EFFECT OF PROTEIN SUPPLEMENTATION ON RELATIONSHIPS AMONG PERFORMANCE, NUTRIENT INTAKE, AND BLOOD AND FECAL COMPONENTS OF STEERS GRAZING TOBOSAGRASS

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CHAPTER I

INTRODUCTION

Tobosagrass (*Hilaria mutica* [Buckl.] Benth.) range covers large areas of the arid southwest United States and northern Mexico (Neuenschwander et al. 1975). Although coarse and unpalatable, the extensive distribution of this species makes it an important forage resource for ranchers of this region (Anderson 1982). In west Texas, Britton and Steuter (1983) reported that crude protein content of tobosagrass declined from about 16.0% in April to 5.0% in July. Digestible organic matter in current year's growth declined from about 55% to 35%. Digestible organic matter for old standing dead forage ranged from 14% to 23%. Considering the low quality of this forage through spring and summer, performance of grazing animals would be expected to be low. For this reason, areas predominated by tobosagrass have not generally been considered for grazing stocker cattle, but with increasing occurence of retained ownership programs, interest in the nutrition of stocker cattle grazing tobosagrass has increased.

A supplementation program may prove beneficial for optimal gains of stocker cattle grazing tobosagrass.

Protein supplementation has shown to be beneficial on summer range in Oklahoma. Soybean meal fed at 0.50 kg/hd/day increased gains by 0.23 kg/day for supplemented vs. non-supplemented steers (Cantrell et al. 1985). Similar results were reported with steers on bluestem range fed 0.50 kg/hd/day of a soybean and cottonseed meal supplement (Gill et al. 1984, Lusby and Horn 1983).

A means of rapidly assessing the nutritional status of grazing animals would be useful in determining proper time and rate of supplementation. Determining nutritional status of free grazing animals by present methods is expensive and time consuming for researchers and virtually impossible for producers. Total fecal output and esophageal diet samples are required for estimating dietary intake and quality. If these methods can be replaced by more efficient means of arriving at nutritional status, both researchers and producers would benefit. Therefore the primary objectives of this research were to 1) determine the effects of supplemental protein on performance of steers grazing tobosagrass in the spring and summer and 2) to evaluate the potential for predicting performance and nutritional status from selected blood and fecal constituents.

CHAPTER II

REVIEW OF LITERATURE

Tobosagrass

Tobosagrass (*Hilaria mutica* [Buckl.] Benth.) range covers large areas of the arid southwest United States and northern Mexico (Neuenschwander et al. 1975). Although course and unpalatable, the extensive distribution of this species makes it an important forage resource for ranchers of this region (Anderson 1982).

Tobosagrass is found primarily on clay soils and pure stands may occupy clay flats (Neuenschwander et al. 1975). Growth of tobosagrass occurs primarily in the spring and fall from terminal nodes on solid perennial stems (Neuenschwander et al. 1975). Annual forage production in wet years may reach 2250 kg/ha (Richardson 1965) and production can be increased through burning (Wright 1972, Britton and Steuter 1983).

Nelson et al. (1970) observed crude protein levels in tobosagrass of 8.6% in July and 4.8% in dormant growth in February. Crude protein content as low as 2.3% was observed in dormant tobosagrass by Kiesling et al. (1969) in southern New Mexico. Britton and Steuter (1983) reported that crude protein content of tobosagrass declined from 16.0 to 5.0% from April to July in western Texas coinciding with declines in digestible organic matter of about 55 to 35% for current years growth. Digestible organic matter for old standing dead vegetation ranged from 14 to 23%.

Considering the low quality of tobosagrass through spring and summer, performance of grazing animals would be expected to be low. Anderson (1982) reported summer gains of replacement heifers (*Bos taurus* and *Bos taurus* x *Bos indicus*) of 0.13 to 0.63 kg/hd/day depending on year and precipitation with greatest gains occurring in early summer. In western Texas, forage intake by beef steers (*Bos taurus*) grazing tobosagrass from April to July was 1.3% of body weight (Reeves 1987).

Protein Supplementation

Supplementation is used during periods of inadequate nutrient supply to enable animals to survive, increase production or reproduce (Siebert and Hunter 1981). The mechanism behind increased production from protein supplementation in cattle is based on associative effects (improved digestibility, increased intake, and increased efficiency of metabolism) (Siebert and Hunter 1981). Digestion and intake may be improved by supplying limiting nitrogen, specific amino acids, carbon chains, and minerals to the ruminal microbial population (Petersen 1987) and through supplying preformed feed proteins and amino acids to the small intestine, possibly correcting a protein:energy imbalance within the animal (Egan 1977, Liebholz and Kellaway 1984). Increases in rumen passage rates resulting from supplying limiting nutrients to rumen microorganisms also result in increases in forage intake (Liebholz and Kellaway 1984).

Ammonia is generally recognized as a primary requirement of rumen microflora and is probably supplied in adequate ammounts for maximum microbial production from growing forages (Petersen 1987). However, rumen ammonia levels in cattle grazing mature or dormant forages may be inadequate for maximum microbial synthesis (Petersen 1987). NRC (1984) suggests increasing ruminal ammonia to 5 mg/100ml will increase microbial protein production. Petersen (1987) has raised question to this specific value for cattle grazing low quality forages since supplementing non-protein nitrogen to cattle on these forages usually illicits poor response. Petersen (1987) has suggested a ruminal ammonia level of 2 mg/100ml as the level at which addition of nitrogen to to rumen has little effect on increasing microbial production when low quality roughages are consumed. Other researchers suggest using rumen ammonia levels only as a rough guide to the adequacy of supply of rumen degradable nitrogen (RDN) supplied by forage and supplements (Liebholz and Kellaway 1984). Responses in microbial growth to supplemental feeding of natural proteins may be more related to satisfying microbial requirements for specific amino acids (arginine, histidine, and methionine), carbon skeletons, or minerals than increasing rumen ammonia levels (Petersen 1987).

Metabolizable protein supply to ruminants is largely dependent on synthesis of microbial protein in the rumen (NRC 1985). Cattle on low quality forages with low gains (<0.5 kg/day) should be able to meet protein requirements with microbial protein (Liebholz and Kellaway 1984). As energy content of the diet increases, microbial protein production may not be adequate to meet animal requirements (Liebholz and Kellaway 1984, Egan 1977). Supplements should be chosen to maximize bacterial production and possibly supply by-pass proteins which can be digested and absorbed directly by the animal (NRC 1985).

The production of microbial protein, in the presence of adequate nitrogen, is dependent on the total quantity of digestibly energy consumed (Petersen 1987). Liebholz and Kellaway (1984) suggested 28g N/kg of organic matter fermented in the rumen as adequate RDN to maximize microbial protein synthesis. However, the production of microbial protein under these circumstances may not be adequate to meet animal requirements (Petersen 1987). In a study with pregnant beef cows grazing dormant forage in Montana, Petersen (1987) estimated a 200g/day deficit in total protein requirement of the cows with maximum microbial production. This deficit indicates the potential for use of rumen undegradable or by-pass protein to supply total animal requirements.

Egan (1977) increased intake of low quality hays by infusing casein into the duodenum of sheep. Results from this research indicate intakes may be increased if additional protein is supplemented when protein to energy ratios (g digestible protein/MJ digestible energy) are less than 7.5. Egan (1977) suggested that when protein / energy ratios were less than 6.0 g protein / MJ digestible energy, potential exists for increasing intake by supplying protein post-ruminally.

Forage quality declines as forage matures (Leibholz and Kellaway 1984). Voluntary intake declines as a function of declining forage digestibility. Forage digestibility can be increased either by processing or supplementing nutrients (Kellaway and Leibholz 1983). Increases in intake and digestibility have been observed in steers fed roughage diets supplemented with protein meals (McCollum and Galyean 1985; Guthrie and Wagner 1988).

Protein supplementation has been shown to be beneficial on summer range in Oklahoma. Soybean-meal cubes fed at 0.5 kg/hd/day increased gains by 0.23 kg/day for supplemented vs. non-supplemented steers (Cantrell et al. 1985). Similar results were reported with steers on bluestem range fed 0.5 kg/hd/day of a soybean and cottonseed meal supplement (Gill et al. 1984, Lusby and Horn 1983). Smith and Warren (1986) increased weight gain of steers as supplemental cottonseed meal levels were increased from 0 to 1000 g/hd/day at 200 g intervals. Steers grazed either oat stubble (44-47% DMD, 3-4% CP) or dry annual pasture (48-51% DMD, 5% CP). Steers on oat stubble gained 0.50 kg/hd/day with no supplement compared to 0.96 kg/hd/day with 1 kg/hd/day of cottonseed meal. Gains on pasture ranged from 0.13 kg/hd/day to 0.61 kg/hd/day for steers supplemented with 0 and 1 kg/hd/day of cottonseed meal, respectively. These researchers hypothesized that forage intake must have increased as increased gains could not be explained by the metabolizable energy content of the supplement alone.

