SUPPLEMENTAL DEGRADABLE PROTEIN REQUIREMENT OF SPRING CALVING BEEF COWS GRAZING STOCKPILED BERMUDAGRASS

By

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SUPPLEMENTAL DEGRADABLE PROTEIN

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BERMUDAGRASS

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CHAPTER I

INTRODUCTION

Cow-calf producers face increasing challenges to maintain profitability. A large portion of production costs is associated with hay feeding which occurs when standing forage nutritive value and quantity is low. Adams et al. (1994) concluded that extended grazing could result in savings of $65 per calf compared to feeding hay.

Bermudagrass has potential in many parts of Oklahoma to be utilized in late summer stockpiling and fall/winter grazing programs. A major concern for these systems is declining nutritive value due to advanced plant maturity and weathering. In fact, some studies show that late summer protein supplementation increases stocker cattle gains while continuously grazing bermudagrass (Phillips and Horn, 1998; DeRousen et al., 1993). However, data collected by Taliaferro et al. (1987), suggests that bermudagrass fertilized in late fall can maintain acceptable levels of crude protein through the winter months. Implementing forage stockpiling systems, with the goal of optimizing forage quality while minimizing the need for supplemental hay or feed, could reduce the number of hay feeding days and potentially improve producer profitability.

Hence, the objective of this study was to determine the degradable intake protein requirement of spring calving beef cows grazing stockpiled bermudagrass.

Chapter II

LITERATURE REVIEW

Stockpiled Forages

Webster's dictionary defines stockpiling as a reserve supply of something essential accumulated for use during shortage. Extending grazing through fall and winter is a management practice that relies less heavily on machinery and energy to harvest forage. Presumably, grazing stockpiled pastures versus feeding harvested forages would reduce production costs associated with winter-feeding and enhance the profitability of a livestock operation. However, forage production and/or quality may not sustain grazing cattle. Forage production and forage quality is dependent upon forage species, level of soil fertility, late summer and fall precipitation, rate of deterioration after first frost, and plant maturity after first frost. Since costs, weather, forage species and other growing conditions vary, the opportunity to incorporate stockpiling as a winter feeding system varies.

Realizing harvested forage costs range from 18 to 24% of total cost per weaned calf, maintaining or improving cow/calf production and reducing the amount of harvested forage fed can greatly improve producer profitability (Adams et al., 1994). D' Souza et al. (1990) suggested that more dependence on the cow rather than machines to harvest forage is one method to reduce winter feed costs. In certain areas of the country, different options offer the potential to extend the grazing season. As shown in the studies of Hitz and Russell (1997), upper Midwest producers have the opportunity to stockpile perennial forages or utilize crop residues to extend the grazing season. These scientists concluded when pregnant beef cows were provided .81 ha of stockpiled forage/cow, grazing stockpiled perennial forages reduced the amount of hay fed by 62.7%. Forage nutritive value in crop residues is much lower compared to stockpiled perennial forage, particularly if precipitation is excessive. Hay supplementation of cows grazing crop residue is 15 to 149% greater than that of stockpiled perennial forages (Hitz and Russell, 1997).

Other researchers in their respective environments have demonstrated that stockpiling forage is a viable option to reduce winter costs. D' Souza et al. (1990) evaluated four management systems and two grass species in West Virginia. Early spring grazing followed by one mid-summer hay cutting and then late fall grazing had greater returns above all variable costs. Tall fescue performed better than orchard grass with respect to production, cost, and profitability. Adams et al. (1994) assessed different wintering systems in the Sandhills of Nebraska. These researchers concluded that by having the cow harvest the forage rather than feed hay, producers can obtain savings above all variable costs of $65 per calf.

Fescue

Tall fescue (*Festuca arundinacea*) is an excellent species for fall stockpiling because it maintains good nutritive value late into fall (Occumpaugh and Matches, 1977). Collins and Bolasko (1981) reported nitrogen (N) fertilization increased stockpiled forage yield, but yield is dependent upon time and rate of N fertilization. With adequate N and moisture, fescue nutritive value increased (Taylor and Templeton, 1976). These researchers also suggest tall fescue provide a strong sod that supports heavy grazing even during wet weather. Grazing pressure during the winter has minimal influence on yield or quality of fescue the following spring and summer grazing season.

Yield and nutritive value of stockpiled fescue depends on timing and rate of N fertilization, moisture, and temperature. Gerrish et al. (1991) noted that yield of stockpiled fescue increased by 30% when N was applied on 1 August as compared to 29 August. Yield response decreased as N rate increased above 45 kg/ha. This suggests that high rates of N would only be economically justifiable when late summer and fall moisture is optimal for growth. Greater amounts of precipitation during the stockpiling phase resulted in greater responses to applied N. Without adequate moisture during the stockpiling period, maximum yields may not be obtained. Gerrish et al. (1991) also noted that cold temperatures during the stockpiling period caused earlier than normal senescence and a decrease in DM accumulation.

Nitrogen fertilization has been shown to improve forage nutritive value in stockpiled fescue (Taylor and Templeton, 1976; Collins and Balasko, 1981). Archer and Decker (1977) illustrated N applied at 100 kg/ha increased stockpiled forage crude protein (CP) concentration from 15.2 to 19.0% after 30 d of growth and from 13.4 to 16.2% after 105 d. Other researchers (Taylor and Templeton, 1976; Balasko, 1977) found that CP in fescue stockpiled beginning in mid-August meets a gestating cow's CP requirement. This fact should reduce the need for expensive protein supplementation. Improved nutritive value in fescue fertilized in late August is associated with a decrease in the proportion of senesced leaves to immature leaves (Taylor and Templeton, 1976; Archer and Decker, 1977).

The influence of N fertilizer on IVDMD of stockpiled fescue forage has been inconsistent. Collins and Balasko (1981) reported that N fertilization decreased IVDMD and the response was greatly influenced by the date of N application. The reduction in IVDMD between 0 and 180 kg of N/ha was 18.6% for forage stockpiled from mid-June until winter. This compares to reductions of 2.7 and 7.3% for early and mid-July stockpiling dates, respectively. Archer and Decker (1977) who initiated stockpiling in late August demonstrated that N application did not influence IVDMD.

Overall, longer the accumulation period, greater the yield of stockpiled forage, but lesser the quality. When grazing stockpiled forage was delayed until winter, decreases were observed in harvestable DM (Rayburn et al., 1979), digestibility (Allison, 1971; Fribourg and Loveland, 1978), CP (Ross and Reynolds, 1979), water-soluble minerals (Ross and Reynolds, 1979), and carbohydrates (Hannaway and Reynolds, 1979). An early start in stockpiling will result in increased accumulation but negatively influence nutritive value.

Bermudagrass

Bermudagrass (*Cynodon dactylon*) is a warm season species that begins growth in spring or early summer and makes most of its growth during the warmest months of the year. Bermudagrass is known for high production and withstanding intense grazing pressure. Bermudagrass was developed in southeastern Africa and spreads by rhizomes, stolons, and seed. It is highly responsive to N fertilizer, and potassium is essential for survival and production (Ball et al., 1996).

Stage of maturity is an important factor in determining the forage nutritive value of bermudagrass. As bermudagrass matures, forage yield increases but digestibility and CP decrease (Ball et al., 1996). Factors associated with limiting forage quality are complex. Structural characteristics that limit digestibility are highly lignified support tissues like sclerenchyma and xylem (Akin, 1989). Akin (1989) reports warm season grasses have increased concentrations of support tissue that limit digestibility compared to cool season species. Increased cell wall constituents, in response to increased forage maturity, may complex protein in warm season grasses causing more protein to escape ruminal degradation. It is unclear whether this increase in UIP is actually utilized in the small intestine, or whether the majority of this protein fraction is indigestible.

Green et al. (1990) reported stocker cattle grazing bermudagrass pastures during the summer gained at a slower rate during the last half of the grazing season compared to the first half. Beginning on May 1, these scientists reported average daily gains of 1.4 kg during the first 2 weeks. Gains decreased to .5 kg/d from mid-June to late July (Green et al., 1990). Phillips and Horn (1998) provided protein supplementation in the last half of the grazing season to stocker cattle grazing summer bermudagrass and significantly increased average daily gains (0.51 vs 0.69 kg). Grigsby et al. (1989) reported only slight increases in average daily gains of (.1 kg/d) in steers fed .25 kg of a condensed molasses block protein supplement while grazing summer bermudagrass pastures. McMurphy et al. (1981) evaluated stocker performance while cattle were rotationally grazed through a series of bemudagrass paddocks. The grazing objective was to maintain high forage quality. Each paddock was grazed for 1-week followed by a 2-week rest period. These researchers concluded that gains of .73 kg/d can be achieved for stockers grazing midland bermudagrass during the summer without any protein supplementation.

