energy (Hintz et al., 1964; Wagner et al., 1965). High neutral detergent fiber (McDonnell et al.,

1982) coupled with low lignin content (McDonnell et al., 1982) indicates that the fiber should be very digestible by ruminal microbes (Johnson et al., 1962; McDonnell et al., 1982; Van Soest, 1982; Hsu et al., 1987). In contrast to the starch in cereal grains, the digestible fiber component of soybean hulls may supply ruminal energy in a noncompetitive form that could complement forage utilization (McDonnell et al., 1982; Merrill and Klopfenstein, 1985).

The objective of these experiments was to compare soybean hulls with traditional corn or cottonseed meal supplements on the productivity of lactating beef cattle maintained on dormant, native grass in the winter.

Materials and Methods

Trial 1 (1985). Eighty-one mature, lactating Hereford x Angus cows (average weight, 475 kg; average calving date, November 2, 1984) bred to Limousin bulls were blocked by calving date, weight and body condition and allotted to three supplemental treatments starting December 7, 1984 for a 117-d study. Cows were maintained on similar native tallgrass pastures dominated by little bluestem (Andropogon scoparius) at the Southwest Forage and Livestock Research Laboratory near El Reno, Oklahoma. All supplemental treatments were equally represented within each of three pasture groups. Cows were rotated to a new pasture when forage quantity was deemed inadequate to maintain performance.

Supplements were 1.48 kg/d cottonseed meal (CSM), 2.62 kg/d corn-cottonseed meal blend (CORN/CSM) and 3.45 kg/d soybean hulls (SBH). Supplements were balanced to provide approximately 610 g of crude protein/d (table 1). The CORN/CSM and SBH supplements supplied 2.2 kg of TDN/d, twice that offered by the CSM (NRC., 1984). Cows were put in stalls and individually fed the designated supplement between 0800 and 1000, six times per week, Monday through Saturday. Samples of each supplement were taken at approximately 2-week intervals and ground with a Wiley mill through a 1-mm screen. All samples were subjected to dry matter, ash and macro-kjeldahl protein (N * 6.25) determination (AOAC., 1975). Equal quantities of each sample were combined by treatment for neutral detergent fiber (NDF), a sequential acid detergent fiber (ADF) and permanganate lignin (PL) analysis (Goering and Van Soest, 1970) and starch analysis (MacRae and Armstrong, 1968). Concentrations of hemicellulose (NDF minus ADF) and cellulose (ADF minus PL minus ADF-ash) were calculated by difference.

Cow weights and condition scores were taken at approximately two-week intervals. Weights were measured after an 18-h separation from feed and water. Body condition was quantified on a scale of 1 to 9 (1 = emaciated, 9 = obese) by visual assessment in conjunction with palpation of rump, back, ribs and brisket by two independent evaluators. Calf weights were measured with no

TABLE 1. INGREDIENT COMPOSITION OF SUPPLEMENTS (DRY MATTER BASIS) AND DAILY INTAKE OF SUPPLEMENTAL CHEMICAL COMPONENTS

Item	SUPPLEMENT CSM	CORN/CSM	SBH/CSM	SBH
Ingredient,				
Cottonseed meal, %	96.55	44.54	27.71	---
Corn, ground, %	---	53.62	---	---
Soybean hulls, %	---	---	69.62	92.01
Soybean meal, %	---	---	---	5.26
Dicalcium phosphate, %	.79	.31	1.39	1.72
Trace mineralized salt, %[a]	1.53	.87	.87	.66
Sodium sulfate, %	.49	.16	.42	.35
Limestone, %	.64	.49	---	---
Intake, g/d				
Total dry matter[b]	1418	2537	2629	3316
Total digestible nutrients[c]	1068	2106	1740	2099
Crude protein, g/d[b]				
Trial 1	600	623	---	667
Trial 2	634	689	634	615

[a]Trace mineralized salt contained 16% zinc, 12% iron, 6% manganese, 3% magnesium, 1% copper, 1% potassium, .6% iodine, .3% cobalt and 1% mineral oil.

[b]Actual analysis

[c]Estimated from NRC. (1984)

shrink, at monthly intervals until March when weights were taken biweekly.

Diet samples were collected via four esophageally fistulated heifers throughout the study (Jan. 11, Feb. 8, Feb. 23 and Mar. 22, 1985). Diet samples were composited by animal, stored at -15 C, lyophilized and allowed to air-equilibrate. Air-dry diet samples were ground with a Wiley mill through a 1-mm screen and subjected to the same chemical analyses as the supplements except for starch.

Bermudagrass, alfalfa or wheat hay were fed at an average rate of 8.4 kg/cow/d on 12 d during the study, when snow cover or extreme cold inhibited normal grazing.

Data were subjected to least squares analysis with a model that included calf age (covariate), calf sex, pasture, treatment and treatment*pasture. Treatment responses were evaluated with orthogonal contrasts which compared CSM vs (CORN/CSM + SBH) and CORN/CSM vs SBH.

Trial 2 (1986). Seventy-four mature, lactating Hereford x Angus beef cows (average weight, 467 kg; average calving date, October 23, 1986) bred to Angus bulls were blocked by calving date, weight, body condition and previous treatment and allotted to four supplementation treatments starting December 5, 1985 for a 116-d study. Cows were maintained on the same pastures as trial 1. All supplemental treatments were equally represented within two pasture groups. Cows were rotated to a new pasture when forage quantity was deemed inadequate to maintain performance.

Three supplements were identical to trial 1 (table 1). The fourth, 2.63 kg/d of a blend (SBH/CSM) 70% soybean hulls-28% cottonseed meal, supplied 610 g crude protein/d and was fed at the same daily rate as CORN/CSM (2.6 kg/d). Cows were individually-fed the designated supplement five times per week, on Monday, Tuesday, Thursday, Friday and Saturday. Cows had free access to a mineral consisting of 50% trace mineral salt and 50% dicalcium phosphate. Supplement sampling and analysis were identical to trial 1.

Cow weights and body condition scores were measured at approximately two-week intervals with body condition scores assessed by three independent evaluators. Calves were weighed after a 5-h removal from the dam. Milk production was measured on four dates (January 3, February 4, March 4 and April 1, 1986) utilizing the weigh-suckle-weigh technique (Totusek et al., 1973). Calves were removed from the dam at 1900 and allowed to suckle at 0700 and 1900 the following day. Daily milk production was calculated as the sum of the 0700 and 1900 milkings.

Diet samples were collected on November 22, 1985, January 8, 1986 and March 10, 1986. Diet samples were combined by animal and stored in the freezer (-15 C) until drying in a forced-air oven at 40 C. Air-dry diet samples were ground and subjected to the same analyses as in trial 1.

Old World bluestem hay was fed for nine days during the trial, at a rate of 10.1 kg/cow/d, when adverse weather inhibited normal grazing.

Data were subjected to least squares analysis with the same model as trial 1. Orthogonal contrasts compared CSM vs (CORN/CSM + SBH/CSM + SBH), CORN/CSM vs SBH/CSM and CORN/CSM vs SBH.

Results and Discussion

Trial 1 (1985). Crude protein content of native grass pastures decreased quadratically ($P<.01$) from 4.3% on January 11 followed by an increase to 4.5% on March 22 (figure 1). In contrast, neutral detergent fiber peaked (cubic response, $P<.006$) on February 23 (84.5%) and declined to 81.8% by March 22. Forage quality should decline during the winter due to leaching of plant nutrients and selective grazing of leaf (Waller et al., 1972; Poppi et al., 1981). Increased forage quality in late winter (March 22) is due to growth of winter annual grasses (Waller et al., 1972).

Cows recieving the CSM (control) supplement lost 69.4 kg of body weight (.59 kg/d) and 1.05 units of body condition by the end of the study (table 2). Energy supplementation decreased ($P<.0001$) body weight and condition losses. Lactating cows maintained on dormant native grass typically lose less body weight when fed larger quantities (2 to 4 kg) of a low-protein supplement (20% CP) rather than smaller quantities (1 to 2 kg) of a higher

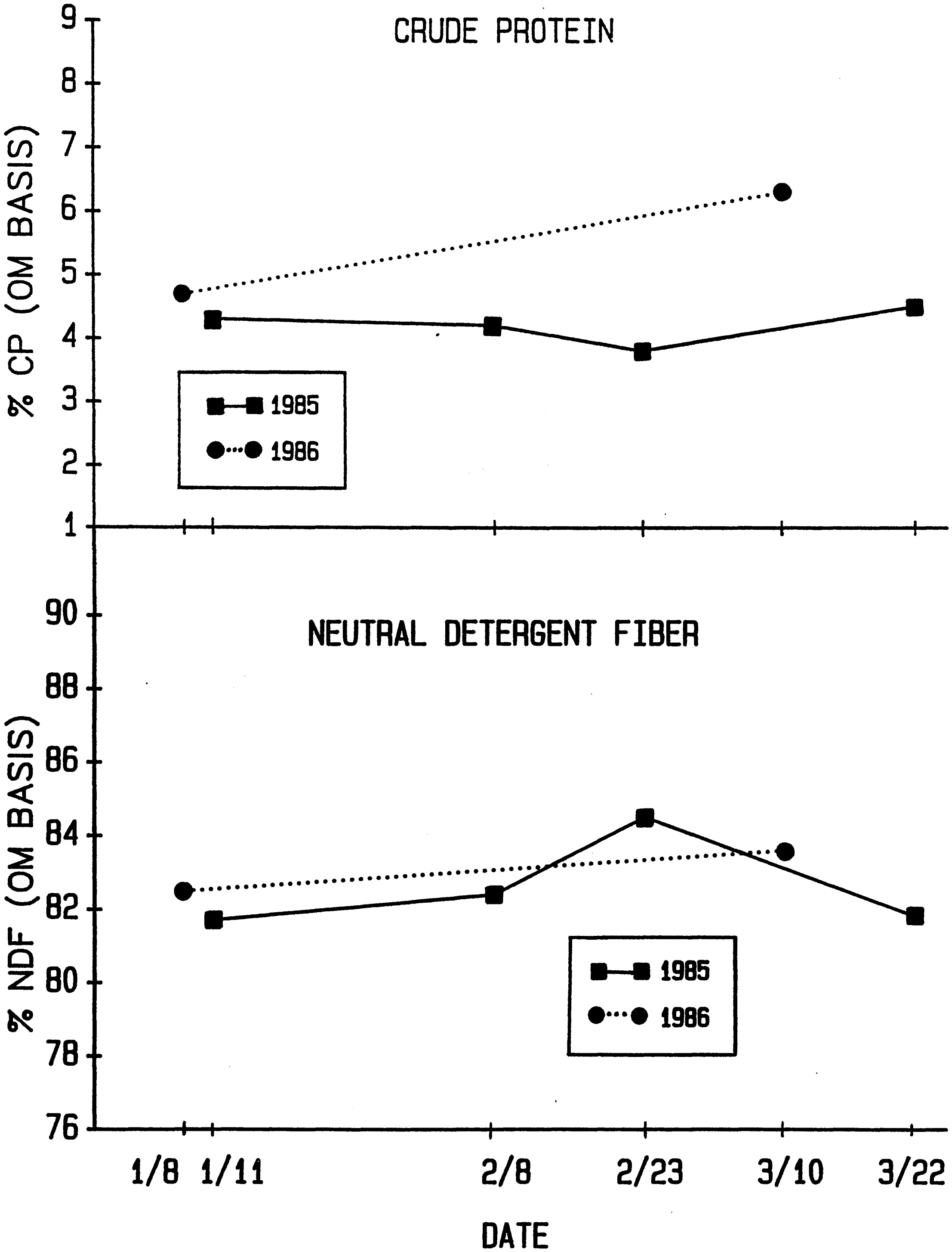

Figure 1. Changes in Forage Quality (Organic Matter Basis) of Dormant Native Tallgrass Pastures during the Winters of 1985 and 1986.