In another study, intake levels responded quadratically to increased levels of cottonseed meal supplementation (Hennessy and Murison 1982). Steers had ad libitum access to hay (43.5% DOM and 4.4% CP) and were supplemented to achieve ration CP levels of 8.8%, 12.1%, or

16.1%. Intake of hay was 11.0%, 19.3%, and 14.5% greater than unsupplemented controls, respectively.

McCollum and Galyean (1985) observed increased intake of hay when steers were supplemented with 0.8 kg/hd/day cottonseed meal. Steers recieving no supplement had intakes of 16.9 g/kg body weight compared to 21.5 g/kg body weight for supplemented steers. Krysl et al. (1987) observed similar increases with sheep. Ewes were fed prairie hay (6.3% CP and 45.4% IVDMD) with 0 or 80 g/hd/day of cottonseed meal. Hay intake increased from 23.7 to 28.3 g/kg body weight with supplementation. These studies indicate that intakes and gains of steers and sheep grazing low quality forages can be increased with protein supplementation.

Blood and Fecal Indicators of Nutritional Status

Different blood and fecal parameters have potential for use as indicators of nutrient intake and nutritional status of ruminants (Biddle et al. 1975, Torell et al. 1974, Warren et al. 1982). Correlations between fecal nitrogen and dietary nitrogen have been observed in cattle (Hinnant 1979, Squires and Siebert 1983, Wofford et al. 1985), deer, and elk (Leslie and Starkey 1985). Wofford et al. (1985) found that fecal nitrogen levels below 1.7%

indicated a dietary nitrogen deficiency for steers and that observations were more reliable with grass diets than with non-grass diets containing protein complexing tannins. Squires and Siebert (1983) reported 1.4% fecal nitrogen corresponded to 0 weight gain in grazing steers while the highest level of fecal nitrogen (2.2%) was associated with the highest gaining steers. These researchers developed the equation C = 1.54NF - 2.11 (r=0.82) where C is liveweight change (kg/hd/day) and NF is fecal nitrogen (g/g OM). Hinnant (1979) observed a range in fecal nitrogen of 1.2 to 1.9% depending on level of nitrogen intake. Six percent CP in the diet corresponded to fecal nitrogen of 1.4% in growing steers. Equations developed by Holecheck et al. (1982) predict dietary crude protein of 6% with fecal nitrogen of 1.5%.

Other studies reported correlations between dietary nitrogen and fecal nitrogen but the relationship varied with seasons (Leslie and Starkey 1985). Relationships between fecal and dietary nitrogen should be determined for specific animal types in specific vegetation types (Leslie and Starkey 1985, Wofford et al. 1985).

Many different blood indices have been linked to dietary nitrogen and energy intake (Bowden 1971, Bowden and Hironaka 1975, Hart et al. 1979). Blood urea nitrogen (BUN) has been correlated with dietary nitrogen in sheep

(Preston et al. 1965, Torell et al. 1974), deer (Seal et al. 1978), and cattle (Preston et al. 1978). In sheep, BUN levels less than 10 mg/100 ml serum indicated restricted dietary nitrogen for rapid growth (Preston et al. 1965). In feedlot cattle, this level was estimated to be 7-8 mg/100 ml serum (Preston et al. 1978). Torell et al. (1974) found correlations between BUN and supplemental nitrogen (r=0.99) and between BUN and weight gain (r=0.95) in sheep. From these studies it appears that equations can be developed to estimate diet nitrogen consumption although relationships may be specific to forage types and animal species.

Albumin has been measured as an indicator of nitrogen status. Some reports suggest that it may be useful as a long term indicator of nitrogen status (Rowlands 1980). Other studies have shown that albumin is of little use as a short term indicator of nitrogen status unless animals are severely deficient in dietary protein (Seal et al. 1978). It appears that changes in animal condition would occur before deficiencies could be determined from albumin analysis.

Blood parameters indicative of energy intake by ruminants are not well studied. A decline in non-esterified fatty acids (NEFA) would be expected as energy intake increases and mobilization of adipose tissue is reduced (Bowden and Hironaka 1975). In deer, NEFA increased as energy intake decreased (Seal et al. 1978). However, Warren et al. (1982) noted that energy intake had no effect on NEFA levels in growing fawns. Bowden (1971) observed decreasing levels of NEFA in growing heifers fed increasing levels of energy over maintenence. Blood levels of NEFA decreased in sheep fed a protein and energy supplement for 9 weeks after weaning (Rhind et al. 1984). Weak correlations between weight gain and NEFA levels were developed by Hart et al. (1979) with cows. Bowden (1971) indicated that NEFA is very sensitive to stress and reports of varying NEFA levels may represent differences in handling of research animals.

Correlations between weight gain and glucose have been observed (Bowden and Hironaka 1975), and combinations of glucose and growth hormone have been correlated with weight gain (r=0.46, Hart et al. 1979). These results suggest that glucose may be useful as an indicator of nutritional status when used in combination with other nutritional indices. Blood glucose levels should be inversely related to NEFA and this relationship may change depending on the types of feeds consumed (Rowlands 1980). Other studies have shown relationships between glucose and energy intake when animals are fed below maintenence (Russel and Wright 1983) but responses of glucose at intake levels above maintenence are not well documented.

Several researchers have investigated ketones as indicators of energy status of livestock and wildlife (Hart et al. 1979, Bowden 1971). Russel (1984) developed equations to predict energy status in pregnant ewes using 3-hydroxybutyrate. A similar equation using 3-hydroxybutyrate, was developed by Russel and Wright (1983) to predict energy status in pregnant cows (r^2=0.92). These researchers were unable to develop any relationship between 3-hydroxybutyrate and energy status in dry non-pregnant cows. Seal et al. (1978) reported that ketones would be of little use as indicators in deer unless the animals were fasting or starving. It appears that ketones would be useful only in animals with a very high energy demand such as lactating or pregnant cows.

In deer studies, triiodothyronine has been correlated with energy intake and may be useful as a nutritional indicator (Seal et al. 1978). Rhind et al. (1984) observed thyroid hormone levels in lambs for 9 weeks post-weaning and concluded that thyroid hormone level was linked to rate of gain and that thyroxine levels were more indicative of changes in weight gain than triiodothyronine. Baccari et al. (1983) developed correlations between weight gain and triiodothyronine in heifers (r=0.91) indicating that triiodothyronine may reflect changes in weight gain in cattle. Thyroxine and triiodothyronine are reported to increase with increased weight gain in both male and female calves from birth, with males having higher thyroid hormone levels than females (Kahl et al. 1977). Male calves, in this study, had a higher rate of gain than females.

Blood urea nitrogen and fecal nitrogen appear promising as indicators of nitrogen status in growing animals. Changes in albumin reflect long term effects of nitrogen intake or severe deficiencies in nitrogen and would not be useful as an indicator of short term changes in nutritional status of growing animals.

Ketones are associated with very high energy demands or severe energy deficiencies and it is felt that changes in ketone levels would not reflect increases in energy intake in growing steers. Glucose and NEFAs may be more sensitive to energy intake changes in growing cattle. In addition, it appears that thyroid hormone levels are associated with changes in weight gain and energy intake.

CHAPTER III

EFFECT OF PROTEIN SUPPLEMENTATION ON PERFORMANCE OF STEERS GRAZING TOBOSAGRASS RANGE IN THE SPRING AND SUMMER

Abstract

A 3-year study was initiated in 1985 to evaluate the performance of beef steers fed 0.00, 0.34, or 0.68 kg/hd/day of cottonseed meal cubes while grazing tobosagrass (*Hilaria mutica* [Buckl.] Benth.) range. In April of each year, mixed breed beef steers (avg. wt. 230 kg) were allotted to 3, 6-pasture grazing cells in Garza County, Texas. Prorated amounts of supplement were group-fed 3 days/week between 1000 and 1100 hours. Cattle were individually weighed at 21-day intervals from April to early July. Standing forage was measured by clipping quadrats in each pasture as steers entered that pasture. Clipped samples collected on or near weigh dates were analyzed for crude protein. Forage crude protein remained above 7.0% during all years except July, 1985 when it dropped to 6.5%. Gains in 1985 averaged 0.38, 0.44, and 0.67 kg/hd/day for the 0.00, 0.34, and 0.68 kg supplement

groups, respectively. Gains in 1986 were 0.65, 0.66, and 0.71 kg/hd/day respectively for the 3 groups, and 0.98, 1.08, and 1.07 kg/hd/day in 1987. Positive responses to supplementation were observed during different periods of each year but no consistent trends in gain were evident. Gain responses did not closely parallel declining forage quality and were possibly influenced by weather and muddy conditions during the third period of each trial.