Environmental conditions experienced in late summer and fall offer opportunities for Oklahoma livestock producers to accumulate bermudagrass for fall and winter grazing. In certain regions of the state, long-term precipitation patterns indicate adequate moisture to stockpile substantial amounts of forage. Gerrish et al. (1994) reported average yields of 2840 kg/ha for tall fescue fertilized with 45 kg of N. The stockpiling period began on August 29 and continued for 77 days. Average precipitation during the stockpiling period, September through October, was 6.6 and 7.4 cm, respectively.

Most producers only utilize bermudagrass for summer grazing. Late summer and fall precipitation combined with late summer N fertilization offers the potential to stockpile forage with acceptable nutritive value for fall and winter grazing. Data collected by Taliaferro et al. (1987) suggest bermudagrass fertilized with 112 kg N/ha in mid-July can maintain concentrations of CP between 10 to 12% through February. Based on the 1984 Beef Cattle NRC, this meets a gestating cow's CP requirement of 7-8%.

McCroskey et al. (1969) measured the effects of increasing amounts of cottonseed meal (CSM 41% CP) on cow performance while grazing bermudagrass during the winter. Cows were fed daily .45 (L), .91 (M), and 1.4 (H) kg of CSM from December to April. There was no control treatment. Pastures were fertilized with 56 kg/ha of N, P, and K in the spring followed by two applications of 56 kg/ha of N in mid and late summer. Cow weight loss through calving decreased with each increase of protein concentration in the supplement. Crude protein in the forage was not reported. Results of the study indicate that .45 kg of cottonseed meal daily was sufficient for adequate cow performance (McCroskey et al., 1969). These researchers also suggested net economic returns were greatest for the (L) fed cows. Depending on weather effects on forage quality, this study suggests that supplemental protein may be required in order to optimize animal and economic performance.

Metabolizable protein system

Before the publication of the 1996 Beef Cattle NRC, protein requirements were expressed in terms of CP. Protein requirements are currently being expressed as metabolizable protein (MP), or protein that is available for maintenance, growth, fetal growth, and milk production. The MP system is comprised of two fractions: protein that is degraded in the rumen and utilized by the rumen microorganisms for the synthesis of microbial protein (DIP), and the portion that escapes rumen degradation (UIP). The CP system assumes all feedstuffs have an equal extent of protein degradation in the rumen, with CP being converted to MP with equal efficiency in all diets (NRC, 1996). Degradation of protein in the rumen varies among feedstuffs. Other factors such as intake and rate of digestion add to the complexity of ruminal digestion. The MP system should allow more accurate assessment of dietary protein adequacy and improve our ability to provide optimum protein supplements.

Bacterial true protein (BTP) or amino acids make up 80% of bacterial crude protein (BCP) and the other 20% is in the form of nucleic acids (Owens and Zinn, 1988). The digestibility of BTP is estimated to be 80%, giving the conversion of BCP to MP coefficient of .64. Undegradable intake protein digestibility is estimated at 80%, consequently UIP conversion to MP is valued at .80 (NRC, 1985). Bacterial crude protein can supply 50-100% of the MP requirement (NRC, 1985; Spicer et al., 1986). Owens and Zinn (1988) suggested that BCP could comprise 40-100% of the MP. In most diets, microbial protein generally makes up 50% of the protein digested in the small intestine (Owens and Bergen, 1983).

Because protein is generally more expensive than energy supplementation, it is economically important to know the animal's DIP and MP requirement. Once the DIP requirement is known, supplements can be formulated to meet this requirement and adjusted with high UIP ingredients to meet any potential MP deficiency. This approach should allow for more accurate supplement formulation.

Microbial Protein Synthesis and DIP Requirement

According to Cochran (1995), DIP requirement is defined as the amount of DIP, expressed as a percentage of digestible OM or total digestible nutrients (TDN), needed to maximize energy intake. The first limiting nutrient in low quality forage diets (CP<7%) is DIP and the amount required is dependent on the level of intake and digestibility of the diet. The 1996 Beef Cattle NRC suggests that ruminal bacteria fixate ammonia nitrogen with an efficiency of 1.0 into bacterial protein. This results in the DIP requirement being equal to BCP synthesis and has a conversion ratio of 1:1.

It is generally accepted that available energy in the rumen determines BCP production. Burroughs et al. (1974) proposed that BCP = 13.05% X TDN. The 13.05%

value for BCP synthesis is a generalization but doesn't fit all situations. Diets associated with low TDN, such as cows grazing dormant native range, have demonstrated low microbial efficiency (Stokes et al, 1988; Krysl et al., 1989; Hannah et al., 1991; Lintzenick et al., 1993; and Villalobos, 1993) ranging from 5 to 11.4%. Cochran (1995) summarized a series of studies evaluating dormant native range and concluded that DIP should compose 10% of the total digestible material in the diet to maximize total digestible organic matter intake (TDOMI). Lardy et al. (1997a) evaluated the DIP requirement for summer calving cows grazing dormant native Sandhills range and found that DIP needed to comprise 9-10% of TDOMI. These values are similar to those of Karges et al. (1990) and Koster et al. (1994) who found that DIP requirements of cows consuming low quality native range hay was 10.9% and 11% of TDOMI, respectively. However, Hollingsworth-Jenkins et al. (1996) reported that DIP requirement was only 7.1% of TDOMI for cows grazing dormant native winter Sandhills range. Mathis et al. (1998) measured the DIP requirement of steers consuming medium quality bermudagrass hay (8.2% CP, 58.6% DIP). In this experiment, the DIP requirement was found to be 8.3% of TDOMI. Differences in DIP requirement may be dependent upon several factors, such as forage type, forage maturity and relative amount of weathering, forage intake, and possibly factors related to the animal such as stage of production.

Diets low in digestibility are associated with slow passage rates and decreased microbial efficiency. Forages associated with slower passage rates result in slower microbial growth, lowering the requirement for DIP and lowering the amount of MP produced by the bacteria that ferment the forage. Slower passage rates increase microbial turnover and reduce efficiency of growth in the rumen (Owens and Zinn, 1988).

Microbial efficiency has also been shown to decrease as pH drops in the rumen (Russell et al., 1992; NRC, 1985). Lower rumen pH is associated with high energy grain diets. Russell et al. (1992) claimed that for every one decrease in effective neutral detergent fiber (e-NDF) below 20% e-NDF there is reduction of 2.2% in microbial yield.

During times of protein deficiencies, ruminant animals have a unique ability to recycle N. Plasma urea may enter the rumen through saliva or the rumen wall. Owens and Zinn (1988) report that 23 to 92% of plasma urea is recycled to the digestive tract, with higher values associated with lower N intake. Due to increased saliva production in forage diets, 15 to over 50% of the total urea recycled is recycled through saliva. Because of this ability to recycle N, slight deficiencies in DIP may not be detrimental to performance. Several researchers have reported that high protein supplements can be fed less frequently than daily without significant negative effects on animal performance (Melton et al., 1960; McIlvain and Shoop, 1962; Wallace, 1988). Beaty et al. (1995) observed the response to changing supplementation frequency was similar regardless of the protein content in the supplement.

Intake and Utilization

Providing supplemental protein to beef cattle grazing lower quality forages can improve animal performance. Increased production can be directly related to increased forage intake (McCollum and Galyean, 1985; Del Curto et al., 1990a) and has also been related to increased forage digestibility (Hannah et al., 1991; Sunvold et al., 1991).

Cochran (1995) surveyed thirty-eight protein supplementation trials that evaluated seventeen different forages (primarily grasses or straw). These forages ranged from 1.9 to 17.4% CP and from 37 to 73% in digestibility. Forage intake ranged from 0.5-2.9% of body weight (BW). He concluded that when forage CP was less than 6 to 7%, forage intake and digestion declined. Furthermore, when CP concentration in the supplement increased from less than 15% to 28%, fiber digestion increased by 22% and forage intake increased by 49%. These researchers also evaluated the relationship between DIP intake and TDOMI and determined as DIP reached 10% of digestible OM, increases in forage intake were noticeably slower. In order to maximize TDOMI, a diet whose OM is 50% digestible and 10% ash would require 4.5% DIP on a DM basis (Cochran, 1995). Koster et al. (1994) reported maximum digestible forage intake when DIP intake was 4 g/kg of $BW^{0.75}$ or approximately 11% of the total energy intake.

DIP Requirement for Cattle Receiving Low Quality Bermudagrass Forage

Bermudagrass is susceptible to continuous changes in forage nutritive value throughout the year and little is known about its protein degradability and the potential digestibility of its UIP. Expressed as a percent of CP, DIP reported in the 1996 Beef Cattle NRC for bermudagrass hay (7.8%CP, 73.3% NDF) was 77%. Mathis et al (1998) reported that bermudagrass hay harvested during the summer contained 8.2% CP of which 58.6% was DIP. These researchers concluded that DIP supplementation had no effect on total OM intake, total OM digestion, TDOMI, NDF intake, or NDF digestibility.