TABLE 2. EFFECT OF SUPPLEMENTAL ENERGY SOURCE ON SEASONAL CHANGES IN COW BODY WEIGHT AND CONDITION AND CALF WEIGHT GAIN OF FALL-CALVING BEEF COWS (1985)

	SUPPLEMENT				Contrasts	
	CSM	CORN/CSM	SBH	SE	a	b
Cow Weight, kg						
Initial	475.8	468.6	481.4	8.98	.94	.32
Final	406.4	407.8	435.1	7.73	.12	.02
Change, 117 d	-69.4	-60.8	-46.2	3.14	.0001	.002
Cow Body Condition, units						
Initial	5.98	5.87	5.78	.123	.31	.64
Final	4.93	5.25	5.44	.175	.06	.45
Change, 117 d	-1.05	-.62	-.35	.109	.0001	.08
Calf Weight, kg						
Initial	60.8	60.6	58.4	1.60	.49	.33
Final	117.4	128.0	125.6	3.11	.02	.59
Change, 117 d	56.5	67.4	67.2	2.10	.0001	.96

[a]CSM vs (CORN/CSM + SBH)

[b]CORN/CSM vs SBH

protein (40% CP) supplement (Lusby et al., 1976; Fleck and Lusby, 1986; Fleck et al., 1986).

Lactating cows fed SBH lost less body weight (14.6 kg, P<.002) and condition (.27 units, P<.08) than cows fed CORN/CSM (table 2). The CORN/CSM supplement supplied 1.4 kg corn/d which is above the 1 kg/d level where Chase and Hibberd (1987) observed decreased forage digestibility. In addition, digestibility trials have shown that corn supplementation decreases fiber digestion while soybean hulls do not (Johnson et al., 1962; Sudweeks, 1977; Merrill and Klopfenstein, 1985). Thus, decreased forage utilization for cows fed CORN/CSM may have lowered energy intake and animal performance. Merrill and Klopfenstein (1985) observed that steers supplemented with soybean hulls gained more weight than steers supplemented with corn.

Treatment differences in body weight were not observed until March 7 (figure 2). Energy supplementation (CORN/CSM or SBH) decreased body condition loss as early as January 18. Energy supplementation may not be critical until mid to late winter when forage quality is extremely low (figure 1). Although protein supplementation may increase the digestibility of low-quality native grass (Guthrie et al., 1984), this response may not equal the response to energy supplementation. In addition, as winter annuals begin to grow in March, cows may begin to select highly palatable green forage in preference to dormant standing warm season forage. Because of the low quantity of winter annuals,

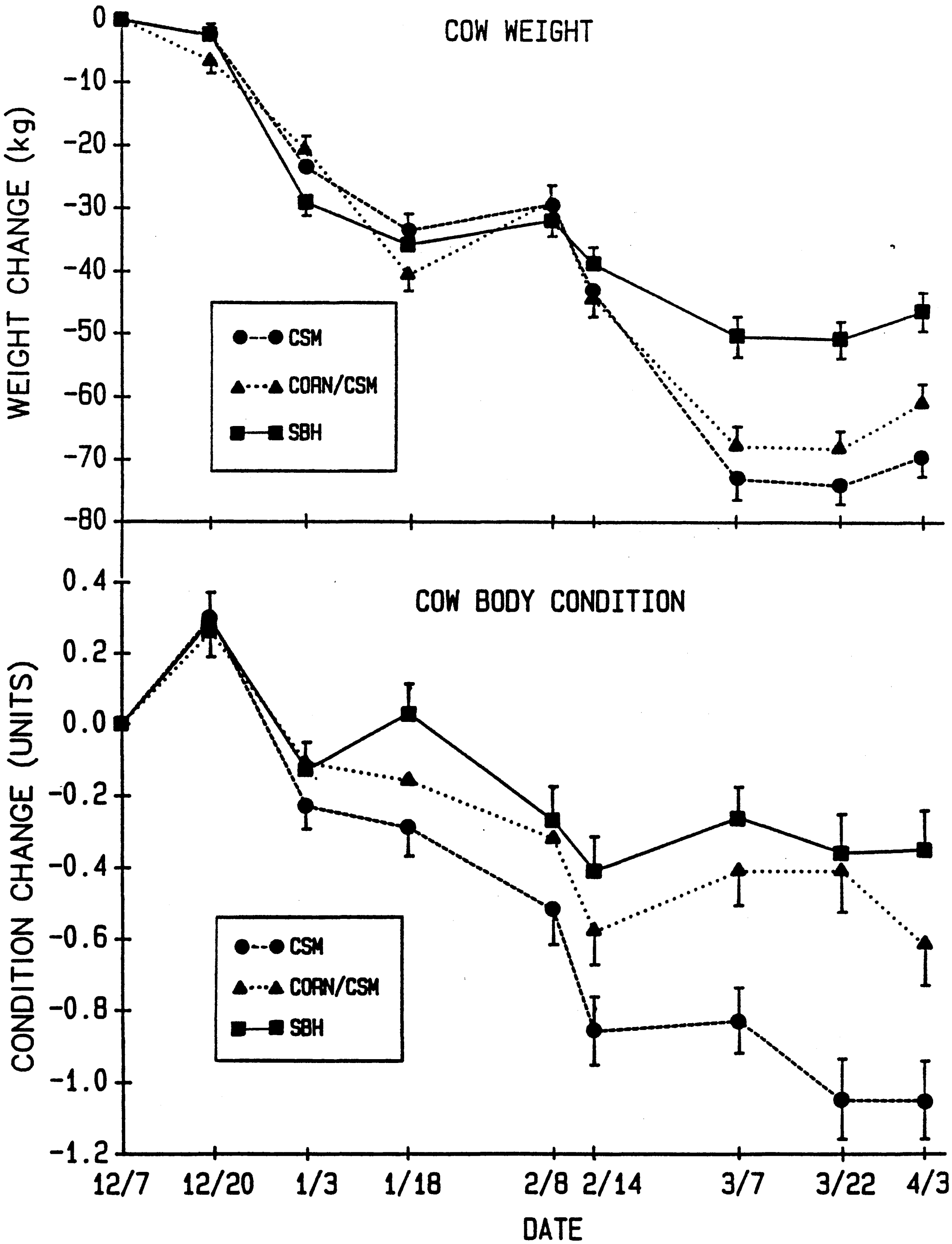

Figure 2. Effect of Supplemental Energy Source on Body Weight and Condition Changes of Fall-calving Beef Cows (1985)

increased energy expenditures due to grazing distance (Osuji, 1974) may further enhance the response to energy supplements.

Calves suckling cows fed CSM (control) gained 56.5 kg (.59 kg/d) during the trial (table 2). Energy supplementation of the dam increased ($P<.0001$) calf weight gain. No difference ($P<.96$) in calf weight gain was observed between CORN/CSM and SBH (figure 3). Increased performance of calves suckling cows supplemented with energy (CORN/CSM or SBH) is probably due to increased milk production (Furr and Nelson, 1964; Jeffery et al., 1971). Although milk production was not measured in this trial, similar weight gain for CORN/CSM and SBH calves suggests that milk supply was probably similar for these two groups. Although cows fed SBH had access to more energy, as evidenced by decreased weight and condition losses (table 2), additional energy was apparently not transferred to milk synthesis.

Trial 2 (1986). Crude protein content was 4.7% on January 8 (figure 1) which is typical of dormant native grass (Waller et al., 1972). By March 10, crude protein had increased to 6.3%, likely due to the growth of winter annual grasses brought about by the increased spring temperatures (Waller et al., 1972). Fiber content (NDF) was 82.5% on January 8 and slightly increased to 83.6% by March 10. Although infrequent sampling limits comparisons to trial 1 (1985), forage quality in January appeared to be similar in

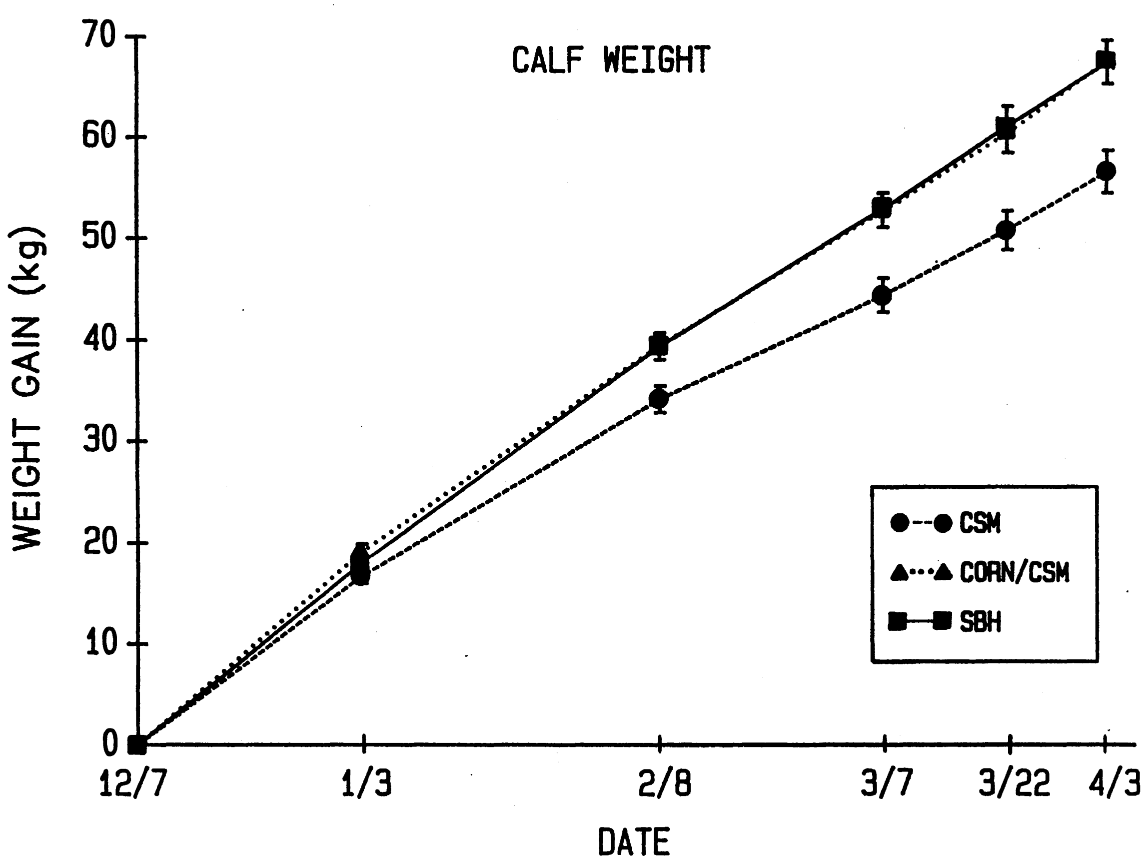

Figure 3. Weight Gain of Fall-born Calves Suckling Cows Supplemented with Different Energy Sources (1985)

both years. Because the winter of 1986 was comparatively mild, growth of winter annuals may have been initiated at an earlier date thus explaining the increased crude protein content on March 10 in trial 2. Throughout the season, forage quality in trial 2 (1986) appeared to be slightly better than in trial 1 (1985).