Introduction

Tobosagrass (Hilaria mutica [Buckl.] Benth.) range covers large areas of the arid southwest United States and northern Mexico (Neuenschwander et al. 1975). The extensive distribution of this species makes it an important forage resource for ranchers of this region (Anderson 1982) despite its coarse unpalatable nature. In western Texas, Britton and Steuter (1983) reported crude protein (CP) values in current year's growth that declined from 16.0 to 5.0% from April to July while digestible organic matter declined from 55 to 35%. Digestible organic matter (DOM) in standing dead forage ranged from 14 to 23%. Considering the low quality of this forage during the summer, performance of grazing animals would be expected to be low. Forage intake as low as 1.3% of body weight was reported by Reeves (1987) in steers grazing spring and summer tobosagrass in Texas. Anderson (1982) observed summer weight gains of only 0.13 kg/hd/day in replacement heifers in New Mexico.

Supplementing protein through the growing season may enhance weight gain and production from grazing livestock. Protein supplementation has improved cattle performance on summer range in other regions. Soybean-meal cubes (0.5 kg/hd/day) increased gains by 0.23 kg/hd/day for supplemented vs. non-supplemented steers grazing native grass in southeastern Oklahama (Cantrell et al. 1985). Similar results were reported with steers on bluestem range fed 0.5 kg/hd/day of soybean or cottonseed meal (CSM) cubes (Gill et al. 1984, Lusby and Horn 1983).

In another study, forage intake responded quadratically to increased levels of CSM supplementation (Hennessy and Murison 1982). Steers had ad libitum access to hay (43.5% DOM and 4.4% CP) and were supplemented to achieve ration crude protein levels of 8.8%, 12.1%, or 16.1%. Intake of hay was 11.0%, 19.3%, and 14.5% greater than unsupplemented controls, respectively, suggesting diminished benefit of feeding levels above 12.0% CP. Guthrie and Wagner (1988) also observed increases in intake of prairie hay (4.0% CP) when steers were fed 0.67 kg/hd/day of 37% CP soybean meal based supplement. Intakes ranged from 4.1 kg/hd/day for control steers to 6.9 kg/day for steers recieving 0.67 kg supplement.

The objective of this study was to determine the influence of level of protein supplementation and changes in forage protein content on performance of steers grazing tobosagrass range in the spring and summer.

Materials and Methods

Study Area

This study was conducted at the Texas Tech Experimental Ranch located 90 km southeast of Lubbock, Texas in Garza County. Mean elevation is 800 m. The area is dominated by clay flat range sites made up of gently sloping Stamford clay soils (fine, montmorillonitic, thermic Typic Chromusterts). Tobosagrass is the dominant forage with alkali sacaton (Sporobolus airoides [Torr.] Torr.) present in depressions. Upland areas produce buffalograss (Buchloe dactyloides [Nutt.] Engelm.). In excellent condition, average yearly forage production is 1500 kg/ha (Richardson et al. 1965). During the study, average standing crop was 836 kg/ha, 663 kg/ha, and 1574 kg/ha, for 1985, 1986, and 1987, respectively. Mesquite (Prosopis glandulosa var. glandulosa Torr.) covers the area and was chemically treated in 1983.

The climate is warm, temperate, and subtropical with dry winters. Average precipitation is 478 mm. Drought is common. Average length of growing season is 216 days (Richardson et al. 1965). Rainfall was above average in each year of this study (Fig. 1).

Field Trials

Crossbred beef steers, *Bos taurus* x *Bos indicus*, (200-250 kg/hd) were randomly allocated (based on weight) to each of 3, 6-pasture grazing cells in March 1985, 1986, and 1987. Cell areas were 68, 91, and 95 ha. Cells were stocked based on forage production so that forage allowance/hd/day was similar in all 3 cells (Table 1). Steers were rotated through the cells on 42-day cycles with length of stay in each pasture from 4-10 days. Twenty-seven to 57 steers were used in each cell for an average stocking rate of 1 steer/1.9 ha over the 3 years.

On 21 March, 1985, 150 steers (avg. wt. 207 kg) were purchased through auctions in northeast Texas and southeast Oklahoma. Ten additional steers were purchased through the Lubbock Livestock Commission to replace culls from the original 150. Individual steer weights are given in appendix tables 1-9. The cattle were pastured on wheat until 17 April at which time they were moved to the tobosagrass study site. The steers were weighed and allocated to treatment groups on 23 April. Supplementation began at this time and continued until 23 July.

Steers (avg. wt. 226 kg) were purchased from a single ranch in eastern New Mexico in 1986 and arrived at the Experimental Ranch on 6 March. The 89 steers were weighed and allocated to treatments on 7 April. Supplementation began on this date and continued until 30 June.

In 1987, 105 steers were contracted on gain and came from overgrazed wheat pasture in Lubbock, Texas on 15 November. These steers were wintered on tobosagrass and fed either CSM, 32% CP cube, or 20% CP grain block. On 11 April, these steers were weighed (avg. wt. 211 kg) and allocated to treatment groups based on previous treatment and weight. Trials in 1987 ended on 4 July.

In all three years steers were processed on arrival at the ranch. A four-way vaccine (Clostridium chauvoei, C. septicum, C. novyi, and C. sordellii) and Ivermectin were administered to each steer. Ralgro implants were administered at the beginning of the supplement trials.

Three rates of CSM (41% CP solvent extracted) supplementation were studied (0.00, 0.34, or 0.68 kg/hd/day, as-fed basis). Supplement treatments were rotated among the three cells during the three year study. All cattle within a cell were fed similarly. Cattle were group-fed a prorated amount of supplement three days per week. Free choice mineral (13% Ca, 7% P, 50% NaCl) was available at all times. Steer weights were recorded at the start of the supplementation period and every 21 days thereafter until supplementation was terminated. Steers were penned 14 hr overnight, without feed and water, before weighing.

Forage standing crop was measured in each cell in each of the 3 years. Transects were established through each pasture of each cell and 10 random 0.25-m^2 plots were hand clipped to ground level along each transect. All pastures were clipped at the initiation and end of the grazing season. Pastures were also clipped during the trial as cattle were rotated among pastures in the cells. Composite samples of grass and composite samples of forbs were collected in 1985. Samples of tobosagrass, alkali sacaton, other grass, and forbs were collected in 1986 and 1987. Samples were dried in a forced-air oven at 40 C and weighed.

Forage CP was estimated from clipped samples taken in each cell on or about the day cattle were weighed. Kjeldahl nitrogen (AOAC 1980) was determined for each forage sample in duplicate and reported as CP (N x 6.25).

Cost of additional weight gain by supplemented steers was estimated at 3 different feed costs ($250, $200, and $150/ton) and was calculated from the following equation: Cost of additional gain = Feed cost ($/hd/day) / Gain (kg/hd/day above control).

Statistical Analyses

Gain data were originally analyzed with year, treatment (TRT), and pasture (PAS) as main effects and period (PER) as a repeated measure. Model components were YEAR, TRT, PAS, YEAR*TRT*PAS, PER, YEAR*PER, TRT*PER, and PAS*PER. The YEAR*PER, TRT*PER, and PAS*PER interactions were significant ($P<0.01$) and data were subsequently analyzed within period. Means were separated using the least significant difference procedure.

Results and Discussion

Forage CP followed similar trends in all years of the study with peak level occuring during late April (Fig. 2). Period (PER) 1, 1985 began about 2 weeks later than PER 1, 1986, and 11 days later than PER 1, 1987, therefore, a decline in forage CP was observed during PER 1, 1985 while an increase in forage CP occurred during PER 1 in the latter 2 years. Precipitation was closest to normal during 1985 and forage CP declined from 9.0% in April to 6.5% in late July. Precipitation in 1986 and 1987 was above normal. Forage CP in 1986 increased during April to 9.3% then declined to 8.1% in late June. Similarly, forage CP in 1987 peaked at 10.5% and declined to 7.0% by early July. Britton and Steuter (1983) reported CP of tobosagrass declining from 16.0% in April to 5.0% by July.

Above average rainfall during this study may account for higher crude protein values.

Control (CON) steers gained 0.38 kg/hd/day during the trial in 1985 (Fig. 3, Appendix table 10). Gains increased from PER 1 (0.30 kg/hd/day) to PER 2 (0.69 kg/hd/day) then declined throughout the remainder of the grazing season reflecting the decline in forage CP. Forage CP fell from 7.0% to 6.5% during PER 4. Gains for the CON group in PER 4 were 0.10 kg/hd/day indicating the steers were able to select a maintenance level diet only.