This agrees with Cochran's (1995) generality that suggests when forages contain greater than 7% CP, little or no response to protein should be expected.

Alexander et al. (1960) determined the effects of N fertilization and harvest date on nutritive value, digestibility, and feeding value of bermudagrass hay. Bermudagrass pastures were clipped and fertilized with 56 kg of N/ha in late August. Hay was harvested either before first killing frost or directly after first killing frost. Both hays were used in a performance and digestion trial. Hay CP decreased from 8.9 to 7.1% in hay harvested after first frost compared to hay harvested before first frost. Cattle consuming hay harvested after first frost lost more weight, .3 kg/d, compared to cattle consuming hay harvested before first frost that gained .3 kg/d. Cattle that consumed hay harvested after first frost consumed 16% less hay compared to cattle consuming hay harvested before frost. Apparent CP digestibility for hay harvested after first frost was 46.8%. Additionally, DM apparent digestibility was 49.3% and TDN equaled 52.7% for hay harvested after first frost. These data helps demonstrate the effects of maturity and weather effects on forage quality and feeding value of stockpiled bermudagrass.

Lagasse et al. (1989) measured the effects of increasing amounts of alfalfa (16.9% CP) on intake and digestion of high quality bermudagrass hay. Bermudagrass hay (14.3% CP) was supplemented with incremental increases in alfalfa hay that composed 0, 15, or 30% of total DM. Total DM intake increased 12 and 17% with 15 and 30% alfalfa added to the diet, respectively. In addition, digestible OM intake increased 15 and 24% when 15 and 30% alfalfa was fed. Alfalfa supplementation had no effect on NDF digestibility. These researchers suggested the bermudagrass was limiting in fermentable carbohydrates and alfalfa provided adequate fermentable carbohydrates for high growth of fiber degrading microbes.

Conclusion

Stockpiling forage is a management practice utilized by livestock producers to decrease production costs associated with hay feeding when forage nutritive value and quantity is low. Researchers have proven production costs can be reduced utilizing stockpiled forages. However, since stockpiling is dependent upon forage growing conditions, the potential economic advantage is variable from year to year. Tall fescue responds positively to N fertilization and is able to maintain high nutritive value late into fall; thus, establishing itself as the predominant forage stockpiled.

Bermudagrass is a popular warm season perennial that is highly productive and withstands heavy grazing pressure. As bermudagrass matures, forage nutritive value declines. Degradable intake protein is usually the first limiting nutrient when cattle consume low quality forage. Late summer protein supplementation for cattle grazing bermudagrass has been shown to improve weight gain. This suggests that improved performance is due to increased forage intake and digestibility when a DIP deficiency is met.

In Oklahoma, bermudagrass has traditionally been managed as though its productive use ends in late August. Late summer and fall precipitation combined with late summer N fertilization offers the potential to stockpile bermudagrass forage with acceptable nutritive value for fall and winter grazing. However, cows grazing stockpiled bermudagrass may require supplemental protein to optimize animal performance.

CHAPTER III

SUPPLEMENTAL DEGRADABLE PROTEIN REQUIREMENT FOR SPRING CALVING BEEF COWS GRAZING STOCKPILED BERMUDAGRASS

ABSTRACT: Three experiments were conducted to determine the supplemental degradable protein (DIP) requirement for spring calving cows grazing stockpiled bermudagrass and to determine the effects of DIP supplementation on intake and digestibility of stockpiled bermudagrass hay. During the third week in August, bermudagrass pastures were clipped or grazed to an approximate 10 cm stubble height and fertilized with 56 kg of N/ha. Grazing was initiated early November and continued through the end of January. Treatments for Exp. 1 and 2 were no supplement (C), 53 g of supplemental DIP (L), 152 g of supplemental DIP (M), and 252 g of supplemental DIP (H). Supplements were formulated to be isocaloric, fed at the equivalent of .91 kg/d, and prorated for 4d/wk feeding. Varying the concentration of soybean hulls and soybean meal in the supplements created incremental increases in DIP. Initial forage production was 3390 and 3330 kg/ha for Exp.1 and Exp.2, respectively. Harvest efficiency for Exp. 1 and Exp. 2 was 60.8 and 63.4%, respectively. Model level one of the Beef Cattle NRC (1996) was used to calculate DIP balance during mid-December. During Exp. 1, supplemented cows lost less weight and condition compared to non-supplemented animals ($P < .05$). Forage dry matter intake tended to be greater ($P = .13$) in

supplemented cows. During Exp. 2, supplemented groups gained more weight (P = .06) and lost less condition (P < .05) compared to non-supplemented animals. Forage dry matter intake was greater (P = .07) for supplemented animals. In Exp. 1 and Exp. 2, increasing supplement DIP concentration had no affect on cow weight change, BCS change, or forage intake (P > .1). In Exp. 3, 4 crossbred steers (BW = 366 ± 3.7 kg) were used in a Latin square design to determine the effects of DIP supplementation on intake and digestibility of stockpiled bermudagrass hay. Treatments were no supplement (C), 33 g of supplemental DIP (L), 95 g of supplemental DIP (M), and 161 g of supplemental DIP (H). Forage intake increased (P < .05) 16% and total organic matter (OM) intake increased (P < .01) 30% in supplemented compared to non-supplemented animals. Total diet OM digestibility increased (P = .08) 6% and total digestible OM intake increased (P < .05) 49% in supplemented compared to non-supplemented animals. Increased supplement DIP concentration did not significantly affect hay OM intake, or OM, ADF and NDF digestibility (P > .1). As DIP increased in the supplement, diet CP digestibility increased (linear P < .05). Assuming constant supplement protein digestibility of 80%, apparent digestibility of hay protein increased by 29% when steers were fed the H supplement compared to the non-supplemented animals. During the initial thirty days after first killing frost, beef cows did not respond to supplementation. However, later in the grazing period, supplemental fermentable carbohydrate improved utilization of stockpiled bermudagrass forage. During these three experiments, we conclude fermentable energy rather than degradable protein limited forage utilization. More research is needed to determine if protein supplementation is justified during varying winter conditions.

Materials and Methods

Experiment 1

A grazing experiment, beginning in the fall of 1997, was conducted to determine the supplemental DIP requirement for mature pregnant beef cows grazing stockpiled bermudagrass (*Cynodon dactylon*). Average initial weight and body condition score (BCS) was 547 ± 6 kg and 5.5 ± .1, respectively. The study was conducted at the Eastern Oklahoma Research Station, near Haskell (HSK), OK and the Range Cow Research Center near Stillwater (STW), OK. At each location, 44 cows grazed stockpiled common bermudagrass forage.

Cows grazed experimental pastures from May through August. During May, pastures at both locations received approximately 80 kg/ha of N and P was applied according to soil test recommendations. During the third week in August, bermudagrass pastures were clipped or grazed to an approximate 10 cm stubble height and fertilized with 56 kg of N/ha. Fall grazing initiated November 2 and continued through January 20 for a total of 79 d. The planned grazing period was shortened by approximately 14 d due to excessive weight and body condition loss. In order to minimize trampling and prolong forage nutritive value, frontal grazing (Allen, 1991) was utilized at STW and cows were given sequential access to paddocks at HSK.

On day -6, initial forage production was estimated at each location by hand-clipping 30 randomly selected .25-m^2 areas. Beginning on d 32, harvest efficiency was estimated at both locations. Fifteen .9 X 6.1-m ungrazed plots were harvested to estimate standing crop dry matter. On d 36, cows were moved to paddocks used to determine harvest efficiency. Forage availability was monitored and cows were moved from the harvest efficiency paddock when it was determined that forage utilization was similar to previous grazing events. Subsequently, fifteen .9 X 6.1-m plots, parallel to the pre-graze sites, were harvested to determine post-grazing standing crop dry matter (DM). Post-grazing standing crop DM was then divided by the pre-grazing value to estimate harvest efficiency.

Grazed forage diet samples were collected monthly at the STW location using esophageally fistulated heifers. Fistulated heifers were maintained in the same pasture as the experimental cows, but were not supplemented. Heifers were removed from pasture, with no access to feed or water three hours prior to masticate collection. Heifers were fitted with a screen bottom masticate collection bag and allowed to graze for thirty minutes. Masticate samples were gathered from the collection bags, mixed, sub-sampled, and immediately placed on ice and stored at –20 ° C. Samples were lypholyzed at -50 ° C and ground (No. 4 Wiley mill, Thomas Scientific, Swedesboro, NJ) to pass through a 2-mm screen.