Cows fed CSM (control) in trial 2 lost 30.1 kg (.26 kg/d) body weight and .92 units of body condition (table 3). Although condition losses were similar in both years, cows in trial 2 (1986) lost only 43% as much weight as in trial 1 (table 2). Mild winter weather coupled with improved forage quality may explain this response.

Cows receiving energy supplements (CORN/CSM, SBH/CSM or SBH) lost less body weight (P<.02) and tended to lose less body condition (P<.15) than cows fed CSM (table 3). Although forage quality and environmental factors were both improved in trial 2 (1986), cows still responded to energy supplementation probably because of the energy demand from lactation.

In contrast to trial 1 (1985), cows fed SBH tended (P<.18) to lose more body weight than cows fed CORN/CSM (table 3). Improved forage quality may have minimized the detrimental effects of grain supplementation and improved cow performance (Burroughs et al., 1949).

Cows supplemented with SBH/CSM performed similarly to cows receiving the same daily quantity of CORN/CSM (table 3). This response suggests that the energy value of soybean

TABLE 3. EFFECT OF SUPPLEMENTAL ENERGY SOURCE ON SEASONAL CHANGES IN COW BODY WEIGHT AND CONDITION AND CALF WEIGHT GAIN OF FALL-CALVING BEEF COWS (1986)

	SUPPLEMENT					Contrasts		
	CSM	CORN/CSM	SBH/CSM	SBH	SE	a	b	c
Cow Weight, kg								
Initial	456.4	467.1	467.6	466.7	15.33	.50	.99	.99
Final	426.3	455.3	453.7	445.4	13.51	.08	.93	.56
Change, 116 d	-30.1	-11.8	-13.9	-21.3	5.60	.02	.79	.18
Cow Body Condition, units								
Initial	5.45	5.82	5.38	5.87	.259	.37	.21	.87
Final	4.53	5.01	4.87	5.20	.279	.09	.71	.58
Change, 116 d	-.92	-.81	-.51	-.67	.173	.15	.21	.52
Calf Weight, kg								
Initial	66.4	66.1	68.5	69.4	2.57	.53	.48	.30
Final	135.2	143.1	148.5	149.4	5.26	.04	.45	.34
Change, 116 d	68.9	77.0	80.0	80.0	3.83	.02	.57	.53

[a]CSM vs (CORN/CSM + SBH/CSM + SBH)

[b]CORN/CSM vs SBH/CSM

[c]CORN/CSM vs SBH

hulls may be underestimated with current TDN values (NRC., 1984). Johnson et al. (1962) observed that the cellulose digestibility of a soybran flake/timothy hay diet was greater than the digestibility of either soybran flakes or timothy hay fed alone. No associative effects were observed when 3 kg of soybean hulls were fed with low-quality native grass hay (Martin and Hibberd, 1987). Alternatively, the TDN value of corn may be overestimated for use in range supplements. Numerous studies have documented the negative associative effects of grain supplementation (Kane et al., 1959; Hennessy et al., 1983; Chase and Hibberd, 1987).

Similar to trial 1, energy supplements had no significant effect on cow performance until February 4 (figure 4). Consistent responses in both years suggest that energy supplementation of lactating, beef cows may not become critical until late January or early February as long as forage quantity remains adequate.

Cows receiving energy supplements (CORN/CSM, SBH/CSM or SBH) produced more milk ($P<.04$) than control (CSM) cows throughout the study (figure 5). Lactating beef cows apparently shuttle increased supplemental energy towards milk synthesis (Huber and Boman, 1966; Kropp et al., 1973). Supplementation with SBH supported a higher ($P<.03$) level of milk production than CORN/CSM through March 4. Cows receiving CORN/CSM were more persistent, however, resulting in similar levels of milk production by April 1. Cows produced similar quantities of milk when supplemented with

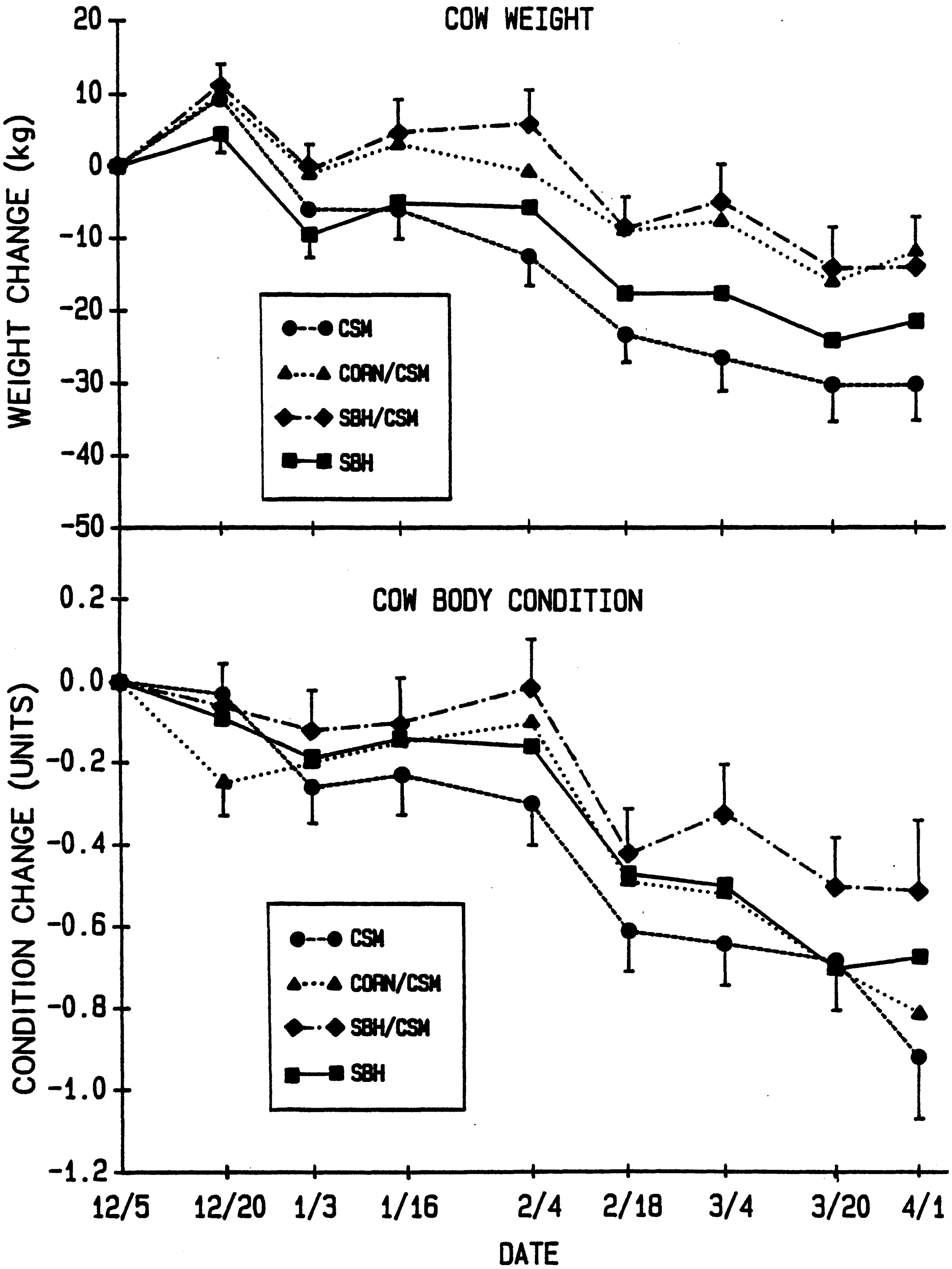

Figure 4. Weight and Condition Changes of Fall-calving Beef Cows Supplemented with different energy sources (1986)

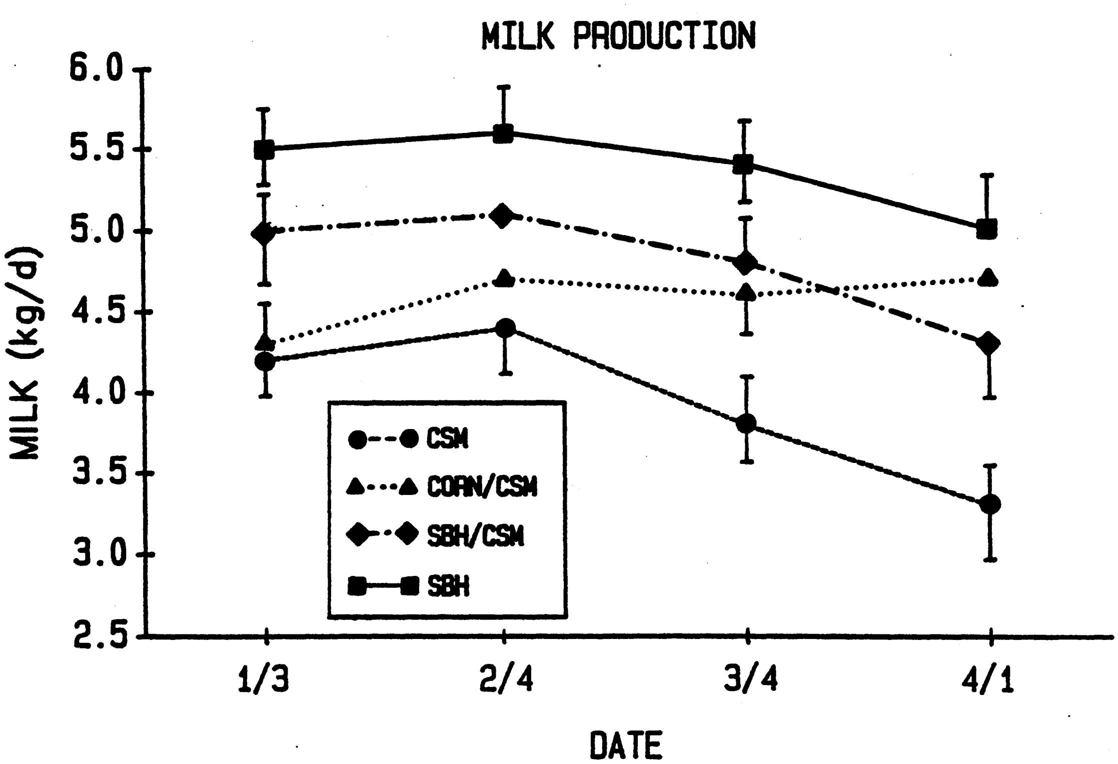

Figure 5. Effect of supplemental energy source on Milk Production of Fall-calving Beef Cows (1986)

the same daily amount of CORN/CSM or SBH/CSM. MacGregor and Owen (1976) reported that soybean hulls supplied as much NE_l as corn in the concentrate mixture of dairy cow rations.

Increased milk production due to energy supplementation resulted in increased ($P<.02$) calf body weight gain (figure 6). Supplemental energy should increase milk production and subsequent calf weight gain (Furr and Nelson, 1964; Jeffery et al., 1971; Bellido et al., 1981). Source of supplemental energy had no significant effect on calf weight gain although calves in the SBH/CSM and SBH groups gained 3 kg more weight than calves in the CORN/CSM group by the end of the trial. Significant differences in milk production among energy supplements were not observed for calf growth.

These studies support the contention that energy supplementation of lactating beef cows will decrease body weight and condition losses, increase milk production and increase calf weight gain. Energy supplementation may be delayed, however, until mid-winter (February) when forage quality and possibly quantity are lowest. Feeding smaller quantities (1 to 2 kg) of high protein (40% CP) supplements in late fall and early winter should be economically advantageous to feeding larger quantities (2 to 4 kg) of energy (20% CP) supplements.