Weight gain of steers receiving the low level of supplement (LS) followed the same general trend as the CON steers. Gains increased from 0.42 kg/hd/day in PER 1 to 0.87 kg/hd/day in PER 2 then declined the remainder of the grazing season (Fig. 3). Average daily gain over the entire season was 0.44 kg/hd/day for this group. The LS steers gained 0.12 kg/day and 0.18 kg/day more than CON steers during PER 1 and PER 2 ($P<0.05$). In PER 3 gains fell below the CON group. Lack of response to supplementation during the latter two periods cannot be explained. It is felt that relatively high precipitation was partially responsible for reduced gains during PER 3. Supplemented steers expended additional energy trailing to the feeding area through mud. These steers may also have reduced grazing time on feed days during foul weather.

Performance of steers receiving the high level (HS) of supplement followed the same general trend as the other groups through PER 3 (Fig. 3). These steers gained 0.23 kg/day more than LS steers in PER 1 ($P<0.05$) and had similar gains to LS steers in PER 2 and 3. Daily gain for HS steers (0.92 kg/hd) was considerably greater ($P<0.05$) than the other groups during PER 4. Low gains for the HS steers in PER 3 were again attributed to weather and mud in the pastures. Forage CP dropped to 6.5% by the end of PER 4 and HS steers appeared to be responding to protein supplementation during this period. However, lack of response by the LS steers during this period suggests that gains of HS steers during PER 4 could be attributed to compensatory growth after relatively poor gains in PER 3 or lack of fill at the PER 3 weighing. Average gain for the HS group for the season was 0.67 kg/hd/day.

In 1986, gain patterns for all treatment groups followed the same general trend as the HS steers in 1985 (Fig. 4). Forage CP during 1986 was above 8.0% at each weigh date and gain for all groups was generally higher than in 1985. The CON steers averaged 0.65 kg/hd/day gain in 1986. Gain was constant over PER 1 and PER 2 at 0.80 kg/hd/day and again declined during PER 3. The gain pattern of these steers differed from those in 1985 in that gains increased during PER 4. Forage CP at the end of PER

4, 1986 was 8.1% compared to 6.5% in 1985 (Fig. 2). This greater level of forage CP at the end of the grazing season could explain the difference in gain response between the years.

Steers in the LS group gained 0.66 kg/hd/day over the 1986 grazing season. Their pattern of gain was very similar to the CON group only differing at PER 2 and PER 3 ($P<0.05$). Forage CP decreased from 9.3% to 8.6% during PER 2. Reeves (1987), in a concurrent study, reported diet CP about 2.5% higher than the total CP content of the forage on offer. This suggests that steers were able to select a diet containing at least 11.0% CP during PER 2. This diet would supply adequate protein for gains up to 0.80 kg/hd/day (NRC 1984) assuming adequate dry matter and energy intake.

The LS steers gained less ($P<0.05$) than CON steers during PER 3 (-0.20 vs. 0.14 kg/hd/day, respectively). Gain was similar ($P>0.10$) during PER 4. Forage CP decreased from 8.6 to 8.1% during this period and was slightly lower than during PER 2 where a response to supplementation was observed. Compensatory growth during PER 4 after poor gain in PER 3 or reduced fill at the PER 3 weighing may have affected the response to supplementation.

The HS steers averaged 0.71 kg/hd/day in 1986. Gains were similar to CON steers during PER 1 but less than

(P<0.05) LS steers (Fig. 4). Forage CP was greater than 9.0% by the PER 1 weighing which, assuming diet CP was 2.5% greater than forage CP, would supply protein in greater amounts than needed for the recorded gains of all three groups (NRC 1984) if forage intake was adequate. Gains of HS steers were greater (P<0.05) than the other groups during PER 2 when forage CP was decreasing indicating supplemental protein was effective. Gains of HS and LS steers were similar during PER 3. No difference in gain was observed among the 3 groups during PER 4.

A similar pattern of gain was observed during the grazing season in 1987 as in 1986. Control steers averaged 0.98 kg/hd/day during the trial. Gains increased from 0.83 kg/hd/day in PER 1 to 1.57 kg/hd/day in PER 2 then dropped again in PER 3 to 0.37 (Fig. 5). Gain then increased during PER 4. Forage CP increased during PER 1 to 10.5% (Fig. 2). This high CP level must have persisted during PER 2 providing for high gains in the CON group during the second period.

Gains of the LS group were higher (P<0.05) than CON steers during PER 1 when forage protein was increasing from 7.6% to 10.5%. Period 1 occured during April, a very dry month in 1987, thus, high levels of protein probably only occurred at the end of this period. Protein supplementation was beneficial during this period. Gain of the LS group fell below that of the CON group during PER 2 after forage CP peaked at 10.5% similar to the HS and CON groups in PER 1, 1986 when forage CP peaked at 9.3%. Identical responses in gain were observed during PER 3 and PER 4 as in 1986. Average gain for the LS group in 1987 was 1.08 kg/hd/day.

Gains of HS steers were similar to the LS steers in 1987. There was no benefit to feeding the high supplement in this year. These steers had been wintered on dormant forage and overall gains during the 1987 trial were unusually high. Compensatory growth would account for these high gains and may account for the lack of difference between the LS and HS steers.

Neither the LS or HS rate was consistently better than the CON when subjected to economic analysis (Table 2). The HS proved beneficial in PER 1 and PER 2, 2 out of 3 years and only beneficial in PER 4 in 1985. The LS rate was beneficial in PER 1 in all years although gains were not significantly different, beneficial in PER 2 and PER 4 in 2 out of 3 years, and beneficial in PER 3 in only 1 year.

Weight gain of CON steers averaged 0.67 kg/hd/day over the three years. Anderson (1982) reported gains of 0.52 to 1.01 kg/hd/day, dependent on year, for heifers grazing tobosagrass during May and June in southern New Mexico. Weight gain of CON steers in 1987 was 0.98 kg/hd/day, similar to the highest gains reported by Anderson (1982). Lusby and Horn (1983) observed summer gains of unsupplemented steers (0.59 kg/hd/day) on Oklahoma tall grass prairie similar to average gains of the CON steers in the current study. Higher steer gains were reported by McCollum et al. (1986) for steers grazing Cross Timbers rangeland during spring and early summer (0.81 kg/hd/day). Steers grazing bermudagrass (*Cynodon dactylon* [L.] Pers.) in Oklahoma gained 0.50 kg/hd/day from May to September (Ford et al. 1983). Results from these studies indicate that expected steer gains from tobosagrass in the spring and summer generally fall within the range of summer steer gains on the Southern Great Plains.

No consistent response to supplementation was observed over the 3 years of the study. Rainfall was above average in each year of the study and forage CP remained higher than levels reported in the literature (Britton and Steuter 1983). A general decline in forage CP was observed during each of the years of study but animal gains did not parallel forage quality probably as a result of weather effects. Reeves (1987), in a concurrent study, observed increased intake with supplementation in July, 1985. Forage CP had declined to 6.5% by that period and a gain response to supplementation was observed. Rittenhouse et al. (1970) indicated that the positive effect of supplementation on digestion and intake may not be observed when diet CP is above 6.0-8.0%. Inconsistent responses to supplementation in the current study would suggest that dietary CP remained above this 6.0-8.0% level through all periods of all years except July, 1985. Other studies have shown improvement in performance with protein supplementation but forage CP in these studies was generally below 5.0% (Hennessy and Murison 1982, Smith and Warren 1986).

Reeves (1987) observed 9.2% diet CP and 45.6% diet dry matter digestibility (DMD) with steers grazing early summer tobosagrass with little or no intake response to protein supplementation. Forage intake in this study was 1.4% of body weight for steers supplemented with 0.68 kg/hd/day CSM and 1.3% of body weight for steers supplemented 0.34 kg/hd/day CSM and unsupplemented controls. These intake values for tobosagrass are considerably lower than those reported in other vegetation types. Holechek and Vavra (1982) reported forage intake over 2% of body weight in steers grazing native range in Oregon during spring and early summer.

Lack of consistent response to supplementation in this study may be related to low intakes of spring and summer tobosagrass as a result of low digestibility of the forage (Reeves 1987). No intake response may be observed when forage CP is high relative to digestibility (Liebholz and Kellaway 1984). Other studies which have shown increases in intake and performance with protein supplementation were with forages with %CP / %DMD ratios of less than 0.13 (Lusby and Horn 1983, McCollum and Galyean 1985, Smith and Warren 1986). Reeves (1987) reported diet %CP / %DMD ratios of generally over 0.20 in steers grazing spring and summer tobosagrass.