Forage sample DM concentrations were determined by drying at 50°C for 48 h. Organic matter concentrations of all samples were determined as the weight loss during combustion in a muffle furnace at 500°C for 6 h. Masticate samples were analyzed for NDF, ADF (ANKOM ^{200} Fiber Analyzer, Ankom, Fairport, NY), ADIN, NDIN (Goering and Van Soest, 1970), and N (LECO-NS2000, Leco Corporation, St. Joeseph, MI).

The two stage digestion method of Van Soest (1970) was used to determine digestible organic matter (DOM) from the freeze dried masticate forage samples. This method utilized a 48 h incubation in rumen inoculum and buffer followed by a neutral detergent extraction. Ruminal fluid was collected from a fistulated steer being fed praire hay and a soybean meal based supplement. Fluid was strained through four layers of cheesecloth into an insulated thermos, and transported to the laboratory. In order to determine organic matter digestibility (OMD), .5 g of sample was incubated in buffered ruminal fluid for 48 h. Samples were frozen immediately following the 48 h incubation in order to halt microbial activity. Samples were thawed and an NDF extraction was performed on the residue. The NDF residue was then ashed. In vitro OM disappearance was calculated using the organic matter content of the original sample and the NDF residue. Two standards of known in vivo digestibilities were used to convert in vitro values to in vivo values by regressing the in vitro disappearance values of standards on the known in vivo digestibility of those same samples. In vitro OMD was converted to in vivo DOM using the obtained regression equation.

Model level one of the Beef Cattle NRC (1996) was used to estimate DIP balance. Measured values for weight, forage intake, forage digestibility, forage DIP and UIP, and supplement protein characteristics were used in the calculations. Body weight, forage nutritive value, and forage intake values were collected from d 36-41 at the STW location. Microbial efficiency was assumed to be 10% of total digestible DM intake.

The *Streptomyces griseus* protease (SGP) procedure was used to estimate DIP and UIP of masticate and supplement samples (Krishnamoorthy, 1983). The SGP (P-5147; Sigma Chemical Co., St. Louis, MO) used 4.4 enzyme activity units per mg of solid (one activity unit of enzyme was able to hydrolyze casein to produce color equivalent to 1.0 μmol (181 μg) of tyrosine per minute at pH 7.5 and 37°C). The equivalent of 15 mg of feed N from each masticate and supplement sample were incubated in duplicate for one hour in borate-phosphate buffer. Incubation was conducted in a shallow form shaker water bath (Model No. 6679: Precision Scientific, Chicago, IL) at 39°C, filtered through Whatman #541 filter paper (Whatman International Ltd., Maidstone, England), washed with 400 ml of distilled deionized water, and dried in a forced air oven at 50°C for 24 h. After drying, residue filter paper was weighed, residue subsampled, and N content determined by closed chamber rapid combustion. Estimates of DIP were calculated as 100 – [(residual N / total sample N) x 100], and UIP as 100 - %DIP.

Cows were weighed and BCS were recorded on d 0, 30, and 79 following a 16 h removal from feed and water. Body condition score (scale 1=emaciated, 9=extremely fat Newmann and Lusby, 1986) was assigned by two independent evaluators. Treatments were no supplement (C), 53 g of supplemental DIP (L), 152 g of supplemental DIP (M), and 252 g of supplemental DIP (H). Supplements were formulated to be isocaloric, fed at the equivalent of .91 kg/d, and prorated for 4d/wk feeding. Supplement composition is shown in Table 1. Varying the concentration of soybean hulls and soybean meal in the supplements created incremental increases in DIP. At both locations and during both experiments, cows were individually fed in portable supplementation trailers (Commanche Manufacturing, Joplin, MO).

Forage intake was estimated at the STW location beginning on d 36 of the experiment. Slow release chromic oxide boluses (Captec Chrome for Cattle, Captec Ltd., Auckland, New Zealand) were used to estimate fecal output. Boluses were administered on d 30, 6 d prior to a 5 d fecal collection period. Fecal grab samples were collected once daily at 0800 h. Four crossbred steers were used to determine the chromium release rate from the bolus. Steers grazed stockpiled bermudagrass pastures at the STW location and were administered boluses on d 30 of the experiment. Steers were equipped with fecal collection bags on the morning the first grab samples were taken from the cows. Collection bags were removed, weighed and emptied twice daily at approximately 0800 h and 1600 h for five consecutive days. Upon bag removal, feces was mixed by hand, then thirty grams of sub-sample was collected after mixing.

Fecal grab and collection sub-samples were dried at 50°C in a forced air oven for 48 h. All samples were ground as described above. Chromium analysis with phosphoric acid was performed using atomic absorption (4000 Atomic Absorption Spectrophotometer, Perkin-Elmer, Norwalk, CT). Fecal output was determined by dividing the mean chromium release rate from the bolus by the concentration of chromium in the feces (Williams et al., 1962). Forage intake was estimated by dividing fecal output by indigestibility of the forage. The masticate DOM value collected on d 38 was used to calculate forage indigestibility.

Experiment 2

Experiment 2 began in the fall of 1998 and similar methods were used with the following modifications. The STW pasture received 74 kg/ha of N and the HSK pasture received 80 kg/ha of N in May. Twenty-four and 32 cows were used at STW and HSK, respectively. Average initial weight and BCS was 540 ± 16 kg and 5.2 ± .3, respectively. Treatments were no supplement (C), 53 g of supplemental DIP (L), 162 g of supplemental DIP (M), and 275 g of supplemental DIP (H). The grazing period began November 3 and continued through February 1 for a total of 90 d. Cows were weighed and BCS were recorded on days 0, 28, 63 and 90.

Experiment 3

Four crossbred steers (BW = 366 ± 3.7 kg) were used in a Latin Square design to determine the effects of protein supplementation on intake and apparent digestibility of stockpiled bermudagrass hay. Treatments were no supplement (C), 33 g of supplemental DIP (L), 95 g of supplemental DIP (M), 161 g of supplemental DIP (H), and were fed at a rate of .63 kg of supplement DM/day. Varying the concentration of soybean hulls and soybean meal in the supplements created incremental increases in DIP. Ungrazed stockpiled bermudagrass forage was harvested at the STW location on December 6, 1997, 30 d after first killing frost. Stockpiled bermudagrass hay was stored and then chopped to an approximate 5 cm length to be used in the digestion trial.

Each period consisted of 14 d of adaptation followed by 5 d of collection. Steers were fed 130% of the previous day's hay intake and daily hay intake, refusal, and fecal output were measured directly. Hay samples were composited by steer for each period and a 60 g sub-sample was lypholyzed at -50 ° C and used for analysis. Orts and feces were composited by steer for each period. Thirty grams of hay, ort, and feces sub-samples were weighed, dried at 50° C for 48 h and re-weighed to determine DM. Hay, ort, and feces composites were ground as described above. The analysis for hay, ort, fecal, and supplement samples were the same as described in the forage analysis. The actual DIP and MP balance of steers within each treatment were calculated based on measured values for body weight, forage intake, forage digestibility, forage DIP and UIP, and supplement protein characteristics.

Statistical Analysis

Data in the grazing trials were analyzed as a completely random design using the general linear models of SAS (1991) and the least squares means were calculated. The initial model included effects of year, location, treatment, location x treatment, and year x treatment. Because there was no location by treatment interaction, the data were pooled across locations. There was a significant year x treatment interaction for total weight change. Consequently, results for each year are reported separately. Means were tested for differences in supplemented versus non-supplemented treatments. Supplemented treatments were tested for linear and quadratic effects (Steel and Torrie, 1980). Diet quality data were analyzed using the REG procedure of SAS (1991) with animal as the experimental unit. Monthly means were tested for linear, quadratic, and cubic effects.

Experiment 3 was analyzed as a Latin Square design. The initial model included effects of steer, period, and treatment. Means were tested for differences in supplemented versus non-supplemented treatments and supplement treatments were tested for linear and quadratic effects.

Results and Discussion

Experiment 1

In central and east central Oklahoma, early fall precipitation patterns are conducive to stockpiling substantial amounts of forage (Figures 1 and 2) In north central Missouri, Gerrish et al. (1994) reported average yields of over 2000 kg/ha for tall fescue fertilized with 45 kg of N in late August and receiving 14 cm of precipitation during stockpiling

(September through October). Forage accumulation began on August 29 and continued for 77 d. In the current study, forage accumulation began on August 18 and continued for 76 d. Forage production averaged 3390 kg/ha and did not differ among locations (Table 2). Precipitation during the stockpiling period, September through October, was 14 cm (Oklahoma climatology survey, 1999).

Taliaferro et al. (1987) found that bermudagrass fertilized with 112 kg N/ha in mid-July maintained CP concentrations between 10 and 12% through February. In Exp. 1, when precipitation was substantially above the 10 yr average, CP concentrations in monthly masticate samples ranged from 13.1 to 11.0%. Based on the Beef Cattle NRC (1984), these values exceed a gestating cow's CP requirement.