Within energy supplements, responses appeared to be dependent on the severity of the environment and the quality of the forage. In trial 1, 3.4 kg soybean hulls improved cow performance and maintained calf weight gain relative to

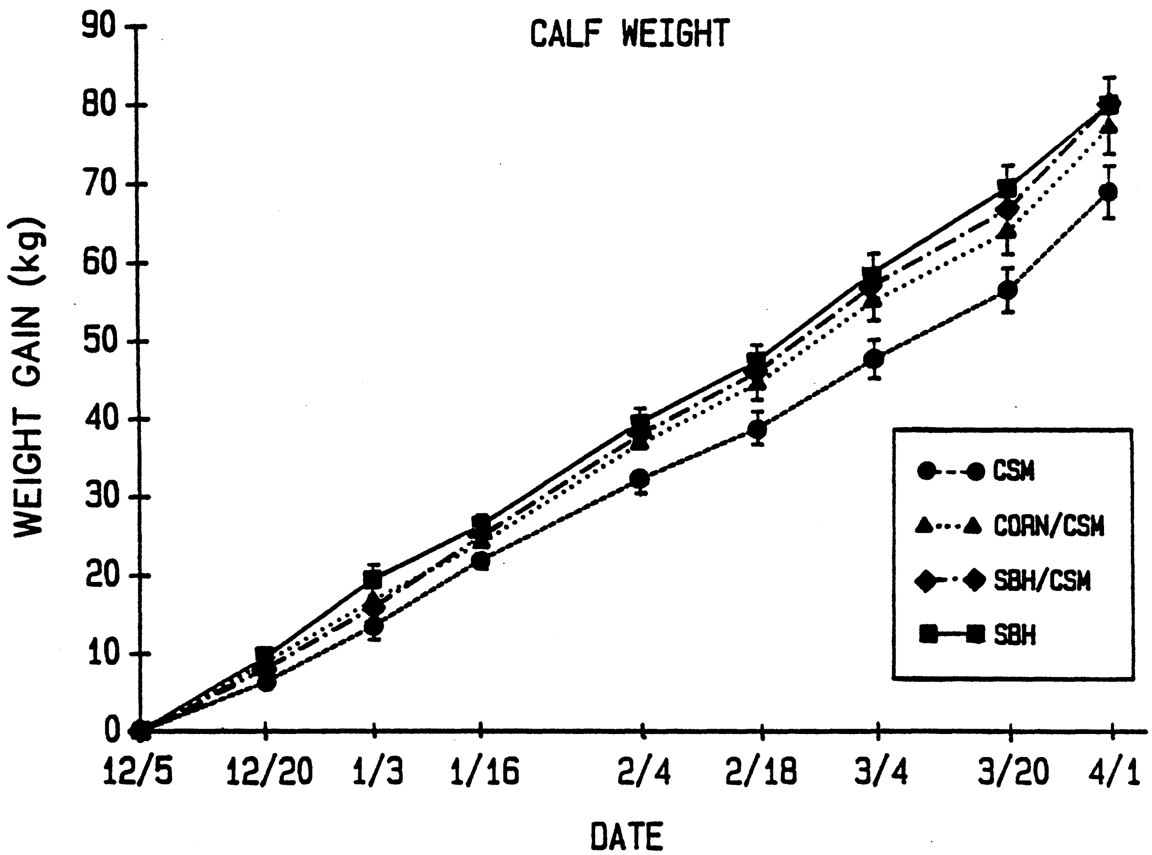

Figure 6. Weight Gain of Fall-born Calves Suckling Cows Supplemented with Different Energy Sources (1986)

2.6 kg of corn/cottonseed meal. In trial 2, cows fed soybean hulls (equal TDN or equal DM intake to corn) performed similarly to cows fed corn. Although the TDN values for corn and soybean hulls are quite different (91 vs 64%, respectively; NRC., 1984), negative associative effects on forage fiber digestion due to starch probably decreased overall energy intake when cows received corn. Thus, soybean hulls appear to be at least as effective as corn in range supplements for lactating beef cows. When formulating range energy supplements, the decision to use corn or soybean hulls should probably be based on cost/unit of dry matter assuming an equivalent energy content.

CHAPTER IV

EFFECT OF COTTONSEED MEAL, CORN OR SOYBEAN HULL SUPPLEMENTATION ON FORAGE DIGESTIBILITY, INTAKE AND RUMINAL PARAMETERS OF BEEF COWS MAINTAINED ON DORMANT NATIVE GRASS

Abstract

Four intake studies were conducted to evaluate the effect corn vs soybean hull supplements on the digestibility and intake of dormant, native range forage by mature, lactating, beef cows. A digestion study was conducted with 5 mature, ruminally cannulated Hereford cows to compare digestibility, intake and ruminal responses to corn vs soybean hull supplements. Treatments in 1985 consisted of .55 kg/d cottonseed meal (control), 1.48 kg/d cottonseed meal (CSM), 2.62 kg/d 54% corn-45% cottonseed meal blend (CORN/CSM) and 3.45 kg/d soybean hulls (SBH). A fifth treatment was added in 1986 consisting of 2.63 kg/d 70% soybean hulls-28% cottonseed meal (SBH/CSM). In the intake studies, energy supplements (CORN/CSM, SBH/CSM and SBH) increased total organic matter digestibility and intake compared to CSM. Supplementation with CORN/CSM decreased forage organic matter digestibility and intake compared to CSM, while SBH increased forage organic matter digestibility and slightly decreased forage organic matter intake. Digestible organic matter intake increased with energy supplementation (CORN/CSM, SBH/CSM, SBH) although cows fed SBH consumed the largest quantity of a highly digestible supplement. In the digestion study, forage organic matter intake was not affected by CSM, CORN/CSM, SBH/CSM or SBH supplements. Thus, total organic matter intake was a direct reflection of the amount of supplement fed. Total organic matter digestibility increased with CORN/CSM but rate and extent of hay organic matter digestion decreased. Feeding SBH increased liquid and particulate passage rates and total volatile fatty acid concentrations. These studies suggest that both corn and soybean hull supplements increase energy (digestible organic matter) intake of lactating beef cows grazing dormant native grass. Corn supplements, however, tend to decrease forage digestibility and intake while soybean hulls supply a noncompetitive source of energy that may maintain or improve the efficiency of forage utilization.

(Key Words: Soybean hulls, Corn, Supplements, Native grass, Beef Cattle)

Introduction

Native tallgrass pastures in Oklahoma provide large quantities of forage, but are poor in quality (approximately

4% CP or less) during the winter when the grass is dormant (Waller et al., 1972). Energy requirements of fall-calving beef cows are increased during this time due to lactational and environmental stress. Increased nutrient requirements coupled with low forage quality creates a large nutritional void because the cow is unable to consume enough of the standing forage to meet her increased nutrient requirements. Supplementation with large quantities (2 to 4 kg) of a high-energy supplement (20% CP) can be used to increase the energy status of the lactating cow. Many energy supplements contain large quantities of cereal grains which can decrease forage digestibility and intake due to the negative associative effects of starch (Cook and Harris, 1968; Chase and Hibberd, 1987). Under these circumstances, the standing forage commodity is inefficiently utilized.

Soybean hulls, a byproduct of the soybean milling industry, are moderate in both crude protein (McDonnell et al., 1982) and energy (NRC., 1984). High NDF (McDonnell et al., 1982) coupled with low lignin content (McDonnell et al., 1982) indicates that the NDF should be easily digested by ruminal microbes (Johnson et al., 1962; McDonnell et al., 1982; Hsu et al., 1987). In contrast to the starch in cereal grains, the digestible fiber component of soybean hulls may supply ruminal energy in a noncompetitive form that could complement forage utilization (McDonnell et al., 1982; Merrill and Klopfenstein, 1985).

The objective of these experiments was to compare soybean hull supplements vs traditional corn or cottonseed meal supplements on forage digestibility, intake and ruminal parameters of beef cows maintained on dormant native grass.

Materials and Methods

Intake studies (1985 and 1986). Twenty-four (1985), mature, lactating Hereford x Angus cows (average weight, 475 kg; average calving date, November 2, 1984) were blocked by calving date, weight and body condition and allotted to four supplemental treatments starting December 7, 1984 for a 117-d study. In 1986, 30 mature, lactating Hereford x Angus cows (average weight, 467 kg; average calving date, October 23, 1986) were blocked by calving date, weight, body condition score and previous treatment and allotted to five supplemental treatments starting December 5, 1985 for a 116-d study.

Cows were maintained on a pasture consisting primarily of little bluestem (Andropogon scoparius) at the Southwest Livestock and Forage Research Laboratory near El Reno, Oklahoma. In 1986, cows were moved to an adjacent pasture on February 19 due to diminished forage supply.

Supplements were .55 kg/d cottonseed meal (control), 1.48 kg/d cottonseed meal (CSM), 2.62 kg/d 54% corn-45% cottonseed meal blend (CORN/CSM) and 3.45 kg/d soybean hulls (SBH). A fifth supplement, SBH/CSM (2.63 kg/d 70% soybean hulls-28% cottonseed meal), was added in 1986. The CSM, CORN/CSM, SBH/CSM and SBH supplements were balanced to provide 610 g of crude protein/d (table 4). Energy supplements (CORN/CSM and SBH) were formulated to provide 2.2 kg of TDN/d, twice that offered by CSM (NRC., 1984).

Four, 12-d intake studies were conducted; January 6 to 17, 1985; February 17 to 28, 1985; January 3 to 14, 1986; March 5 to 16, 1986. Cows were stalled and individually fed their respective supplement between 0800 and 0900 each day. On d 1 to 7, cows were dosed with 100 g (as-is) ytterbium-labeled native grass hay (.79 g, .46 g, .34 g and .28 g Yb/dose; intakes 1 through 4, respectively) blended with the supplement. Labelled hay was prepared by immersion (Teeter et al., 1984). Fifty ml of cobalt·EDTA (Uden et al., 1980) was blended with Yb-labelled hay (1.05 g, .94 g, .86 g and .78 g Co/dose; intakes 1 through 4, respectively) and administered as a pulse dose on d 6.

Supplement samples were collected each morning, combined by treatment and frozen (-15 C). Diet samples were collected with four esophageally-fistulated heifers on d 6 and 7 of each intake period. Diet samples were combined by animal, and stored at -15 C prior to drying (lyophilization, 1985; 40 C forced-air oven for 36 h, 1986).

Fecal composite samples (450 g as-is) were collected at 0900 and 1700 on d 6, 0100, 0900 and 2100 on d 7 and 0500 on d 8, and combined by animal. Fecal composites were refrigerated (2 C) until the completion of the intake study when samples were mixed, subsampled (1500 g as-is) and dried

TABLE 4. INGREDIENT COMPOSITION OF SUPPLEMENTS (DRY MATTER BASIS) AND DAILY INTAKE OF SUPPLEMENTAL CHEMICAL COMPONENTS

Item	SUPPLEMENT				
	Control	CSM	CORN/CSM	SBH/CSM	SBH
Ingredient,					
Cottonseed Meal, %	82.2	96.6	44.5	27.7	---
Ground Corn, %	---	---	53.6	---	---
Soybean Hulls, %	---	---	---	69.6	92.0
Soybean Meal, %	---	---	---	---	5.3
Dicalcium phosphate, %	13.24	.79	.31	1.39	1.72
Trace mineralized salt, %	4.11	1.53	.87	.87	.66
Sodium sulfate, %	.41	.49	.16	.42	.35
Limestone, %	---	.64	.49	---	---
Intake, g/d					
Total dry matter[b]	530	1418	2537	2629	3316
Total digestible nutrients[c]	340	1068	2106	1740	2099
Crude protein[b]					
Intakes 1 & 2	194	541	582	---	614
Intakes 3 & 4	188	642	692	634	614
Digestion trial	196	622	622	524	454

[a]Trace mineralized salt contained 16% zinc, 12% iron, 6% manganese, 3% magnesium, 1% copper, 1% potassium, .6% iodine, .3% cobalt and 1% mineral oil.