In years when rainfall is average or below average, forage CP may reach 5% by July (Britton and Steuter 1983) and diet %CP / %DMD ratios may decline. Supplementation in these years may be beneficial as it has been with summer feeding programs in Oklahoma (Gill et al. 1984, Lusby and Horn 1983).

Table 1. Standing crop and allowance of grass at the Texas Tech Experimental Ranch, 1985, 1986, and 1987.

Year	Cell	Supplement level	Forage available (kg/ha)	Steers/ cell	Forage allowance[1] (kg/str)
	1	HS[2]	810	57	1350
1985[3]	2	CON	690	57	1111
	3	LS	1010	57	1192
	1	CON	810	37	2078
1986[4]	2	LS	490	27	1649
	3	HS	700	27	1739
	1	LS	1420	40	3385
1987[5]	2	HS	1570	28	5115
	3	CON	1730	37	3158

[1] Total grass available per steer at the beginning of each year.

[2] HS = high supplement, 0.68 kg/hd/day cottonseed meal, CON = control, no supplement, LS = low supplement, 0.34 kg/hd/day cottonseed meal.

[3] Forage was sampled in each pasture of each cell between 23 April and 27 May before steers were allowed to graze. No differences ($P>0.05$) in forage allocation were observed.

[4] Forage was sampled in each pasture of each cell on 11 March. No differences ($P>0.05$) in forage allocation were observed.

[5] Forage was sampled in each pasture of each cell on 10 April. Differences ($P<0.05$) in forage allowance were observed.

Table 2. Cost of added gain ($/kg) by steers grazing tobosagrass and supplemented with 2 levels of cottonseed meal, Texas Tech Experimental Ranch, 1985, 1986, and 1987.

Supplement level (kg/hd/day)	0.34	0.34	0.34	0.68	0.68	0.68
Supplement price ($/kg)	0.28	0.22	0.17	0.28	0.22	0.17[1,2]
Year	Grazing period 1					
1985	0.78	0.62	0.47	0.53	0.43	0.32
1986	0.94	0.75	0.56	NC	NC	NC
1987	0.19	0.15	0.11	0.29	0.24	0.18
	Grazing period 2					
1985	0.52	0.42	0.31	0.98	0.79	0.59
1986	0.52	0.42	0.31	0.32	0.25	0.19
1987	NC	NC	NC	NC	NC	NC
	Grazing period 3					
1985	NC	NC	NC	NC	NC	NC
1986	NC	NC	NC	NC	NC	NC
1987	0.58	0.47	0.35	NC	NC	NC
	Grazing period 4					
1985	4.68	3.74	2.80	0.22	0.18	0.13
1986	0.72	0.58	0.43	2.34	1.87	1.40
1987	1.04	0.83	0.62	4.68	3.74	2.81
	Overall					
1985	1.56	1.25	0.94	0.64	0.52	0.39
1986	9.35	7.48	5.61	3.12	2.49	1.87
1987	0.94	0.74	0.56	2.08	1.66	1.25

[1] Feed costs ($/kg) represent $250, $200, and $150/ton CSM.
[2] NC = cost of gain unestimable due to lack of gain response to supplement.

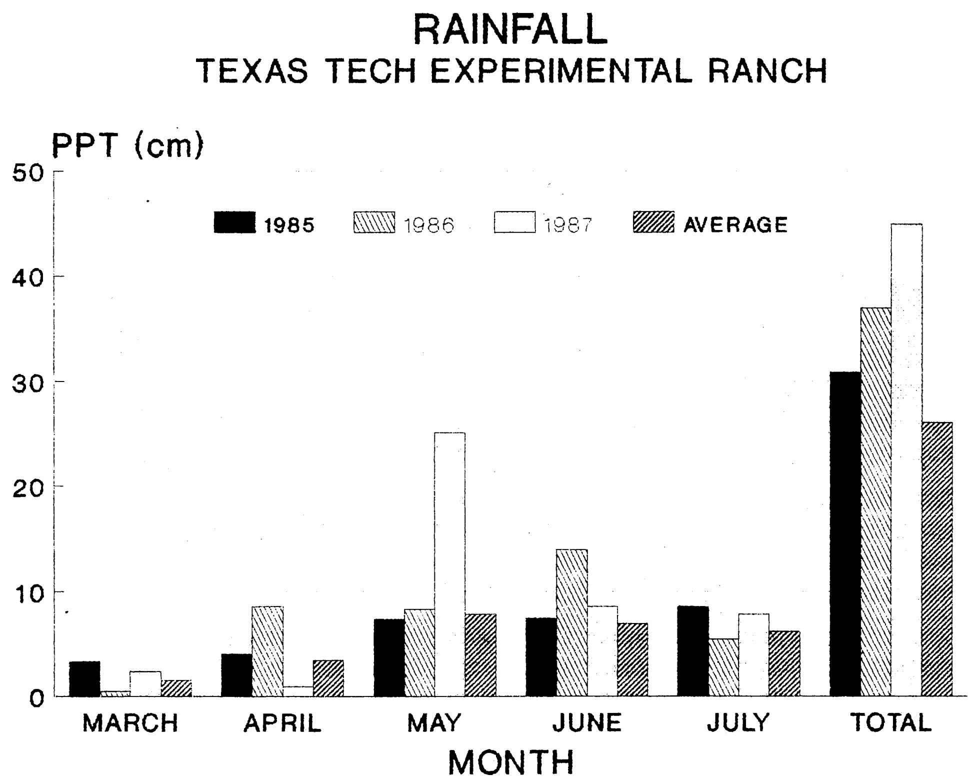

Figure 1. Rainfall (PPT) at the Texas Tech Experimental Ranch from March to July, 1985, 1986, and 1987. Average rainfall is taken from the Garza County Soil Survey (Richardson 1965).

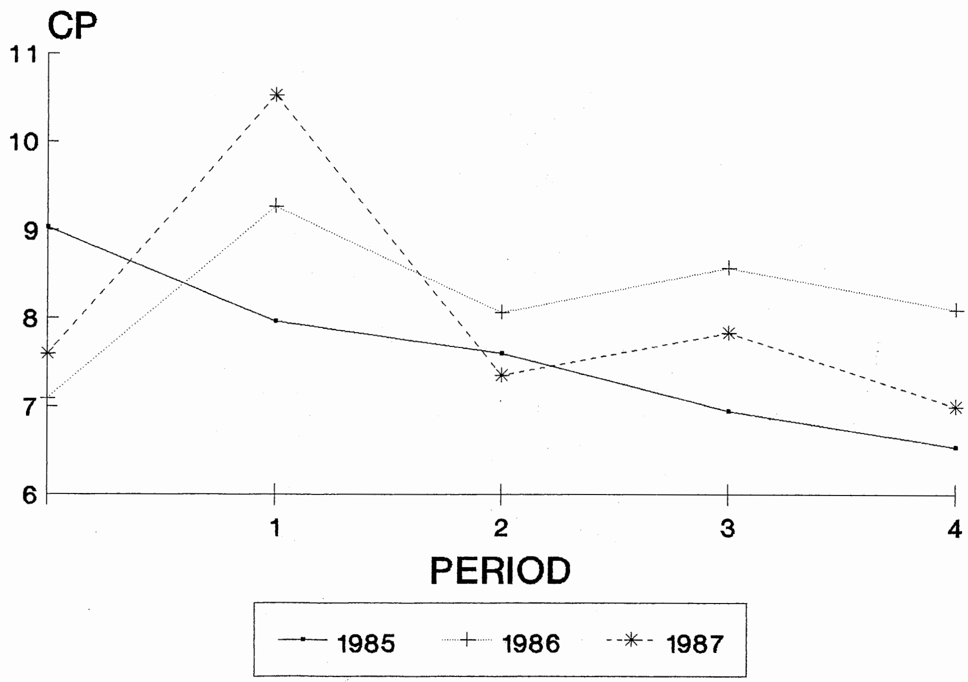

Figure 2. Crude protein (% of dry matter; CP) of clipped grasses at the Texas Tech Experimental Ranch at 21 day intervals beginning on May 14, 1985, April 28, 1986, and May 2, 1987.