Acid detergent fiber values ranged from 30.3% in November to 38.0% in January (cubic P = .08). Stage of maturity and amount of weathering is an important factor in determining the nutritive value of bermudagrass. As bermudagrass matures, digestibility and CP concentration decline (Ball et al., 1996). Structural characteristics that limit digestibility are lignified support tissues like sclerenchyma and xylem (Akin, 1989). Apparent improvement in forage nutritive value during the month of February is likely due to growth of cool season annual species in response to moderate temperatures during the first of January through the first of February.

Akin (1989) reports warm season grasses have increased concentrations of support tissue that limit digestibility compared to cool season species. Increased cell wall constituents, in response to increased forage maturity or weathering, may complex protein in warm season grasses causing more protein to escape ruminal degradation. Masticate DIP values ranged from 6.5% in January to 8.8% in February. Expressed as a percentage of CP, DIP values in this study were lower than those reported by the Beef Cattle NRC (1996) where bermudagrass hay (7.8% CP, 73.3% NDF) was reported to contain 77% DIP. However, values in this study were similar to those found by Mathis et al. (1998) in bermudagrass hay (8.2% CP, 70.8% NDF).

During d 0-79 of Exp. 1, supplemented cows lost less weight and condition compared to non-supplemented cows ($P < .05$) (Table 4). Even though the first killing frost occurred in early November, all cows gained weight and maintained condition during the first 30 d (November) ($P > .1$). This indicates nutrients supplied by the forage met the cow's nutrient requirements. A positive DIP balance was calculated for all treatments during d 36-41 (Table 5). Cows receiving supplement gained ($P < .05$) more weight and lost less body condition during the last 49 d of the study. As supplement DIP concentration increased, weight loss declined (linear $P = .08$) during the last 49 d. During this period, precipitation was 120 and 127% above the 10 yr average at STW and HSK, respectively. Researchers have shown that rain increases heat loss by reducing insulation and through heat of vaporization (McDonald et al., 1995). These conditions may have increased animal energy requirement and decreased forage DM intake. In this study, the grazing period was terminated in mid-January due to excessive body condition and weight loss.

Dry matter intake (kg/d) for supplemented cows was greater ($P < .05$) compared to non-supplemented cows (Table 4). Dry matter intake for supplemented cows tended to be greater ($P = .13$) when expressed as percentage of BW. Alexander et al. (1960) reported that cattle consuming bermudagrass hay harvested after first frost lost more weight and consumed less forage compared with cattle consuming hay harvested before frost. However, the limiting nutrient in post-frost hay was not determined.

A positive DIP balance was calculated for all treatments (Table 5). Even though a positive DIP balance was calculated, cow weight loss was reduced with increasing supplemental DIP during the final 49 d of the study. Researchers have shown that late summer protein supplementation has improved stocker performance while grazing bermudagrass with forage CP concentrations ranging from 10 to 16% (Grigsby et al., 1989; Greene et al., 1990; Phillips and Horn, 1998). Our observations suggest that even though non-supplemented cows had a positive calculated DIP balance, increased supplemental DIP minimized weight loss the final 49 d of the study. Since measured values used to calculate DIP balance were taken during d 36-41, DIP may have been deficient during the latter part of Exp. 1. Wet, cold temperatures may have reduced forage intake during late December and January. In Exp.1, supplemental energy decreased weight and body condition loss. Supplemental DIP tended to reduce weight loss late in the grazing period.

Experiment 2

Forage production was greater ($P < .05$) at the HSK location compared to STW (Table 2). Crude protein concentrations in masticate samples ranged from 15.3% in November to 11.6% in January (cubic $P < .05$). Forage ADF and NDF concentrations were higher in January with a gradual decline in February (cubic $P < .05$). Masticate DOM values ranged from 76.8% in November to 66.7% in February (quadratic $P = .07$) (Table 3). Milder winter conditions later in the grazing season increased growth of cool season annuals and may have improved forage nutritive value.

First killing frost occurred in early November. During d 0-90 of Exp. 2, supplemented groups gained (P = .06) more weight and lost (P < .05) less condition compared to non-supplemented animals (Table 4). No significant differences were found for weight or BCS change until the final 26 d period where supplemented cows lost less body condition compared to non-supplemented cows (Table 4). During d 36-41, a positive DIP balance was calculated for all treatments (Table 5). There was no significant influence of increasing supplemental DIP concentration on cow performance (P > .1). When expressed as percentage of BW, supplementation increased (P = .07) forage DM intake.

Forage DIP concentration ranged from 6.8% in November to 9.7% in December. Cochran (1995) evaluated several studies and concluded that DIP should compose 10% of digestible OM in order to maximize energy intake. A diet whose OM is 50% digestible and 10% ash would require 4.5% DIP on a DM basis to maximize DOM intake (Cochran, 1995). According to this 4.5% value, forage DIP in both grazing experiments was not limiting.

Temperatures were 80 and 34% above the 10 yr average at STW and HSK, respectively. Increased temperatures and decreased precipitation may have reduced forage nutrient loss. Kartchner (1981) determined that protein supplementation increased digestion and forage intake of native tallgrass prairie, especially when winter conditions were severe. This researcher also concluded that under mild fall-winter conditions, providing either protein or low levels of grain had neither beneficial nor detrimental effects on forage intake, digestibility, or animal performance in comparison with feeding no supplement.

A positive DIP balance was calculated for all treatments during d 36-41. Gain was maximized and body condition loss was minimized when .91 kg of any one of the supplements was provided. This suggests fermentable energy rather than protein limited cow performance. Lagasse et al. (1990) measured the effects of increasing amounts of alfalfa (16.9% CP) supplementation on intake and digestion of high quality bermudagrass hay (14.3% CP). These researchers concluded that this particular bermudagrass hay was limiting in fermentable carbohydrates and alfalfa provided adequate fermentable carbohydrates for growth of fiber degrading microbes.

Experiment 3

Protein degradability in hay harvested in December was 54.3% of CP (Table 6). This value is similar to that found by Mathis et al. (1998) who reported that bermudagrass hay harvested during the summer contained 8.2% CP of which 58.6% was DIP. These researchers concluded that DIP supplementation had no effect on total OM intake, total OM digestion, TDOMI, NDF intake, or NDF digestibility.

All treatment groups were adequate in DIP, but non-supplemented animals were deficient 15 g of MP/d (Table 7). Forage intake increased ($P < .05$) 16% and total organic matter (OM) intake increased ($P < .01$) 30% in supplemented compared to non-supplemented animals. Total diet OM digestibility increased ($P = .08$) 6% and total digestible OM intake increased ($P < .05$) 49% in supplemented compared to non-supplemented animals. As DIP increased in the supplement, diet CP digestibility increased (linear $P < .05$). Assuming constant supplement protein digestibility of 80%, apparent digestibility of hay protein increased by 29% in animals fed the H supplement compared to the non-supplemented animals. In this study, even though non-supplemented steers received adequate DIP through forage alone, supplementation enhanced intake and digestibility. This suggests energy rather than protein supplementation enhanced forage utilization.

Stockpiled bermudagrass hay was harvested approximately 30 d after first killing frost and received 2.5 cm of precipitation. Apparent CP and DM digestibility was 48.0% and 45.9%, respectively, in the non-supplemented animals. These values are in close agreement with Alexander et al. (1961) who reported apparent CP digestibility for bermudagrass hay harvested within 7 d after first frost to be 46.8% and DM digestibility to be 49.3%.

Diets low in digestibility are associated with slow passage rates and decreased microbial efficiency. Forages associated with slower passage rates result in slower microbial growth, lowering the requirement for DIP and lowering the amount of MP produced by the bacteria that ferment the forage. Slower passage rates increase microbial turnover and reduce efficiency of growth in the rumen (Owens and Zinn, 1988). Microorganisms that ferment cellulose and hemicellulose grow slowly and utilize ammonia as a N source (Russell et al., 1992). The growth rate of microorganisms is directly proportional to the rate of carbohydrate digestion and available N. Passage rate can influence ruminal fermentation products. If carbohydrates are slowly digested in the rumen, microbial growth and ammonia utilization will be reduced (Russell et al., 1992).

Stockpiled bermudagrass hay provided a positive calculated DIP balance in all treatment groups. Perhaps supplemental fermentable carbohydrates increased passage rate and improved microbial efficiency. Our data suggests digestibility increased with supplementation. However, Owens and Goetsch (1988) reported that OM digestion declined as microbial efficiency increased.

Cochran et al. (1995) concluded that maximum TDOMI occurs when DIP composes 10% of TDOMI of low quality forage diets. In this study, maximum energy intake did not appear to be related to total DIP intake and may be due to the fact that DIP was adequate in non-supplemented steers (Table 8).