[b]Actual analysis.

[c]Estimated from NRC. (1984).

in a forced-air oven (55 C). Timed fecal grab samples (250 g) for liquid passage (Co·EDTA) were collected at 24, 36, 48, 72 and 96 h post-dosing. Timed samples for particulate passage (Yb-labelled hay) were collected at 48, 72, 96 and 120 h after the final Yb dose on d 7. Timed fecal samples were immediately frozen (-15 C) until drying in a forced-air oven (55 C). After drying, all fecal samples were allowed to air-equilibrate for approximately 6 h before storage at -15 C.

Supplement, diet and fecal composite samples were ground through a Wiley mill (1-mm screen). Samples were frozen (-15 C) until analysis for dry matter (DM), ash and macro-kjeldahl protein (N * 6.25) analysis (AOAC., 1975); neutral detergent fiber (NDF) and a sequential acid detergent fiber (ADF) and permanganate lignin (PL) analysis (Goering and Van Soest, 1970). Concentrations of hemicellulose (NDF minus ADF) and cellulose (ADF minus PL minus ADF-ash) were calculated by difference. Supplement samples were also subjected to starch analysis (MacRae and Armstrong, 1968).

Fecal output was estimated from fecal Yb concentrations. Forage OM indigestibility was estimated using lignin ratios with fecal output corrected for supplement indigestibility (Kartchner, 1980). Supplement OM digestibility was assumed to be equal to TDN (NRC., 1984).

Timed fecal samples were ground through a Wiley mill (1-mm screen) before storage (-15). Timed samples were dried (100 C for 24 h) and ashed (500 C for 8 h). Ashed samples were digested in a solution of 3 N HNO_3: 3 N HCl for 24 h, .5 ml KCl (9.54% w/v) was added (Teeter et al., 1984) and then diluted to 25 ml, with additional dilutions (50 ml) for 48 h Yb and 24, 36, 48 and 72 h Co samples. Concentration of Yb was determined with an atomic absorption spectrophotometer with a nitrous oxide-acetylene flame. Determination of cobalt concentration was made using an air-acetylene flame. Passage rates (particulate and liquid) were estimated from the slope of the natural log of Yb or Co concentration over time.

Data were subjected to least squares analysis with cow body weight (covariate) and treatment included in the model. Treatment means were separated at a probability level of .05 using Tukey's HSD test.

Digestion study (1986). Five mature, ruminally cannulated, Hereford cows (average weight, 538 kg) were individually housed in concrete-slatted pens (2.9 x 3.8 m). Hay was harvested in March, 1986 from a native grass pasture at the Southwest Forage and Livestock Research Laboratory at El Reno, Oklahoma, which was similar to those utilized in the intake studies. Baled hay was coarsely chopped through a 5-cm screen prior to feeding. Hay was fed at a rate of 4.5 kg plus the previous day's consumption. Supplements (table 4) were fed at 0800 each day.

Fourteen-day experimental periods consisted of 10 d of adaptation and 4 d of sampling. On d 10 to 13, hay and supplements were sampled and composited. Hay refusals were sampled (10% of refusal) on d 11 to 14 and composited by animal. All samples were frozen (-15 C) prior to grinding.

Cobalt·EDTA (50 ml; .58 g Co/dose, period 1; 1.1 g Co/dose periods 2 through 5) was blended with Yb-labeled hay, (200 g as-is, 1.7 g Yb/dose) and fed with the supplement at 0700 on d 10.

Fecal samples (450 g as-is) were taken at 0700 and 1900 on d 11 to 14, refrigerated (2 C) until the end the of sampling period, subsampled (1500 g as-is) and dried in a forced-air oven (55 C). Timed fecal samples (250 g as-is) were collected simultaneously with fecal composites (24, 36, 48, 60, 72, 84, 96 and 108 h post-dose) and immediately placed in a forced-air oven (55 C). Dried fecal samples were allowed to air equilibrate for 6 h prior to storage (-15 C). All samples were ground through a Wiley mill (1-mm screen) and stored (-15 C) until laboratory analysis.

Samples (hay, hay refusals, supplement and fecal composite) were subjected to dry matter (DM), ash and kjeldahl protein (N * 6.25, AOAC., 1975); acid-insoluble ash (AIA, Van Keulen and Young, 1977); neutral detergent fiber (NDF) and a sequential acid detergent fiber (ADF) and permanganate lignin (PL) analysis (Goering and Van Soest, 1970). Concentrations of hemicellulose (NDF minus ADF) and cellulose (ADF minus PL minus ADF-ash) were calculated by difference. In addition, supplement samples were subjected to starch analysis (MacRae and Armstrong, 1968).

Acid insoluble ash was used as an indigestible marker to estimate nutrient digestibilities with the marker ratio technique (Schneider and Flatt, 1975). Supplement OM digestibilities were assumed to equal TDN (NRC., 1984). Hay OM output was calculated by subtracting the indigestibile supplement OM from total fecal OM output. Hay OM digestibility was calculated by dividing digestible hay OM by hay OM intake.

Timed fecal samples were subjected to ytterbium and cobalt analysis in the same manner as trials 1 and 2.

Chromium·EDTA was prepared (Binnerts et al., 1968) and dosed intraruminally at 0700 on d 14, as a ruminal liquid flow marker. Ruminal samples were collected at 0, 2, 4, 6, 9, 12 and 24 h post-supplementation on d 14. Samples (500 ml) were collected from the same location (lower ventral sac) and pH measured immediately. A 250-ml aliquot was strained through four layers of cheesecloth, acidified (1 ml 20% H_2SO_4/50 ml fluid) and frozen (-15 C).

Ruminal samples were prepared by centrifugation (1000 x g for 15 min) Ammonia was determined using the phenol-hypochlorite procedure (Broderick and Kang, 1980). Chromium concentration was analyzed by atomic absorption spectrophotometry with an air-acetylene flame. Ruminal fluid was composited (5 ml/sampling time) for each animal for volatile fatty acid (VFA) analysis. Metaphosphoric acid (2 ml, 25% w/v) was added to 10 ml of each composite and centrifuged at 25,000 x g for 20 min. Supernatant (1 ml) was combined with .2 ml of 2-ethylbutyric acid (internal standard) and vortexed. Samples (1.5 µl) were analyzed by gas chromatography.

Duplicate dacron bags (6 x 10 cm) containing 1 g (as-is) of ground (1-mm) hay were suspended in the rumen beginning on d 9, at increments corresponding to 6, 12, 24, 48 and 96 h of incubation. Bags were removed from the rumen and immediately washed with lukewarm water until the effluent was clear. Bags not subjected to ruminal incubation were washed in a similar manner to estimate initial washout. Bags were then placed in a forced-air oven (55 C) to dry excess water prior to laboratory analysis. Incubated bags were dried (80 C for 24 h) and ashed (500 C for 8 h) to determine ruminal forage organic matter (OM) disappearance. The potentially digestible portion was determined using the disappearance from 96 h incubation. Rate of forage digestion was determined by plotting the natural log of OM disappearance over time for the 6, 12, 24 and 48 h incubations.

At the completion of the trial, quadruplicate dacron bags containing 1 g of each of the five supplements were suspended in the rumen of the cow consuming CSM supplement at increments corresponding to 6, 12, 18, 24, 48 and 96 h. Bags were removed, washed and dried (80 C for 24 h). Half of the bags were ashed (500 C for 8 h). The remaining bags were subjected to macro-kjeldahl analysis (AOAC., 1975).

Nitrogen and organic matter disappearance were evaluated using a model described by Orskov and McDonald, (1979).

Digestibility, intake and passage rate data were subjected to least squares analysis with a model which included period, animal and treatment. Supplement digestion rates were analyzed by least squares with treatment and replicate in the model. Differences between treatment means were detected at the .05 level using Tukey's HSD.

Results and Discussion

Intake studies (1985 and 1986). Forage quality during 1985 was lower on February 23 compared to January 11 (table 5). Crude protein tended to decrease from 4.3 to 3.8% while NDF increased ($P<.05$) from 81.7 to 84.5%. In Oklahoma, native grass is dormant during the winter and would be expected to be of low nutritional quality (Waller et al., 1972). However, forage quality during 1986 remained more constant except for an increase ($P<.05$) in crude protein from 4.7% during intake 3, to 6.3% during intake 4 (table 5). Increased crude protein could be due to moderate March temperatures which may have stimulated early growth of winter annual grasses (Waller et al., 1972).

Supplementation with 1.5 kg cottonseed meal (CSM) increased ($P<.05$) total OM digestibility compared to the control (.5 kg cottonseed meal) in intakes 2, 3 and 4 (table 7, 8 and 9, respectively). Feeding a larger quantity of a highly digestible feed such as cottonseed meal should

TABLE 5. CHEMICAL COMPOSITION OF DORMANT NATIVE TALLGRASS FORAGE (ORGANIC MATTER BASIS)

	Intake 1	Intake 2	Intake 3	Intake 4	Digestion trial
Nutrient, %					
Crude protein	4.3	3.8	4.7	6.3	3.5
Neutral detergent fiber	81.7	84.5	82.5	87.0	87.6
Acid detergent fiber	54.7	55.3	60.0	63.3	58.7
Lignin	9.8	9.8	12.7	12.0	8.0

TABLE 6. DIGESTIBILITIES, PASSAGE RATES AND INTAKES OF PROTEIN AND ENERGY SUPPLEMENTED DORMANT NATIVE GRASS DIETS. INTAKE 1 (JANUARY 11, 1985).

	Supplement					
	Control	CSM	CORN/CSM	SBH/CSM	SBH	SEM
Digestibility, %						
Total OM	52.5[a]	53.8[a]	56.1[b]	---	56.7[b]	.40
Forage OM	52.0[ab]	50.5[ab]	46.7[a]	---	54.7[b]	1.93
NDF	53.4	53.1	52.8	---	54.7	.66
Organic matter intake, % BW						
Supplement	.08[a]	.31[b]	.57[c]	---	.71[d]	.010
Forage	2.34	2.33	1.76	---	1.97	.168
Total	2.43	2.64	2.33	---	2.68	.164
Digestible OM intake, % BW						
Forage	1.22[a]	1.18[a]	.82[b]	---	1.08[ab]	.085
Total	1.27	1.42	1.31	---	1.52	.082
Passage rate, %/h						
Particulate	3.4	3.4	3.7	---	3.2	.18
Liquid	3.9	4.1	4.3	---	3.9	.18

[abcd]Means within a row with different superscripts differ ($P<.05$).

TABLE 7. DIGESTIBILITIES, PASSAGE RATES AND INTAKES OF PROTEIN AND ENERGY SUPPLEMENTED DORMANT NATIVE GRASS DIETS. INTAKE 2 (FEBRUARY 23, 1985).

	Supplement					
	Control	CSM	CORN/CSM	SBH/CSM	SBH	SEM
Digestibility, %						
Total OM	50.1[a]	53.1[b]	54.2[b]	---	56.5[c]	.37
Forage OM	49.5[ab]	50.2[ab]	44.6[a]	---	54.7[b]	1.64
NDF	51.7[b]	52.8[b]	48.9[a]	---	55.4[c]	.64
Organic matter intake, % BW						
Supplement	.08[a]	.32[b]	.61[c]	---	.74[d]	.012
Forage	2.85	2.72	1.99	---	2.45	.237
Total	2.93	3.04	2.60	---	3.19	.233
Digestible OM intake, % BW						
Forage	1.42[a]	1.36[ab]	.89[b]	---	1.34[ab]	.121
Total	1.47	1.61	1.40	---	1.80	.118
Passage rate, %/h						
Particulate	3.1	3.5	3.4	---	3.2	.26
Liquid	3.5	3.8	4.4	---	3.6	.26

[abcd]Means within a row with different superscripts differ ($P<.05$).