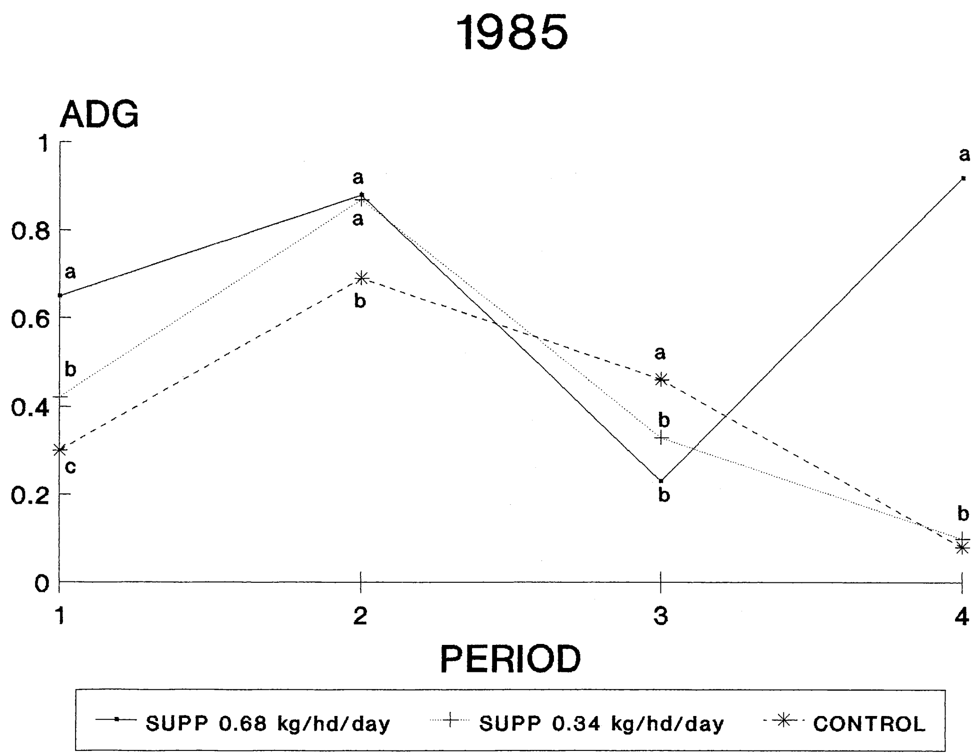

Figure 3. Average daily gain (kg) of steers fed 3 levels of cottonseed meal while grazing tobosagrass, period 1 (May 14), period 2 (June 6), period 3 (July 2), and period 4 (July 23), 1985. Letters denote differences among treatments within periods (P<0.05).

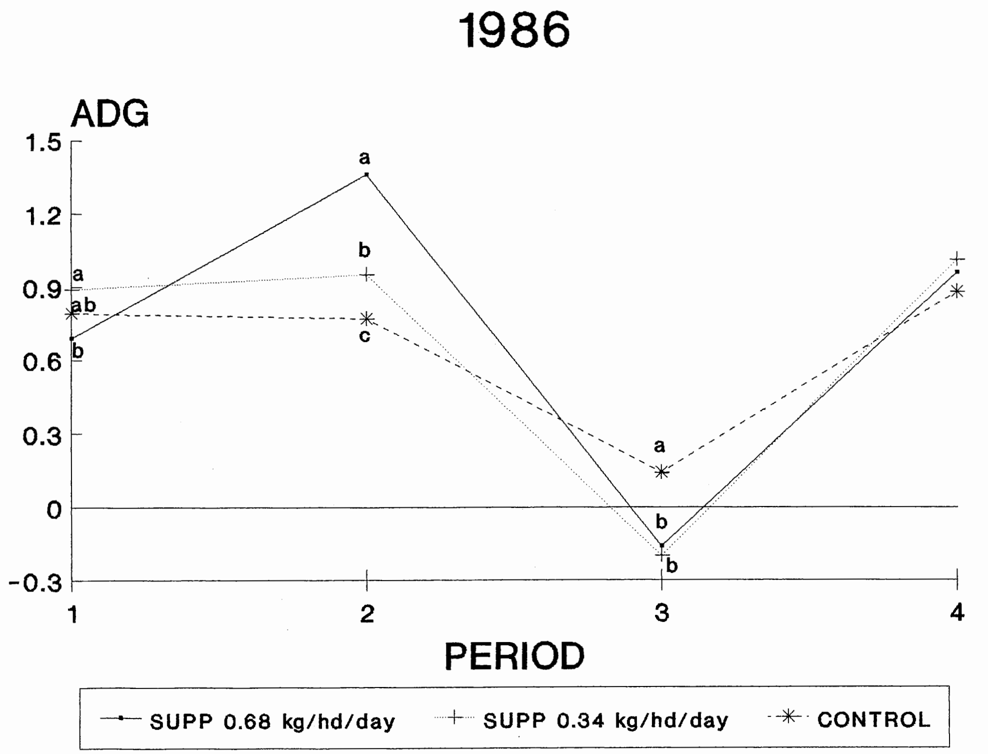

Figure 4. Average daily gain (kg) of steers fed 3 levels of cottonseed meal while grazing tobosagrass, period 1 (April 28), period 2 (May 19), period 3 (June 9), and period 4 (June 30), 1986. Letters denote differences among treatments within periods (P<0.05).

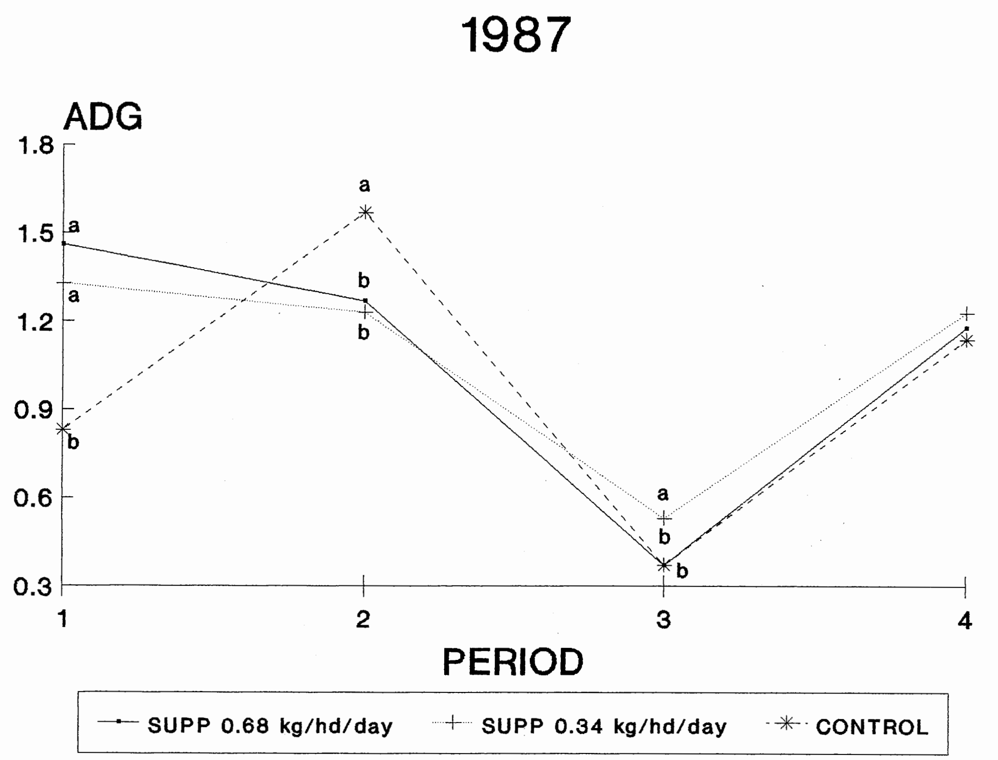

Figure 5. Average daily gain (kg) of steers fed 3 levels of cottonseed meal while grazing tobosagrass, period 1 (May 2), period 2 (May 23), period 3 (June 13), and period 4 (July 4), 1987. Letters denote differences among treatments within periods (P<0.05).

CHAPTER IV

RELATIONSHIPS AMONG PROTEIN SUPPLEMENTATION, BLOOD AND FECAL CONSTITUENTS, AND PERFORMANCE OF GRAZING STEERS

Abstract

Beef steers grazing tobosagrass (Hilaria mutica [Buckl.] Benth.) range in western Texas were allocated to 3 groups (10 head/group) and fed either 0.00, 0.34, or 0.68 kg/hd/day of cottonseed meal each year of a 2-year study. Steer weights and samples of blood and feces were collected at 21-day intervals beginning in April and ending in July to evaluate relationships among plane of nutrition, average daily gain (ADG), and selected blood and fecal components. Plasma was analyzed for urea nitrogen (BUN), glucose (GLU), non-esterified fatty acids (NEFA), thyroxine (T4), and triiodothyronine (T3). Feces were analyzed for kjeldahl-nitrogen (FN). The high rate of supplement (0.68 kg/day) increased FN and BUN above the control group ($P<0.05$). Responses to the low level were inconsistent. No consistent relationships were observed between supplement level and the other blood constituents. Fecal nitrogen, GLU, T3, and T4 generally declined through each season as forage quality

declined but did not closely reflect changes in daily gain of steers (r=0.09, 0.04, -0.05, -0.01, respectively). Environmental factors may have had a greater effect on daily gain than diet quality and therefore precluded the development of any useful relationships among ADG and blood and fecal components.