Implications

In this study, stockpiled bermudagrass met the nutrient requirement for spring calving beef cows during the month of November. Supplementation improved cow performance in the months of December through January under the conditions of these experiments. Supplemental degradable protein limited weight loss during wet winter conditions of Exp. 1. However, DIP was adequate through January during mild winter conditions experienced in Exp. 2. We conclude fermentable energy, in the form of soybean hulls, resulted in increased animal performance and forage utilization in all three experiments.

Table 1. Supplement composition (Exp. 1 and 2).

Item	Treatment[a]		
	L	M	H
	--% of DM--		
Soybean hulls	92.9	61.3	31.2
Soybean meal	0.0	31.7	61.9
Molasses	3.2	3.3	3.3
Dicalcium phosphate	2.8	2.4	1.2
$CaCO_3$	.5	1.2	2.5
KCl	.5	0.0	0.0
CP %, actual	11.7	23.1	35.8
	--Experiment 1--		
CP calculated, g/d	89	197	307
DIP calculated, g/d[b]	67	134	201
CP actual, g/d	106	210	325
DIP actual, g/d[c]	53	152	252
NEm, Mcal/d	1.5	1.5	1.6
	--Experiment 2--		
CP calculated, g/d	89	197	307
DIP calculated, g/d[b]	67	134	201
CP actual, g/d	110	211	318
DIP actual, g/d[c]	53	162	275
NEm, Mcal/d	1.5	1.5	1.6

[a] L = 67 g/d of calculated supplemental DIP, M = 134 g/d of calculated supplemental DIP, H = 201 g/d of calculated supplemental DIP.

[b] NRC 1996

[c] Protein degradability determined using in vitro protease procedure as described by Krishnamoorthy (1983).

Table 2. Initial forage availability, percent utilization, and stock density of stockpiled bermudagrass (Exp.1 and Exp. 2).

	----------STW----------		----------HSK----------		
Item	Exp. 1	Exp. 2	Exp. 1	Exp. 2	SEM
Forage availability, kg	3052	2109[a]	3728	4551[b]	28
Harvest efficiency [c]	61.2	64.8	60.4	62.0	.7
Stock density, AU/ha	1.8	1.0	1.4	2.1	-

[a,b] Means within experiment that do not have a common superscript differ ($P < .05$).
[c] Harvest efficiency was estimated on d 39-44.

Table 3. Chemical composition and organic matter digestibility of esophageal masticate samples collected from cows grazing stockpiled bermudagrass (Exp. 1 and 2, STW location).

Item	November	December	January	February	SEM	L[a]	Q[a]	C[a]
	--------------------Experiment 1--------------------							
OM	88.0	88.8	91.6	89.0	.9	.27	.20	.17
CP	13.1	12.6	11.0	12.7	.8	.43	.35	.31
DIP	55.3	56.2	59.4	69.1	-	-	-	-
ADIN	10.6	10.9	21.1	11.8	3.0	.14	.11	.09
NDIN	35.7	49.5	39.8	30.4	1.4	<.01	<.01	<.01
NDF	56.4	66.6	68.0	63.3	2.1	.36	.60	.80
ADF	30.3	33.8	38.0	32.9	1.0	.28	.13	.08
Lignin	5.5	6.1	9.7	7.5	1.2	.28	.23	.20
DOM	67.5	66.2	57.0	56.1	2.4	.28	.23	.23
	--------------------Experiment 2--------------------							
OM	85.6	85.9	86.0	84.1	.9	.86	.79	.72
CP	15.3	14.7	11.6	13.2	.6	.10	.06	.05
DIP	50.5	65.9	58.6	67.4	-	-	-	-
ADIN	11.7	13.0	15.7	10.3	1.4	.38	.27	.20
NDIN	36.6	26.7	40.5	30.4	1.9	<.01	<.01	<.01
NDF	60.6	57.0	64.6	62.0	1.3	.01	.01	.01
ADF	30.5	32.1	38.9	33.4	.8	.28	.13	.08
Lignin	6.8	8.6	9.5	7.2	1.2	.92	.71	.57
DOM	76.8	58.4	62.1	66.7	2.4	.03	.07	.11

[a] Probabilities for linear, quadratic and cubic response over time, respectively.

Table 4. Live weight change, BCS change, and daily forage dry matter intake in spring calving cows grazing stockpiled bermudagrass and fed increasing amounts of degradable intake protein (Exp. 1 and 2).

Item		Treatment[a] C	L	M	H	SEM	Contrasts S[b]	L[c]	Q[c]
		Experiment 1							
Initial cow weight, kg		482	494	485	492	13.9	.59	.99	.51
0-30	Wt, kg	17.8	21.0	21.0	20.0	5.5	.29	.74	.89
	BCS[d]	.13	-0.02	-.02	-.03	.10	.39	.75	.85
31-79	Wt, kg	-38.0	-15.0	-8.9	-8.6	6.1	<.01	.05	.38
	BCS	-.74	-.28	-.40	-.11	.10	<.01	.29	.13
0-79	Wt, kg	-20.3	5.9	11.9	11.5	4.0	<.01	.29	.44
	BCS	-.65	-.31	-.42	-.09	.10	<.01	.20	.11
Forage intake, kg/d		12.3	13.2	12.8	13.5	.45	.05	.68	.28
Forage intake, % of BW		2.12	2.29	2.21	2.33	.10	.13	.78	.38
		Experiment 2							
Initial cow weight, kg		480	485	482	481	14.7	.63	.79	.54
0-28	Wt, kg	24.8	26.0	25.7	24.7	5.5	.70	.69	.87
	BCS	0	.12	-.04	.10	.10	.44	.90	.12
29-63	Wt, kg	.8	12.1	13.9	7.4	6.7	.17	.25	.37
	BCS	.03	.01	.14	-.04	.10	.83	.76	.17
64-90	Wt, kg	1.9	3.6	4.4	5.8	4.8	.45	.53	.87
	BCS	-.45	-.11	-.19	-.14	.10	<.01	.80	.48
0-90	Wt, kg	27.6	41.4	43.9	37.9	8.2	.06	.49	.37
	BCS	-.42	-.03	-.10	-.08	.11	<.01	.84	.64
Forage intake, kg/d		11.7	13.0	13.5	13.0	.95	.14	.97	.62
Forage intake, % of BW		2.04	2.32	2.39	2.26	.10	.07	.77	.55

[a] C = no supplement, L = 67 g/d of calculated supplemental DIP, M = 134 g/d of calculated supplemental DIP, H = 201 g/d of calculated supplemental DIP.

[b] S = Observed probability for control versus mean of supplemented groups.

[c] Observed probability for linear (L) or quadratic (Q) effects of increasing degradable intake protein within supplemented treatments.

[d] BCS = body condition score change.

Table 5. Metabolizable and degradable protein balance of spring calving beef cows grazing stockpiled bermudgrass (Exp. 1 and Exp. 2).

	Treatment [a]			
	C	L	M	H
	-----------------------Experiment 1-----------------------			
Body Weight, kg	557	573	562	572
Body condition	5.5	5.4	5.5	5.6
Forage intake, % of BW	2.12	2.29	2.21	2.33
DIP required, g/d [b]	696	775	727	773
Forage DIP supplied, g/d	836	928	859	904
Supplement DIP supplied, g/d	0	53	152	252
DIP balance, g/d	141	206	284	383
MP required, g/d	436	445	438	444
Microbial MP supplied, g/d [b]	570	635	598	633
MP supplied by forage UIP, g/d	497	658	620	656
Supplement MP supplied, g/d	0	43	48	61
MP balance, g/d	631	891	828	906
	-----------------------Experiment 2-----------------------			
Body Weight, kg	563	570	565	563
Body condition	5.3	5.4	5.3	5.2
Forage intake, % of BW	2.04	2.32	2.39	2.26
DIP required, g/d [b]	565	658	681	650
Forage DIP supplied, g/d	1089	1270	1314	1254
Supplement DIP supplied, g/d	0	53	162	275
DIP balance, g/d	525	660	778	856
MP required, g/d	439	443	441	439
Microbial MP supplied, g/d [b]	361	421	436	416
MP supplied by forage UIP, g/d	451	526	544	519
Supplement MP supplied, g/d	0	43	39	37
MP balance, g/d	374	547	578	533

[a] C = no supplement, L = 67 g/d of calculated supplemental DIP, M = 134 g/d of calculated supplemental DIP, H = 201 g/d of calculated supplemental DIP.

[b] Microbial efficiency was assumed to be 10% of total digestible dry matter intake.

Table 6. Nutritive value of stockpiled bermudagrass hay (Exp. 3).