TABLE 8. DIGESTIBILITIES, PASSAGE RATES AND INTAKES OF PROTEIN AND ENERGY SUPPLEMENTED DORMANT NATIVE GRASS DIETS. INTAKE 3 (JANUARY 9, 1986).

	Supplement					
	Control	CSM	CORN/CSM	SBH/CSM	SBH	SEM
Digestibility, %						
Total OM	40.6[a]	42.7[b]	51.7[d]	47.5[c]	51.3[d]	.18
Forage OM	39.7[a]	37.9[a]	42.4[ab]	42.3[ab]	47.0[b]	1.69
NDF	39.7[a]	39.6[a]	46.6[b]	43.8[b]	46.0[b]	.77
Organic matter intake, % BW						
Supplement	.08[a]	.29[b]	.54[c]	.54[c]	.71[d]	.006
Forage	2.13	2.05	1.81	1.96	1.98	.088
Total	2.21[a]	2.34[ab]	2.35[ab]	2.50[ab]	2.69[b]	.086
Digestible OM intake, % BW						
Forage	.85[ab]	.78[ab]	.77[a]	.83[ab]	.93[b]	.037
Total	.90[a]	1.00[a]	1.22[b]	1.18[b]	1.38[c]	.036
Passage rate, %/h						
Particulate	2.9	3.2	3.3	2.9	2.8	.22
Liquid	4.4[a]	4.6[a]	5.0[ab]	5.2[ab]	5.6[b]	.23

[abcd]Means within a row with different superscripts differ ($P<.05$).

TABLE 9. DIGESTIBILITIES, PASSAGE RATES AND INTAKES OF PROTEIN AND ENERGY SUPPLEMENTED DORMANT NATIVE GRASS DIETS. INTAKE 4 (MARCH 12, 1986).

	Supplement					
	Control	CSM	CORN/CSM	SBH/CSM	SBH	SEM
Digestibility, %						
Total OM	31.1[a]	39.6[b]	45.4[d]	41.5[bc]	42.8[cd]	.64
Forage OM	29.0	31.4	28.9	31.0	30.5	2.94
NDF	28.7[a]	30.7[ab]	33.4[bc]	31.9[abc]	34.1[c]	.80
Organic matter intake, % BW						
Supplement	.07[a]	.32[b]	.58[c]	.57[c]	.74[d]	.006
Forage	1.52	1.46	1.34	1.34	1.24	.111
Total	1.59	1.78	1.92	1.91	1.98	.110
Digestible OM intake, % BW						
Forage	.44	.46	.38	.41	.38	.034
Total	.49[a]	.70[b]	.86[c]	.79[bc]	.85[c]	.034
Passage rate, %/h						
Particulate	4.6	4.7	5.9	4.8	6.0	.40
Liquid	5.4	5.2	5.8	5.3	6.1	.26

[abcd]Means within a row with different superscripts differ ($P<.05$).

increase OM digestibility. Supplemental protein should stimulate ruminal fiber fermentation when forage protein is low (Guthrie et al., 1984; McCollum and Galyean, 1985). Compared to the control, however, feeding 1.5 kg of cottonseed meal (CSM) did not significantly alter forage OM or NDF digestibility (tables 6, 7, 8 and 9). Either the protein supplied by the control was adequate to meet ruminal N requirements under these conditions or highly-lignified dormant grass is not highly responsive to protein supplementation (Rittenhouse et al., 1970).

Energy supplementation (CORN/CSM, SBH/CSM, SBH) tended to increase total OM digestibility compared to CSM (tables 6, 8, 9). Feeding large quantities of highly digestible supplement should increase total OM digestibility. The CORN/CSM and SBH supplements were fed at similar levels of energy intake based on TDN content (NRC., 1984) and resulted in similar total OM digestibilities in intakes 1, 3 and 4 (tables 6, 8 and 9, respectively). During intake 2, however, SBH increased ($P<.05$) total OM digestibility compared to CORN/CSM (table 7). Although CORN/CSM and SBH/CSM supplements were fed at similar daily rates (2.6 kg/d) in 1986, decreased TDN content of the SBH/CSM was reflected by decreased total OM digestibility (tables 8 and 9).

Compared to CSM, SBH tended to increase forage OM digestibility while CORN/CSM tended to depress forage OM digestibility (tables 6, 7, 8 and 9). Total tract particulate passage rate for SBH supplements tended to be slower in intakes 1, 2 and 3. Increased ruminal residence time may explain increased forage OM digestibility when SBH supplements are fed. Neutral detergent fiber digestibility decreased with CORN/CSM and increased with SBH during intake 2 (table 7). During intakes 3 and 4, supplemental energy, regardless of source, tended to increase NDF digestibility. Supplemental corn tends to decrease digestion of low-quality forage (Kane et al., 1959; Chase and Hibberd, 1987) while soybean hulls increase ration OM and fiber digestion (Sudweeks, 1977; McDonnell et al., 1982; Merrill and Klopfenstein, 1985; Martin and Hibberd, 1987; Highfill et al., 1987). Similar trends were observed in our studies although differences within a particular intake study were not consistent.

Although treatment differences were not significant, CORN/CSM consistently decreased forage OM intake compared to CSM (tables 6, 7, 8 and 9). Forage OM intake was also decreased with SBH, but to a lesser extent than with CORN/CSM. Total OM intake was similar for CSM and SBH in 1985 (intakes 1 and 2) suggesting that intake of SBH supplement was substituted for an equivalent amount of forage. Similar to previous studies, small quantities of CORN/CSM substituted for large quantities of forage (Lusby et al., 1976; Kartchner, 1980; Chase and Hibberd, 1987).

Digestible forage OM intake was similar for control and CSM supplements (tables 6, 7, 8 and 9). This response suggests that the quantity of ruminal degradable protein available in 550 g cottonseed meal (control) is adequate to maximize ruminal digestibility of low-quality forage. Energy supplementation tended to decrease digestible forage OM intake during intakes 1, 2 and 4. Digestible forage OM intake was depressed to the greatest degree with CORN/CSM, while SBH was more similar to CSM. Assuming digestible OM intake is an indication of TDN intake and digestible forage OM intake is an indication of TDN derived from forage, this suggests that CORN/CSM depressed forage energy intake.

Compared to CORN/CSM, SBH supplements increased total OM and digestible OM intakes. Thus, grazing cattle supplemented with SBH would be expected to perform better than cattle supplemented with CORN/CSM. In 1985, cows fed SBH lost less body weight and condition than cows fed CORN/CSM (Trautman, 1987). During a milder winter in 1986, cows fed SBH/CSM performed similarly to CORN/CSM and decreased body weight loss compared to SBH. Thus, production responses to type of energy supplement appear to be dependent upon the severity of the environment and quality of the forage.

Variation in forage OM intake between intake trials is probably attributable to variation in environment and forage supply. Increased forage OM intake during intake 2 could be due to the onset of cold, wet weather immediately prior to the sample collection period. Changes in barometric pressure have been reported to increase time spent grazing and ruminating (Malechek and Smith, 1976). However, an increase in forage intake, due to cold stress, is usually accompanied by increased digesta passage rate and decreased digestibility (Westra and Christopherson, 1976; Kennedy et al., 1977; Kennedy and Milligan, 1978). Neither total tract liquid nor particulate passage rates increased in our studies (table 6 vs 7). Lower forage OM intake during intake 4 may be explained by increased forage quality. Cows may have changed their grazing behavior by spending a large amount of time searching for small quantities of palatable new growth. In addition, forage quantity may have been limiting during the latter part of the grazing season.

Digestion study. Native grass hay used during this trial was cut from a tallgrass meadow similar to those used during the intake studies. Low crude protein (3.3%) and high NDF (81.8%) concentrations illustrate the low nutritional quality of the hay. Even though this hay was harvested in late March, 1986, the increased quality noted during the fourth intake study (March 10, 1986) due to the growth of winter annuals, was not observed here since hay making removes the effects of selective grazing (Minson, 1981; Poppi et al., 1981).

Additional protein (CSM) increased ($P<.05$) hay OM intake compared to the control (table 10). During the intake studies (tables 6, 7, 8 and 9), hay OM intake was similar for control and CSM supplements. Increased hay intake for control cows during the intake studies may have

TABLE 10. DIGESTIBILITIES AND INTAKES OF PROTEIN AND ENERGY SUPPLEMENTED LOW-QUALITY NATIVE GRASS HAY DIETS.

	SUPPLEMENT					
Item	Control	CSM	CORN/CSM	SBH/CSM	SBH	SEM
Digestibility, %						
Total OM	52.1	51.7	55.7	50.6	52.2	1.16
Hay OM	51.2^{a}	47.3^{ab}	46.1^{b}	45.6^{b}	47.8^{ab}	1.10
NDF	55.1	51.7	54.9	51.4	52.5	1.18
ADF	49.0	46.4	45.4	46.9	48.2	1.18
Organic matter intake, % BW						
Supplement	.08^{a}	.26^{b}	.47^{c}	.44^{c}	.59^{d}	.006
Hay	1.04^{a}	1.39^{b}	1.35^{b}	1.39^{b}	1.46^{b}	.064
Total	1.12^{a}	1.65^{b}	1.81^{bc}	1.83^{bc}	2.04^{c}	.064
Digestible OM intake, % BW						
Hay	.54^{a}	.66^{ab}	.62^{ab}	.63^{ab}	.69^{b}	.032
Total	.59^{a}	.85^{b}	1.01^{c}	.92^{bc}	1.06^{c}	.033
Digestion rate, %/h						
Hay OM	3.8	3.4	3.1	3.0	3.4	.27

^{abcd}Means with different superscripts differ (P<.05) been a physiological response to lactational stress. Neither level of supplement nor source of energy affected hay OM intake. In contrast, energy supplements tended to decrease hay OM intake in the intake studies (tables 6, 7, 8 and 9). Consequently, digestible OM intake increased with energy supplementation (CORN/CSM, SBH/CSM,SBH), a reflection of energy intake from the supplements.

Although treatment had no significant effect on total OM digestibility, CORN/CSM tended to be highest (table 10). Increased total OM digestibility with CORN/CSM is probably attributable to consumption of a large quantity (2660 g/d) of a highly digestible (83%) supplement. In contrast, hay OM digestibility tended to decrease with CORN/CSM supplementation suggesting that this supplement had a deleterious effect on fiber digestion. Although differences were not significant, CORN/CSM tended to decrease ADF digestion compared to other supplements.