Introduction

Monitoring the nutritional status of free-grazing animals by present methods is expensive and time consuming for researchers and virtually impossible for producers. Estimates of fecal output and diet digestibility are required for estimating forage intake. If these methods can be replaced by more efficient means of arriving at nutritional status, both researchers and producers would benefit.

Different blood and fecal constituents have potential for use as indicators of nutrient intake and nutritional status of ruminants. Relationships between fecal nitrogen and dietary nitrogen have been observed in cattle (Hinnant 1979, Squires and Seibert 1983, Wofford et al. 1985), deer, and elk (Leslie and Starkey 1985).

Several blood constituents have been related to nitrogen and energy intake. Plasma urea nitrogen (BUN) has been positively correlated with dietary nitrogen in sheep

(Preston et al. 1965, Torell et al. 1974), deer (Seal et al. 1978), and cattle (Preston et al. 1978). Preston et al. (1965) observed a correlation between BUN and protein intake (r=0.99) in growing wethers fed diets containing 9.0 to 22.0% crude protein. Supplemental nitrogen level and BUN were correlated (r=0.99) in ewes fed alfalfa hay while grazing mature annual grass (Torell et al. 1974). Preston et al. (1978) reported BUN of 7-8 mg/100 ml may be the minimum level for growing feedlot steers.

Plasma non-esterified fatty acids (NEFA) are expected to increase as energy intake decreases and adipose tissue is mobilized (Bowden and Hironaka 1975). This relationship has been observed in white-tailed deer (Odocoileus virginianus) (Seal et al. 1978), heifers, and cows (Bos taurus) (Russel and Wright 1983 and Bowden 1971).

Bowden and Hironaka (1975) observed elevated levels of GLU as the body condition of non-pregnant, non-lactating Angus and Hereford beef cows improved. Combinations of glucose and growth hormone have been positively correlated with weight gain in cows (Hart et al. 1979).

In studies with white-tailed deer, triiodothyronine (T3) was stongly related to energy intake, increasing from 304 to 394 ng/dl when dietary energy was increased from a low to a moderate level (Seal et al. 1978). Baccari et al. (1983) developed correlations between weight gain and T3 in

Holstein heifers (r=0.91) indicating that T3 may reflect changes in weight gain in cattle.

The objectives of this study were to describe the relationships among plane of nutrition (level of supplementation) and blood and fecal constituents, and to determine if these blood and fecal constituents could be used to predict weight change in grazing steers.

Materials and Methods

Study Area

This study was conducted at the Texas Tech Experimental Ranch in Garza County, Texas. The area is dominated by a clay flat range site made up of gently sloping clay soils (fine, montmorillonitic, thermic Typic Chromusterts). Tobosagrass (Hilaria mutica [Buckl.] Benth.) is the dominant forage. Soil depressions contain alkali sacaton (Sporobolus airoides [Torr.] Torr.) and upland areas produce buffalograss (Buchloe dactyloides [Nutt.] Engelm.). Average yearly forage production, in excellent condition, is 1500 kg/ha (Richardson et al. 1965).

The climate is warm, temperate, and subtropical with dry winters. Average rainfall is 478 mm occurring mainly from May to October from convective thunderstorms. Drought is common. Average length of the growing season is 216 days. Mean elevation is 800 m (Richardson et al. 1965).

Field Trials

Three herds, grazing 6-pasture grazing cells, were fed 1 of 3 rates of protein supplement (0.00, 0.34, or 0.68 kg/hd/day of cottonseed meal). Prorated amounts were fed 3 times per week in community troughs. Cell areas were 68, 91, and 95 ha. Cells were stocked based on forage production so that forage allowance/hd/day was similar in all three cells (Pitts 1989a). Steers were rotated through the cells on 42-day cycles with length of stay in each pasture from 4-10 days.

Each cell was stocked in March of each year with 27 to 57 crossbred steers (*Bos taurus* x *Bos indicus*) weighing 200-250 kg. Background of steers is described by Pitts (1989a). Steers were allowed to adjust to the grazing system and the three-day feeding routine before trials began in April. In early to mid April, all steers were weighed after overnight fasting from food and water. This routine was repeated on 21 day intervals until July. In 1985, cattle were weighed on 23 April, 14 May (PER 1), 4 June (PER 2), 2 July (PER 3), and 23 July (PER 4). Steers were initially weighed on 7 April in 1986 and subsequently weighed on 28 April (PER 1), 19 May (PER 2), 9 June (PER 3), and 30 June (PER 4).

Prior to the start of each grazing season, 10 steers from each treatment group were randomly selected for blood and fecal sampling. Steers were selected from the middle weight class of the herd with a range of 23 kg. At 0700 h the evening before weighing, the 30 steers were sorted from the main herd to facilitate sampling and minimize excitement of the animals prior to sampling. Blood and fecal samples were taken and weights recorded between 0700 and 0800 hours the following morning. Two 10-ml blood samples were drawn from each steer via jugular puncture. Fecal samples were taken from each steer via rectal stimulation.

Blood samples were immediately placed in ice and refrigerated overnight to allow the samples to coagulate. The following morning, samples were centrifuged at 3000 rpm for 10 min and the serum was extracted and frozen. Fecal samples were frozen initially and later thawed and dried in a forced-air oven at 40° C. Fecal samples were ground through a 40-mesh screen in preparation for laboratory analysis.

<u>Laboratory Analyses</u>

Fecal samples were analyzed for nitrogen using standard Kjeldahl procedures (AOAC 1980). Dry matter and ash content of fecal samples were determined using procedures outlined by AOAC (1980). Fecal nitrogen (FN) was calculated on an organic matter basis.

Serum T3 and T4 were determined by radioimmunoassay.[1] Serum glucose concentration was analyzed colorimetrically using glucose oxidase.[2] Non-esterified fatty acids were determined by a colorimetric procedure.[3] Blood urea nitrogen was determined by a urease assay method (Chaney and Marbach 1962, Searle 1984).

Statistical Analysis

Data were originally analyzed with treatment (TRT) and period (PER) as main effects and year as a repeated measure. Model components were TRT, PER, TRT*PER, YEAR, YEAR*TRT, YEAR*PER, and YEAR*TRT*PER. The YEAR*TRT interaction was significant for most variables and data were subsequently analyzed within year. Treatment and PER main effects and the TRT*PER interaction were tested. Treatment within periods was analyzed if an interaction was present. Means were separated by least significant difference analysis.

Serum GLU data are not available for 1985. Data for GLU in 1986 are presented. In PER 2, 1985, 6 steers in the

[1] T3 analysis was conducted using Coat-A-Count Canine T3 Set TKC31 radioimmunoassay kits produced by Diagnostic Products Corporation, Los Angeles, CA. T4 analysis was conducted using Coat-A-Count Total T4 Set TKT41 radioimmunoassay kits produced by Diagnostic Products Corporation, Los Angeles, CA.

[2] Glucose was determined using Glucose Set 510, produced by Sigma Diagnostics, St. Louis, MO.

[3] NEFA analysis was conducted using NEFA C Set 990-75401, produced by Wako Pure Chemical Industries, Ltd. Osaka, Japan.

0.34 kg supplement group and 1 steer in the control group were not sampled or weighed. Weights for these steers were estimated based on their previous weights and weight change of their contemporaries in order to provide ADG values for PER 3.

Results and Discussion

Steer gains followed similar patterns in both years with marked declines in ADG during PER 3 (Fig. 1, Appendix tables 11-12). Supplemented steers generally had greater gains than the control (CON) group except at PER 3 when CON steers outgained high supplement (HS) and low supplement (LS) steers ($P<0.05$). Period 3 coincided with the greatest amount of precipitation. Precipitation may have reduced grazing time or possibly increased cold stress. Traveling to and from feeding grounds through clay mud may have increased energy expenditure. Average daily gain for 1985 and 1986 for all groups was 0.59 kg and 0.63 kg, respectively.

Fecal nitrogen decreased over the season in both years ($P<0.01$) coinciding with declining forage quality. Fecal N was highest during PER 1 (2.29% in 1985, and 2.21% in 1986) and lowest during PER 4 (1.27% in 1985 and 1.67% in 1986) (Fig. 2). The HS steers had greater FN than CON steers in each year ($P<0.05$), however, FN of the LS group was not consistent. Similar FN levels were observed for HS and LS groups in 1985, and LS and CON steers in 1986.