Item	%DM	%CP
Organic matter	94.0	-
Crude protein	10.3	-
Neutral detergent fiber	75.4	-
Acid detergent fiber	44.7	-
Lignin	8.6	-
Ether extract	1.7	-
Digestible organic matter	47.6	-
Degradable intake protein	5.6	54.3
Acid detergent insoluble nitrogen	1.6	15.5
Neutral detergent insoluble nitrogen	5.1	49.5

Table 7. Metabolizable and degradable protein balance of steers consuming stockpiled bermudagrass hay (Exp. 3).

	Treatment [a]			
	C	L	M	H
Body Weight, kg	366	366	366	366
Forage intake, % of BW	1.2	1.3	1.4	1.4
DIP required, g/d [b]	215	232	250	250
Forage DIP supplied, g/d	246	266	287	287
Supplement DIP supplied, g/d	0	33	95	161
DIP balance, g/d	31	67	131	197
MP required, g/d	318	318	318	318
Microbial MP supplied, g/d [b]	137	149	160	160
MP supplied by forage UIP, g/d	166	179	193	193
Supplement MP supplied, g/d	0	30	33	41
MP balance, g/d	-15	40	68	76

[a] C = no supplement, L = 33 g/d of supplemental DIP, M = 95 g/d of supplemental DIP, H = 161 g/d of supplemental DIP.

[b] Microbial efficiency was assumed to be 10% of total digestible dry matter intake.

Table 8. Daily intake and apparent digestibility of dietary components (Exp. 3).

Item	Treatments[a] C	L	M	H	SEM	Contrasts S[b]	L[c]	Q[c]
Intake								
Hay OM, kg	4.3	4.9	5.1	5.0	.36	<.01	.48	.65
Supplement OM, kg	0.0	.63	.63	.63	-	-	-	-
Total OM, kg	4.3	5.5	5.7	5.6	.36	<.01	.48	.65
TDOMI[d]	2.1	3.0	3.2	3.2	.47	<.01	.57	.80
Total DIP	238	308	397	473	-	-	-	-
DIP/TDOMI	10.9	10.3	12.5	14.7	-	-	-	-
Digestibility								
Organic matter	48.8	54.8	55.4	57.4	2.9	.07	.59	.86
CP	48.0	57.1	62.4	69.2	2.9	<.01	.03	.80
ADF	49.2	52.4	51.9	53.8	2.6	.41	.84	.84
NDF	54.4	55.5	55.5	58.3	2.6	.52	.57	.75
ADIN	11.5	12.2	14.5	16.4	3.3	.47	.36	.96

[a] C = no supplement, L = 33 g/d of supplemental DIP, M = 95 g/d of supplemental DIP, H = 161 g/d of supplemental DIP.
[b] S = Observed probability for control versus mean of supplemented groups.
[c] Observed probability for linear (L) or quadratic (Q) effects of increasing degradable intake protein within supplemented treatments.
[d] Total digestible organic matter intake.

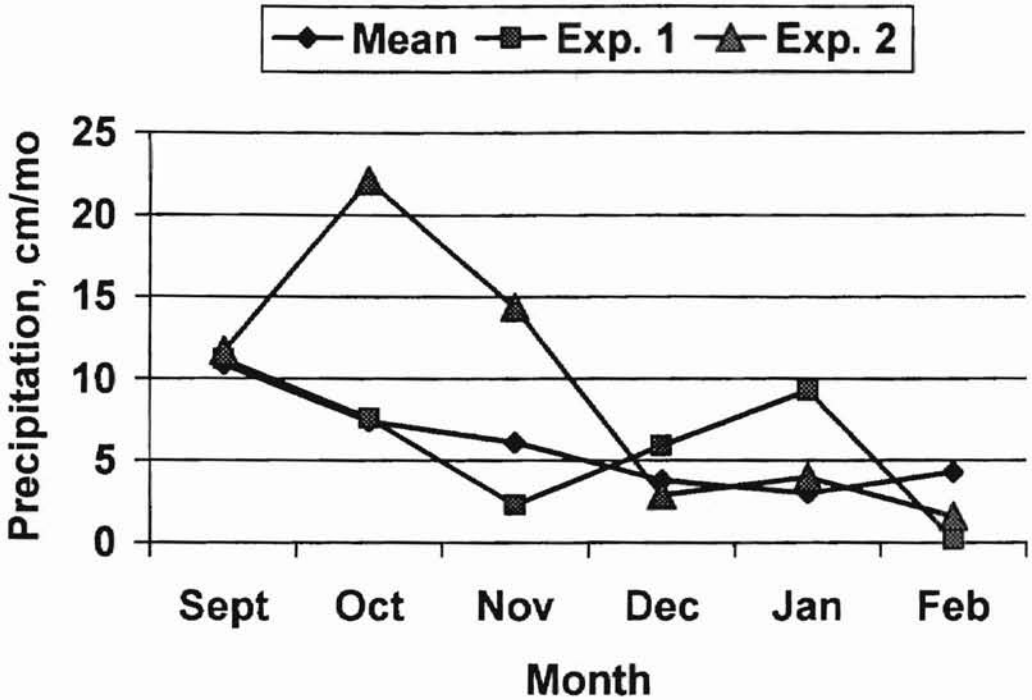

Figure 1. Ten year mean and observed precipitation at Stillwater, Oklahoma during stockpiling and grazing periods for Exp. 1 and Exp. 2.

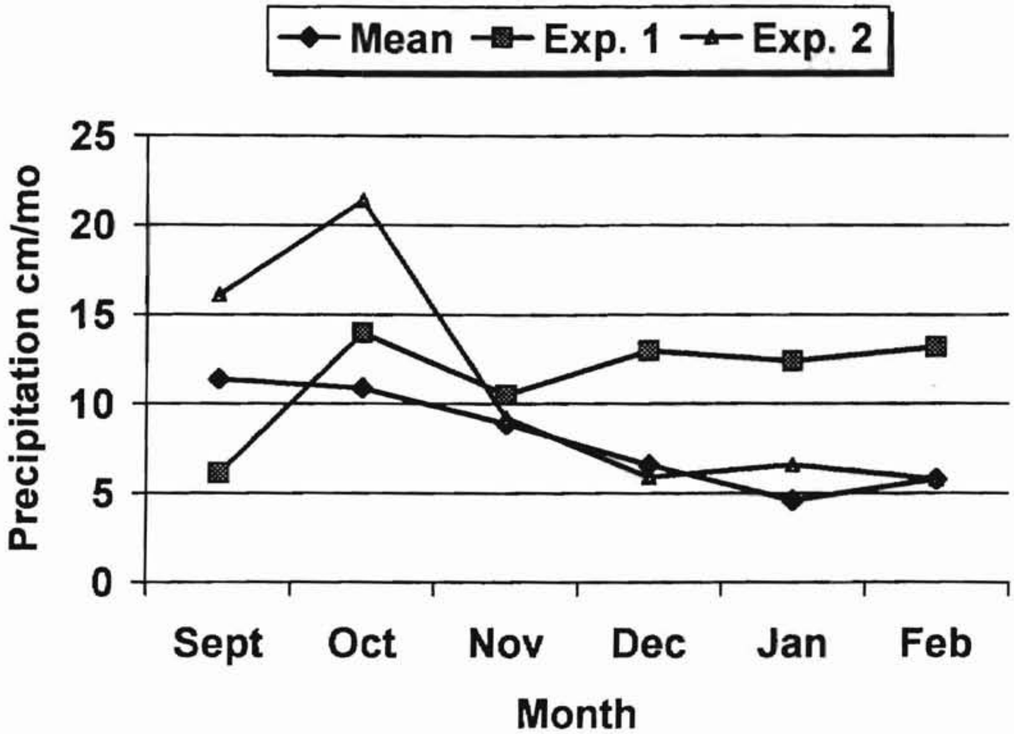

Figure 2. Ten year mean and observed precipitation at Haskell, Oklahoma during stockpiling and grazing periods for Exp. 1 and Exp. 2.