Rate of hay OM digestion (in situ) tended to be highest for the control and lowest for CORN/CSM and SBH/CSM (table 10). Ruminal ammonia concentrations for the control remained above 2 mg/dl throughout the day (figure 7) suggesting that the ruminal degradable protein supplied by the control supplement was adequate to maintain fiber fermentation. Excess ruminal ammonia may have been available because other factors such as available carbohydrates or branched chain volatile fatty acids may have limited total hay OM digestion. Decreased rate of hay

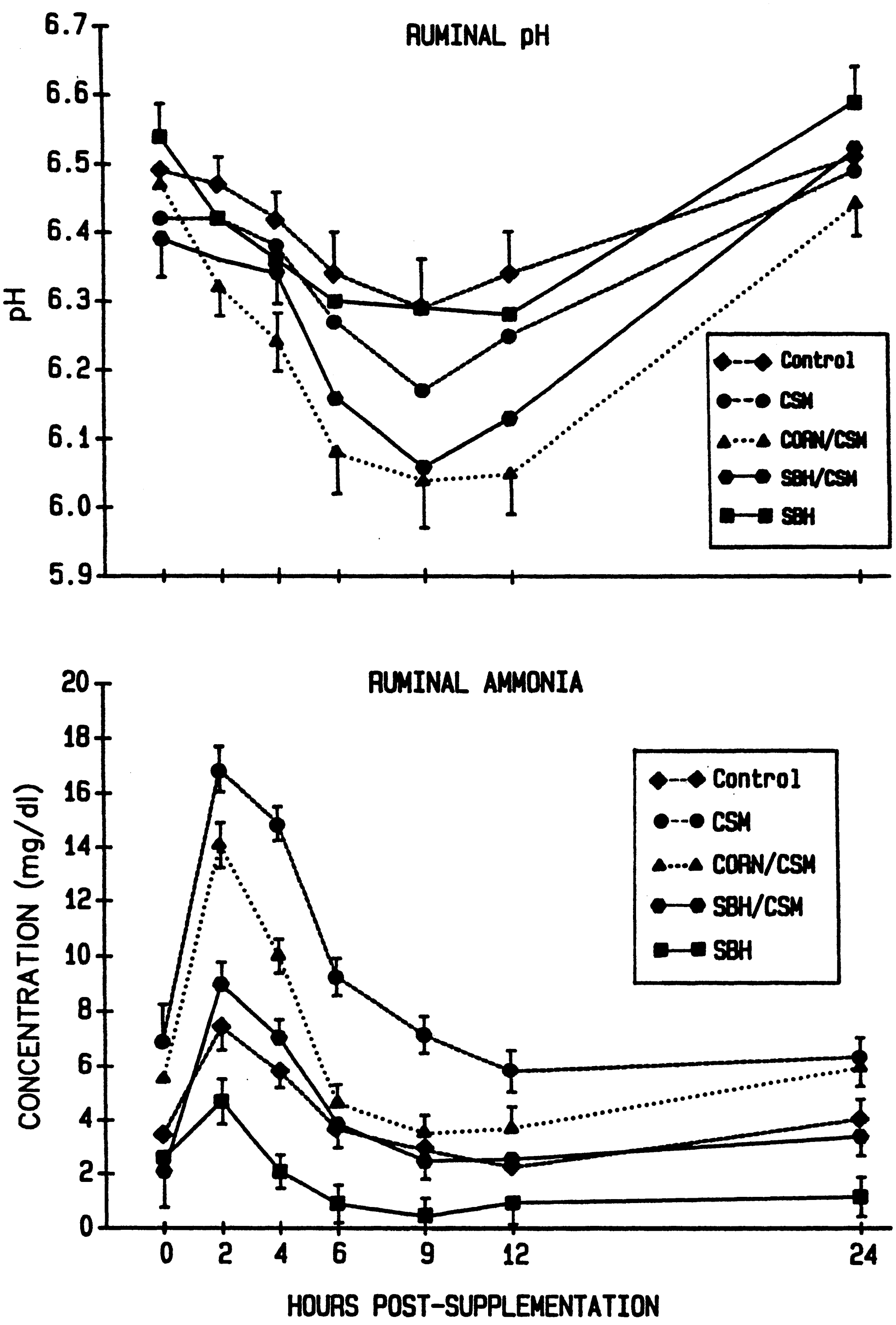

Figure 7. Effect of Supplemental Energy Source on Ruminal pH and Ammonia Concentrations in Beef Cows.

OM digestion for the CORN/CSM and SBH/CSM supplements may be due to low ruminal pH (figure 7).

Particulate passage rate (Yb-labelled hay) tended to increase with SBH and CORN/CSM compared to CSM (table 11). Although rate and extent of hay OM digestion were not affected by SBH, increased hay OM intake (table 10) can be explained by increased particulate passage rate. In addition, decreased rate and extent of hay OM digestion for CORN/CSM was compensated by increased rate of passage so that hay OM intake was unchanged.

Ruminal liquid passage rate (Cr·EDTA) was highest for SBH (table 11). Ruminal fluid volume (l) and outflow rates (l/h) were highest for soybean hull supplements (SBH/CSM and SBH). Soybean hulls rapidly absorb large quantities of water and may increase water flow into the rumen. Rapid liquid passage rate for SBH may have increased microbial growth rate and efficiency (Owens and Isaacson, 1977). Increased microbial growth rate explains the increased volatile fatty acid concentrations, decreased ammonia, increased rate of passage and increased hay intake observed with SBH.

Ruminal ammonia concentrations were highest for CSM and lowest for SBH (figure 7). Large quantities of ruminally degradable protein in cottonseed meal contribute to increased ruminal ammonia (NRC., 1985). Low ruminal ammonia concentrations for SBH (< 5 mg/dl) are probably due to the low protein content of this supplement (table 4).

TABLE 11. LIQUID AND PARTICULATE PASSAGE RATES AND RUMINAL LIQUID FLOW RATES, VOLUMES AND RETENTION TIMES OF PROTEIN AND ENERGY SUPPLEMENTED LOW-QUALITY NATIVE GRASS DIETS.

Item	Control	CSM	CORN/CSM	SBH/CSM	SBH	SEM
Passage rates, %/h						
Ruminal liquid	6.4[a]	8.9[ab]	9.0[ab]	8.7[ab]	11.0[b]	.67
Total tract,						
liquid	3.3	3.9	4.0	3.6	4.0	.18
particulate	2.2	2.8	2.9	2.8	3.2	.28
Ruminal flow rate, l/h liquid	4.2[a]	6.4[b]	7.2[bc]	8.2[bc]	9.0[c]	.44
Ruminal volume, l	67.0[a]	75.3[a]	80.9[ab]	97.1[b]	88.0[ab]	4.13
Ruminal retention time, h liquid	16.6[a]	12.0[ab]	11.4[b]	12.5[ab]	9.2[b]	1.10

[ab]Means with different superscripts differ ($P<.05$)

Alternatively, ammonia from SBH may have been incorporated into microbial protein at a faster rate. Ruminal ammonia concentrations for CORN/CSM were higher (4 to 14 mg/dl) than expected. Previous studies have reported low ruminal ammonia concentrations (< 1 mg/dl) with cereal grain supplementation (Chase and Hibberd, 1987; Hennessy et al., 1983). The cottonseed meal component of the CORN/CSM supplement may have supplied enough ruminal degradable protein to overcome problems with low degradability of corn protein.

Feeding soybean hull supplements (SBH/CSM or SBH) resulted in higher ruminal pH than feeding CORN/CSM (figure 7). Ruminal pH for CORN/CSM remained below 6.2, the recommended minimum for uninhibited cellulolysis (Orskov, 1982), for at least 6 h. Ruminal volatile fatty acid concentrations, however, were highest for soybean hull supplements (table 12). Although increased volatile fatty acid concentrations coupled with low ruminal ammonia for SBH should have decreased ruminal pH, the buffering capacity of soybean hulls may have compensated for ruminal acid load (Van Soest, 1982).

Soybean hull supplements (SBH/CSM and SBH) tended to be digested more slowly than CSM or CORN/CSM (table 13). Although soybean hulls contain a large quantity of digestible (low lignin) fiber, the digestion rate of fiber would be expected to be lower than that of starch (Van Soest, 1982). Rate and extent of nitrogen disappearance

TABLE 12. RUMINAL VOLATILE FATTY ACID PARAMETERS OF PROTEIN AND ENERGY-SUPPLEMENTED LOW-QUALITY NATIVE GRASS DIETS.

Item	SUPPLEMENT					SEM
	Control	CSM	CORN/CSM	SBH/CSM	SBH	
Total VFA, mM	93.9[a]	102.7[ab]	106.8[ab]	114.3[b]	114.7[b]	3.82
Acetate, %	80.7[a]	80.0[a]	77.4[b]	79.1[ab]	77.9[b]	.46
Propionate, %	13.7	14.0	14.8	14.5	15.3	.42
Butyrate, %	5.6[a]	6.0[ab]	7.8[c]	6.3[ab]	6.8[b]	.17

[ab]Means with different superscripts differ (P<.05)

TABLE 13. RUMINAL ORGANIC MATTER AND NITROGEN DIGESTION PARAMETERS OF PROTEIN AND ENERGY SUPPLEMENTS

	SUPPLEMENT					
	Control	CSM	CORN/CSM	SBH/CSM	SBH	SEM
Organic Matter,						
Total potentiallly available, %	69.8a	69.6a	81.4ab	84.4ab	91.7b	3.21
Soluble, %	20.2a	18.3a	20.8a	10.6b	9.5b	.83
Digestible, %	49.6a	51.2a	60.7ab	73.8bc	82.2c	3.40
Rate of digestion, %/h	7.92	8.00	7.31	5.45	4.86	.836
Nitrogen,						
Total potentially available, %	86.0	89.0	76.7	89.3	86.0	2.86
Soluble, %	13.2	20.0	23.6	23.2	20.8	3.35
Digestible, %	72.8	69.0	53.1	66.1	65.3	4.13
Rate of digestion, %/h	7.18	6.18	4.86	5.84	7.50	.932

tended to be lowest for CORN/CSM. Corn protein is slowly degraded in the rumen (Zinn and Owens, 1983). Although the rate of nitrogen disappearance was low for CORN/CSM, ruminal ammonia concentrations remained high suggesting that microbial nitrogen requirements may have been satisfied by the CORN/CSM supplement.

This study verifies that corn supplements decrease forage utilization although to a lesser extent than observed in previous trials where ruminal degradable protein was inadequate (Hennessy et al., 1983; Chase and Hibberd, 1987). In contrast, soybean hulls appear to maintain or possibly enhance forage utilization. Ruminal changes appear to be less extensive with soybean hulls. As a component of range supplements, soybean hulls appear to complement forage utilization without the detrimental effects of cereal grains.

CHAPTER V

SUMMARY AND CONCLUSIONS

Forage quality of native tallgrass prairie in Oklahoma gradually declines from the summer throughout the winter, due to leaching of plant nutrients and selective grazing of cattle.

Lactating beef cows maintained on dormant native grass during the winter, exhibit increased performance from supplemental protein through January. However, as the winter progresses, additional supplemental energy becomes more beneficial. The form in which supplemental energy is offered (ie. cereal grain or digestible fiber feed) shows varying responses, apparently due to the severity of the environment as well as quantity and quality of the forage.

Energy supplementation appears to decrease forage intake which could be beneficial in times of drought or limiting forage supply. However, the use of cereal grains (2 to 4 kg) as range supplements decreases the utilization of the forage due to negative associative effects associated with the starch component in the grain. In contrast, soybean hulls are highly digestible and appear to complement forage digestion. Soybean hulls appear to maintain or possibly enhance forage utilization although forage intake decreases due to the substitution of the large quantity of soybean hulls. Yet, energy intake derived from the forage (digestible forage OM intake) is not decreased when compared to traditional cottonseed meal supplementation. Cereal grains (corn), however, decrease forage digestibility and intake to the point that energy intake from the forage actually declines.

However, the producer's decision on whether to use protein or energy supplements, should be based on the cost of the program and the weighted benifits of it's outcome. Protein supplementation provides similar performance through late January or early February and therefore energy supplementation would probably not be economically feasible to that point. Energy supplementation does increase cow performance and calf weight gains during the end of the winter grazing season, yet the increase in calf weight gain may not be substantial enough to merit the additional expense of energy supplementation. Decreased cow body weight and condition losses due to energy supplementation may not have a great impact on future performance of the cow, providing the cow is already bred. Therefore, the increased cow performance may not be of major economic importance during that period of time.