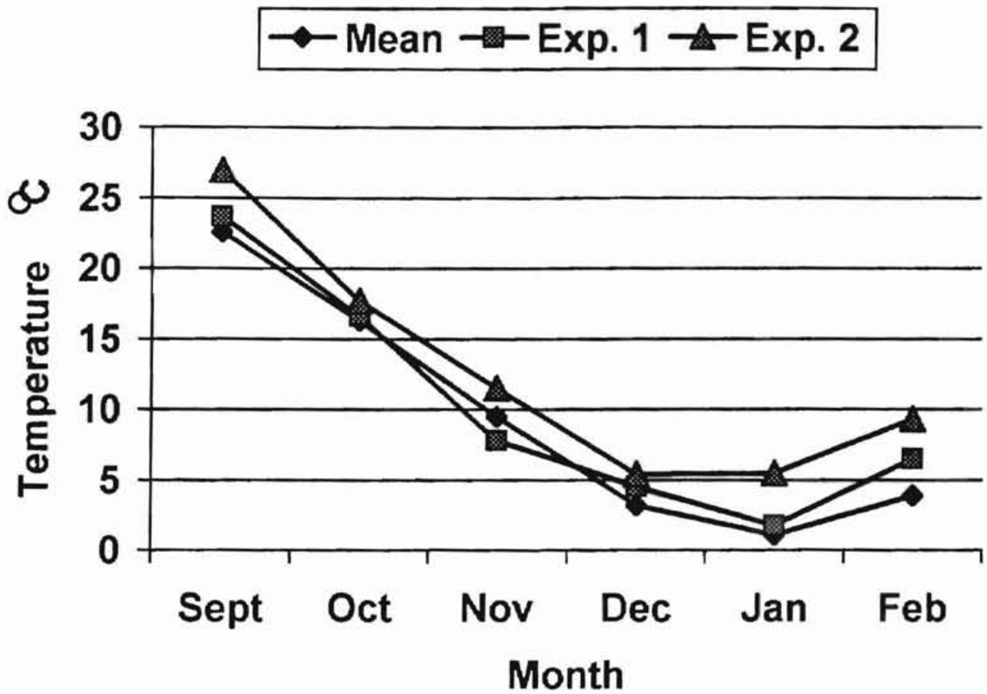

Figure 3. Ten year mean and observed temperature at Stillwater, Oklahoma during stockpiling and grazing periods for Exp. 1 and Exp. 2.

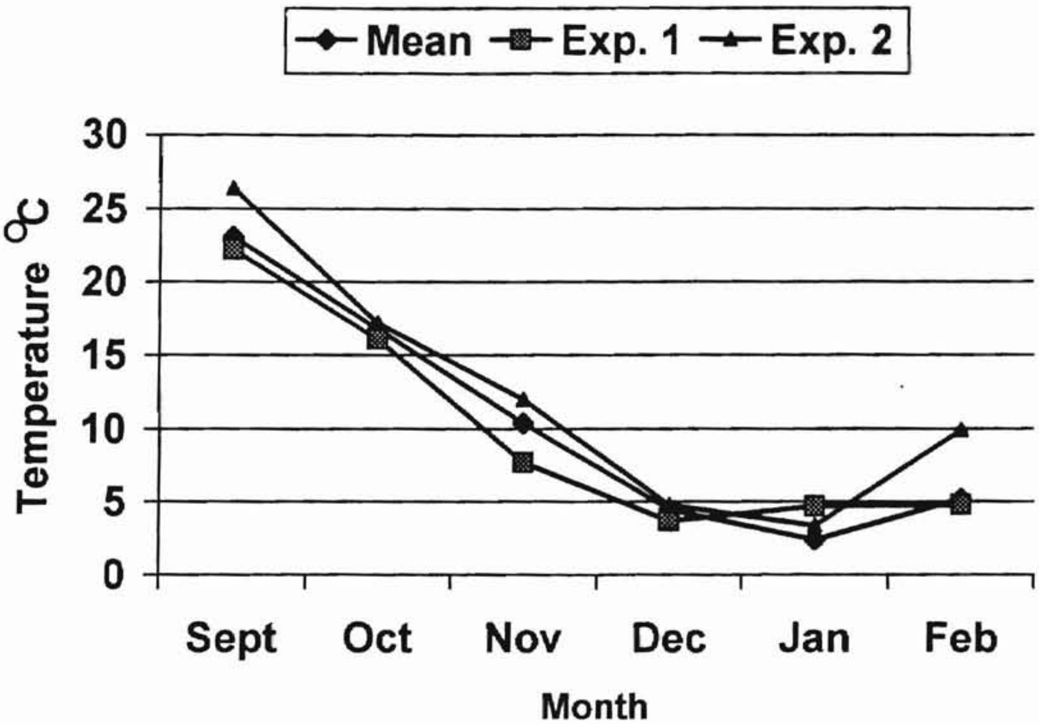

Figure 4. Ten year mean and observed temperature at Haskell, Oklahoma during stockpiling and grazing periods for Exp. 1 and Exp. 2.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Bermudagrasss pastures fertilized with N in late August, followed by deferred grazing through early November resulted in 3390 and 3330 kg/ha of forage accumulation. Harvest efficiency ranged from 60.8 to 63.4% under the management and conditions of this experiment. Stockpiled bermudagrass forage quality was adequate to maintain acceptable animal performance during November. During the last 49 d of Exp. 1, cow weight loss was reduced in wet winter conditions with increasing supplemental DIP. Since measured values used to calculate DIP balance were taken during d 36-41, DIP may have been deficient during the latter part of Exp. 1. In addition wet, cold temperatures may have reduced forage intake during late December and January. In Exp.1, supplemental energy decreased weight and body condition loss. Supplemental DIP tended to reduce weight loss late in the grazing period.

During Exp. 2, temperatures were milder and precipitation was lower compared to Exp. 1. Increased temperatures and decreased precipitation may have reduced forage nutrient loss, promoted growth of cool season annual species, and reduced cow maintenance requirements. During d 36-41, a positive DIP balance was calculated for all treatments. Because projected DIP requirements were met through forage alone, providing fermentable energy rather than protein improved cow performance and forage utilization.

In Exp. 3, hay intake and digestion was improved by supplementation compared to non-supplemented steers. From these results it is apparent that stockpiled bermudagrass forage, accumulated using similar management to that described herein, along with minimal supplementation, can be used to maintain beef cows at least through the month of January. Grazing stockpiled pastures versus feeding harvested forages should reduce production costs associated with winter-feeding and enhance the profitability of livestock operations.

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APPENDIX

Table 1. Mean fecal output and chromium recovery by day (Exp 1).

Day	Fecal dry matter output, kg	Fecal chromium concentration, %	Chromium recovery, g/d
1	2.70	.0261[b]	.70[b]
2	2.64	.0266[b]	.70[b]
3	2.90	.0300[a]	.86[a]
4	2.67	.0268[b]	.72[b]
5	2.60	.0268[b]	.70[b]
SEM	.044	.0006	.023

[a,b] Means within a column with different superscripts differ ($P<.05$).

Table 2. Mean fecal output and chromium recovery by steer (Exp 1).

Steer	Fecal dry matter output, kg	Fecal chromium concentration, %	Chromium recovery, g/d
112	3.06[a]	.0257[c]	.79[a]
188	2.58[b]	.0274[b]	.71[b]
826	2.58[b]	.0292[a]	.75[ab]
951	2.59[b]	.0269[bc]	.70[b]
SEM	.09	.0005	.021

[a,b,c] Means within a column with different superscripts differ ($P < .05$).

Table 3. Mean fecal output and chromium recovery by day (Exp 2).

Day	Fecal dry matter output, kg	Fecal chromium concentration, %	Chromium recovery, g/d
1	3.12[a]	.0454[b]	1.40[a]
2	3.09[a,c]	.035[a,b]	1.12[a,b]
3	2.50[b]	.0326[a,c]	.84[b,c]
4	2.40[b]	.0268[a,c]	.65[c]
5	2.57[a,b,c]	.0228[c]	.59[c]
SEM	.23	.0036	.151

[a,b,c] Means within a column with different superscripts differ ($P<.05$).

Table 4. Mean fecal output and chromium recovery by steer (Exp 2).

Steer	Fecal dry matter output, lb	Fecal chromium concentration, %	Chromium recovery, g/d
112	2.92[a,b]	.0358	1.11
188	3.12[a]	.0302	.95
826	2.40[b]	.0338	.80
951	2.49[b]	.0307	.81
SEM	.21	.0033	.14

[a,b] Means within a column with different superscripts differ ($P<.05$).

Table 5. Chemical composition and organic matter digestibility of forage clip samples collected from stockpiled bermudagrass pastures (Exp. 1 and 2).

Item	November	December	January	February	SEM	L [a]	Q [a]
			Experiment 1				
OM	91.8	94.0	91.8	92.2	.36	30	.10
CP	9.0	7.9	8.4	9.4	.31	.28	.04
NDF	68.1	71.9	71.3	71.7	.81	.08	.13
ADF	46.8	50.1	52.2	52.6	.86	.01	.18
DOM	56.3	52.3	50.3	48.1	1 0	.01	.45
			Experiment 2				
OM	91.1	90.6	92.0	91.4	.45	18	.93
CP	11.2	10.7	11.1	10.9	.46	.88	.72
NDF	67.4	67.4	66.6	65.0	.89	.05	.37
ADF	35.5	34.0	40.6	43.6	2.2	<.01	.30
DOM	56.8	60.8	54.4	53.4	2.0	.04	.21

[a] L = linear effect for month. Q = quadratic effect for month.

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Master of Science

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