Therefore, feeding larger quantities (3 to 4 kg) of a digestible fiber feed, such as soybean hulls, could be a viable approach to energy supplementation of high forage diets, provided energy supplementation is deemed important by the producer.

However, more information needs to be known about the feeding of by-product feeds, such as soybean hulls. As noted by the performance data, the TDN of soybean hulls appears to be equivalent to corn as a range energy supplement. This indicates a need for more knowledge about the associative effects of feeding byproduct feeds. In the digestion study, the ammonia concentrations of SBH were consistently low. This could be primarily due to the lower quantity of crude protein supplied. But, it may also be possible that the nitrogen of soybean hulls is incorporated into microbial crude protein at a higher rate. In addition, the ammonia concentration of CORN/CSM was consistently very high. However, this may be due to the cottonseed meal in the blend. More research needs to be done to determine the effects of the various combinations of supplemental feed components on ruminal microbial activity. Liquid passage increased with SBH, indicating a water influx to the digestive tract. Determination of how this affects ruminal digestive function could lead to an optimum level of soybean hulls which can be fed in conjunction with certain diets.

In general, more needs to be done to determine requirements for optimum digestion of low-quality forages. As noticed in the digestion trial, the control supplement increased hay OM digestibility and rate of hay OM digestion, while decreasing total tract particulate passage rate and hay OM intake. However, during the intake studies control supplemented cows exhibited decreased forage OM digestibility, increased total tract particulate passage rate and intakes similar to CSM. These differing responses may be due to lactational and environmental factors influencing passage of undigested OM. However, it remains unclear as to why this response was not as readily observed with other supplemental treatments.

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APPENDIX

TABLE 14. CHEMICAL COMPOSITION OF DORMANT NATIVE TALLGRASS FORAGE (ORGANIC MATTER BASIS). TRIAL 1 (1985).

	1/11	2/8	2/23	3/22	SE[a]
Crude protein[b]	4.3	4.2	3.8	4.5	.15
Neutral detergent fiber[c]	81.7	82.4	84.5	81.8	.15
Hemicellulose[d]	27.0	27.4	29.2	26.0	.51
Acid detergent fiber	54.7	55.0	55.3	55.8	.57
Cellulose[d]	39.3	39.0	40.0	38.5	.39
Lignin	9.8	9.9	9.8	9.5	.22
Organic matter[c]	89.2	89.4	91.0	89.4	.21

[a]Standard error of the mean.

[b]Quadratic ($P<.01$).

[c]Cubic ($P<.01$).

[d]Cubic ($P<.05$).

TABLE 15. SEASONAL COW BODY WEIGHT CHANGES.
TRIAL 1 (1985)

	SUPPLEMENT			SEM	Contrasts	
	CSM	CORN/CSM	SBH		a	b
	------------kg------------					
Initial weight Dec. 7	475.8	468.6	481.4	8.98	.94	.32
Cumulative weight changes						
Dec. 20	-2.4	-6.5	-2.4	1.92	.39	.14
Jan. 3	-23.4	-20.5	-29.0	2.12	.62	.007
Jan. 18	-33.4	-40.5	-35.7	2.59	.14	.19
Feb. 8	-29.2	-28.7	-31.8	2.55	.74	.41
Feb. 14	-43.2	-44.5	-38.7	2.75	.65	.15
Mar. 7	-73.1	-67.8	-50.4	3.28	.0007	.0003
Mar. 22	-74.1	-68.2	-50.8	2.95	.0001	.0001
Apr. 3	-69.4	-60.8	-46.2	3.14	.0001	.002
Final weight Apr. 3	406.4	407.8	435.1	7.73	.12	.02

[a]CSM vs (CORN/CSM + SBH)

[b]CORN/CSM vs SBH

TABLE 16. SEASONAL COW BODY CONDITION CHANGES. TRIAL 1 (1985)

	SUPPLEMENT			SEM	Contrasts	
	CSM	CORN/CSM	SBH		a	b
	------------units-----------					
Inital body condition						
Dec. 7	5.98	5.87	5.78	.123	.04	.64
Cumulative condition changes						
Dec. 20	.30	.26	.29	.066	.70	.70
Jan. 3	-.23	-.11	-.13	.062	.15	.85
Jan. 18	-.29	-.16	.03	.082	.03	.11
Feb. 8	-.52	-.32	-.27	.093	.05	.67
Feb. 14	-.86	-.58	-.41	.095	.003	.22
Mar. 7	-.83	-.41	-.26	.092	.0001	.26
Mar. 22	- 1.05	-.41	-.36	.111	.0001	.75
Apr. 3	- 1.05	-.62	-.35	.109	.0001	.08
Final body condition						
Apr. 3	4.93	5.25	5.44	.175	.06	.45

[a]CSM vs (CORN/CSM + SBH)

[b]CORN/CSM vs SBH

TABLE 17. SEASONAL CALF WEIGHT GAIN. TRIAL 1 (1985)

	SUPPLEMENT			SEM	Contrasts	
	CSM	CORN/CSM	SBH		a	b
	-------------kg-------------					
Initial weight						
Dec. 7	60.8	60.6	58.4	1.60	.49	.33
Cumulative weight gain						
Jan. 3	16.7	19.1	18.0	.75	.05	.28
Feb. 8	34.1	39.4	39.3	1.31	.002	.97
Mar. 7	44.3	52.6	52.8	1.68	.0001	.96
Mar. 22	50.7	60.3	61.0	1.95	.0001	.81
Apr. 3	56.5	67.4	67.2	2.10	.0001	.96
Final weight						
Apr. 3	117.4	128.0	125.6	3.11	.02	.59

[a] CSM vs (CORN/CSM + SBH)

[b] CORN/CSM vs SBH

TABLE 18. CHEMICAL COMPOSITION OF DORMANT NATIVE TALLGRASS FORAGE (ORGANIC MATTER BASIS). TRIAL 2 (1986).

	11/22	1/8	3/10	SE[a]
Crude protein[b]	8.1	4.7	6.3	.34
Neutral detergent fiber[c]	63.6	82.5	83.6	.67
Hemicellulose[b]	8.4	22.5	23.9	.90
Acid detergent fiber[d]	55.2	60.0	59.6	.47
Cellulose[b]	32.0	38.5	38.6	.30
Lignin[e]	18.1	12.7	11.7	.65
Organic matter[f]	88.4	86.9	86.0	.13

[a]Standard error of the mean.

[b]Quadratic ($P<.001$).

[c]Quadratic ($P<.0001$).

[d]Quadratic ($P<.01$).

[e]Quadratic ($P<.05$).

[f]Linear ($P<.0001$).

TABLE 19. SEASONAL COW BODY WEIGHT CHANGES. TRIAL 2 (1986)

	SUPPLEMENT				SEM	Contrasts		
	CSM	CORN/CSM	SBH/CSM	SBH		a	b	c
	---kg---							
Initial weight Dec. 5	456.4	467.1	467.6	466.7	15.33	.50	.99	.99
Cumulative weight changes								
Dec. 20	9.5	10.0	11.4	4.4	2.76	.74	.71	.11
Jan. 3	-5.9	-1.0	-.4	-9.5	3.50	.54	.90	.05
Jan. 16	-6.0	3.2	4.9	-5.0	4.54	.14	.78	.15
Feb. 4	-12.4	-.7	6.2	-5.6	4.58	.02	.26	.39
Feb. 18	-23.1	-8.8	-8.4	-17.5	4.40	.02	.96	.12
Mar. 4	-26.4	-7.4	-4.6	-17.4	5.16	.003	.69	.12
Mar. 20	-30.2	-16.0	-14.1	-24.0	5.74	.05	.81	.27
Apr. 1	-30.1	-11.8	-13.9	-21.3	5.60	.02	.79	.18
Final weight, Apr. 1	426.3	455.3	453.7	445.4	13.51	.08	.93	.56

[a]CSM vs (CORN/CSM + SBH/CSM + SBH)

[b]CORN/CSM vs SBH/CSM

[c]CORN/CSM vs SBH

TABLE 20. SEASONAL COW BODY CONDITION CHANGES. TRIAL 2 (1986)

	SUPPLEMENT					Contrasts		
	CSM	CORN/CSM	SBH/CSM	SBH	SEM	a	b	c
	------------------units--------------------							
Inital body condition								
Dec. 5	5.45	5.82	5.38	5.87	.259	.37	.21	.87
Cumulative condition changes								
Dec. 20	-.03	-.25	-.06	-.09	.089	.27	.12	.16
Jan. 3	-.26	-.20	-.12	-.19	.100	.36	.57	.92
Jan. 16	-.23	-.15	-.10	-.14	.111	.38	.74	.95
Feb. 4	-.30	-.10	-.01	-.16	.115	.08	.56	.72
Feb. 18	-.61	-.49	-.42	-.47	.111	.21	.65	.91
Mar. 4	-.64	-.52	-.32	-.50	.117	.13	.21	.91
Mar. 20	-.68	-.70	-.50	-.70	.120	.72	.24	.52
Apr. 1	-.92	-.81	-.51	-.67	.173	.15	.21	.52
Final weight								
Apr. 1	4.53	5.01	4.87	5.20	.279	.09	.71	.58

[a]CSM vs (CORN/CSM + SBH/CSM + SBH)

[b]CORN/CSM vs SBH/CSM

[c]CORN/CSM vs SBH

TABLE 21. MILK PRODUCTION ESTIMATES. TRIAL 2 (1986).

	SUPPLEMENT					Contrasts		
	CSM	CORN/CSM	SBH/CSM	SBH	SEM	a	b	c
	kg							
Jan. 3	4.2	4.3	5.0	5.5	.30	.04	.10	.003
Feb. 4	4.4	4.7	5.1	5.6	.29	.009	.30	.02
Mar. 4	3.8	4.6	4.8	5.4	.29	.001	.68	.03
Apr. 1	3.3	4.7	4.3	5.0	.34	.0001	.36	.45

[a] CSM vs (CORN/CSM + SBH/CSM + SBH)

[b] CORN/CSM vs SBH/CSM

[c] CORN/CSM vs SBH

TABLE 22. SEASONAL CALF WEIGHT GAIN. TRIAL 2 (1986)

	SUPPLEMENT				SEM	Contrasts		
	CSM	CORN/CSM	SBH/CSM	SBH		a	b	c
Initial weight Dec. 5	66.4	66.1	68.5	69.4	2.57	.53	.48	.30
Cumulative weight gain								
Dec. 20	6.4	8.9	8.1	9.6	.74	.002	.43	.43
Jan. 3	13.6	16.9	16.0	19.6	2.09	.07	.74	.29
Jan. 16	22.1	24.2	25.1	26.5	1.41	.04	.62	.18
Feb. 4	32.3	36.8	38.0	39.6	2.01	.007	.65	.26
Feb. 18	38.8	44.5	46.0	47.4	2.43	.006	.66	.36
Mar. 4	47.7	55.1	57.1	58.7	2.82	.003	.59	.30
Mar. 20	56.4	63.8	66.7	69.4	3.23	.004	.51	.17
Apr. 1	68.9	77.0	80.0	80.0	3.83	.02	.57	.53
Final weight Apr. 1	135.2	143.1	148.5	149.4	5.26	.04	.45	.34

[a]CSM vs (CORN/CSM + SBH/CSM + SBH)

[b]CORN/CSM vs SBH/CSM

[c]CORN/CSM vs SBH

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VITA

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