Values for fecal nitrogen fell within ranges presented in the literature for beef steers and heifers consuming forage diets (Squires and Siebert 1983, Hinnant 1979, Holecheck et al. 1982). However, the lowest FN values reported in this study (1.27%) were associated with gains of 0.39 kg/hd/day (PER 4; CON herd; Fig. 1, 2). Squires and Siebert (1983) reported 0.00 gain at 1.40% FN in grazing steers while Hinnant (1979) and Holecheck et al. (1982) observed FN values of 1.40-1.50% with dietary crude protein of 6.0%.

Gains of 0.75 to 1.30 kg/hd/day were associated with FN of 1.50 to 2.20% (Fig. 1, 2). Higher FN values were associated with the supplemented groups. Squires and Seibert (1983) also reported FN values of 2.20% in grazing steers with gains of 1.20 kg/hd/day.

In the current study, fecal nitrogen did not closely correspond to performance. During period 3 (Fig. 2), ADG was low and FN remained relatively high. Factors other than forage quality or supplement reduced gain and/or fill during this period. It is felt that FN followed a relationship with forage quality and diet quality even though gains were reduced. Evidently FN cannot be used as an indicator of performance irrespective of environmental conditions.

Relationships among treatments for BUN were similar to those for FN (Fig. 2). Steers in the HS group had higher ($P<0.01$) BUN than CON steers in both years. Serum BUN was similar for HS and LS groups in 1985 and similar for LS and CON steers in 1986. A lack of decline in BUN during PER 3, 1985 and actual increase in BUN during PER 3, 1986 in the HS and LS groups may have been the result of high ruminal ammonia absorption from supplemented protein during a period of decreased energy intake. Level of BUN in the CON steers generally declined through the season with the decline in forage quality.

Values for BUN were higher than reported in the literature (Preston et al. 1978, Richardson 1984). Preston et al. (1965) suggested that 10.0 mg/100 ml BUN indicated adequate protein intake in wether lambs while 7.0-8.0 mg/100 ml indicated adequate nitrogen intake in feedlot steers (Preston et al. 1978). The lowest BUN during this study was 12.9 to 11.1 mg/100 ml (CON group, 1985). These animals had positive weight gain throughout the trial indicating positive nitrogen balance. The range of BUN for the HS group in 1985 was 17.9 to 19.9 mg/100 ml and 17.2 to 18.1 mg/100 ml for the LS group. If BUN over 10 mg/100 ml in the CON group indicates adequate dietary nitrogen for growth, supplementing additional nitrogen should increase the protein to carbohydrate ratio thus increasing the absorption of ammonia from the rumen (Waldo 1968). This would explain relatively high values for BUN in the supplemented groups in 1985 and for all groups in 1986, a year of higher forage quality (Reeves 1987). A protein-carbohydrate imbalance possibly occurred in the supplemented groups during PER 3 of 1986. Both groups experienced weight loss during this period. The greatest values for BUN were reported during this period, 29.7 and 21.9 mg/100 ml for the HS and LS groups, respectively. It appears that BUN does reflect total nitrogen intake to some extent but may be more sensitive to the nitrogen-to-energy ratio.

Relationships between supplement level and NEFA were not consistent between years (Fig. 3). Serum NEFA tended to be greater in the HS group in 1985 compared to the other groups ($P=0.11$) but no difference ($P>0.20$) was observed between the HS and CON group in 1986. The HS and CON groups had greater NEFA than the LS group in 1986 ($P<0.01$). In both years NEFA increased ($P<0.05$) through the season as forage quality declined.

No relationship was observed between NEFA and ADG in any period of the study (Table 1). Values for NEFA remained between 0.44 and 0.98 mE/l during both years and did not follow any consistent pattern. The lack of relationship between NEFA, plane of nutrition, and growth may be partly due to excitation of the steers during collection which may cause temporary elevated levels of NEFA (Bowden 1971). Because steers were gaining weight throughout each year (with the exception of the supplemented groups in PER 3, 1986) NEFA concentration would be expected to remain low (Russel and Wright 1983, Bowden and Hironaka 1975). Weight loss by the supplemented groups in PER 3 of 1986 was not reflected by elevated NEFA levels. This suggests that weight loss was a function of reduced gut fill rather than actual mobilization of body tissue. Although NEFA concentration has shown some potential for determining nutritional status of lactating cows with high energy demand (Russel and Wright 1983, Bowden 1971), current results indicate that NEFA level has little use in prediction of ADG in growing steers. A similar conclusion was drawn by Warren et al. (1982) in growing fawns.

A seasonal decline in GLU occurred for all treatments ($P<0.01$; Fig. 3). Serum GLU was positively correlated with ADG in PER 1 and PER 4, and negatively correlated in PER 3 when ADG was negative (Table 1).

Differences in GLU did not occur among treatments (Fig. 3). This response differs from Richardson (1984) where GLU concentration was elevated by reducing the protein-to-energy ratio in the diet. The negative response to reduced gain in PER 3 would indicate that GLU may be related to diet quality rather than total dietary intake since gains and likely forage intake dropped during this period with only slight decline in forage quality and GLU. Richardson (1984) found elevated GLU with increased level of intake. In agreement with Richardson (1984), it does not appear that GLU is useful in determining nutritional status of grazing animals.

Serum T3 levels tended to be greatest for the HS group during most periods of 1985. In 1986, HS and LS steers had higher ($P<0.05$) T3 during most of the grazing season (Fig. 4). The HS and LS groups had greater ($P<0.01$) T4 levels than the CON steers in 1985, HS and CON steers tended to have greater T4 in 1986. Correlations of thyroid hormones to ADG were also inconsistent with positive correlations observed between T3 and ADG at PER 4, and negative correlation at PER 3 (Table 1). Serum T4 was inversely related to ADG at PER 4, and positively related at PER 3. Kahl et al. (1977) found relationships between increased rate of gain and increased T3 and T4 levels. In this study, serum T3 more closely reflected treatment and weight gain than T4. This opposes Kahl et al. (1977). Baccari et al. (1983) showed strong correlations ($r=0.91$) between T3 and weight gain in heifers which would more closely agree with the current study.

Inconsistencies in the relationships between blood and fecal constituents and ADG among periods were evident. Fecal nitrogen showed no relationship to gain in PER 1 when steers were gaining in excess of 0.5 kg/hd/day and positive effect in all other periods including period 3 when gain was low or negative. Blood urea nitrogen correlations were positive in all periods except PER 2. Serum T3 and T4 exibited a random relationship to ADG and NEFA was nonsignificantly related to ADG during all periods. Inconsistencies in the relationships among blood and fecal components and ADG indicate that other factors were involved that could not be associated with relationships among blood and fecal constituents.

Supplementation did not consistently affect any of the blood or fecal variables. Serum BUN and FN were greatest in HS steers throughout the study but concentrations of these constituents varied depending on year and period for LS and CON steers. No consistencies were observed for other blood variables. Forage crude protein remained above 6.5% throughout this study (Pitts 1989a) and steers were probably able to select diets adequate in crude protein. This would explain the lack of response in ADG and would probably account for the lack of significant effects of supplementation on the measured blood and fecal constituents.

Relationships between blood and fecal constituents and declining dietary quality were observed, however, no consistent relationship was evident among the blood and fecal parameters and animal gains. Predictive equations were developed by period but coefficients of determination were less than 0.48 and error of the predictions was over 0.22 (Appendix table 13). The lack of similarity in response among different periods may reflect environmental changes and forage quality changes as well as inherent changes resulting from maturation of the steers. Trends observed in this study between blood and fecal constituents and diet quality would warrant further investigation into this relationship.

Table 1. Correlation coefficients for weight gain and blood and fecal constituents of steers grazing tobosagrass at the Texas Tech Experimental Ranch, 1985 and 1986.

	Average daily gain			
	PER 1[1]	PER 2	PER 3	PER 4
FN[2]	-0.13	0.57*	-0.29*	0.50*
BUN[3]	0.32*	0.50*	-0.49*	0.50*
NEFA[4]	0.03	0.04	0.15	0.01
GLU[5]	0.25	0.21	-0.73*	0.43*
T3[6]	-0.05	0.07	-0.52*	0.38*
T4[7]	-0.03	0.20	0.41*	-0.43*

[1] PER = period, 21 day intervals beginning 23 April, 1985, and 7 April, 1986.
[2] FN = fecal nitrogen (organic matter basis).
[3] BUN = serum urea nitrogen.
[4] NEFA = serum non-esterified fatty acids.
[5] GLU = serum glucose.
[6] T3 = serum triiodothyronine.
[7] T4 = serum thyroxine.
* Significant ($P<0.05$).

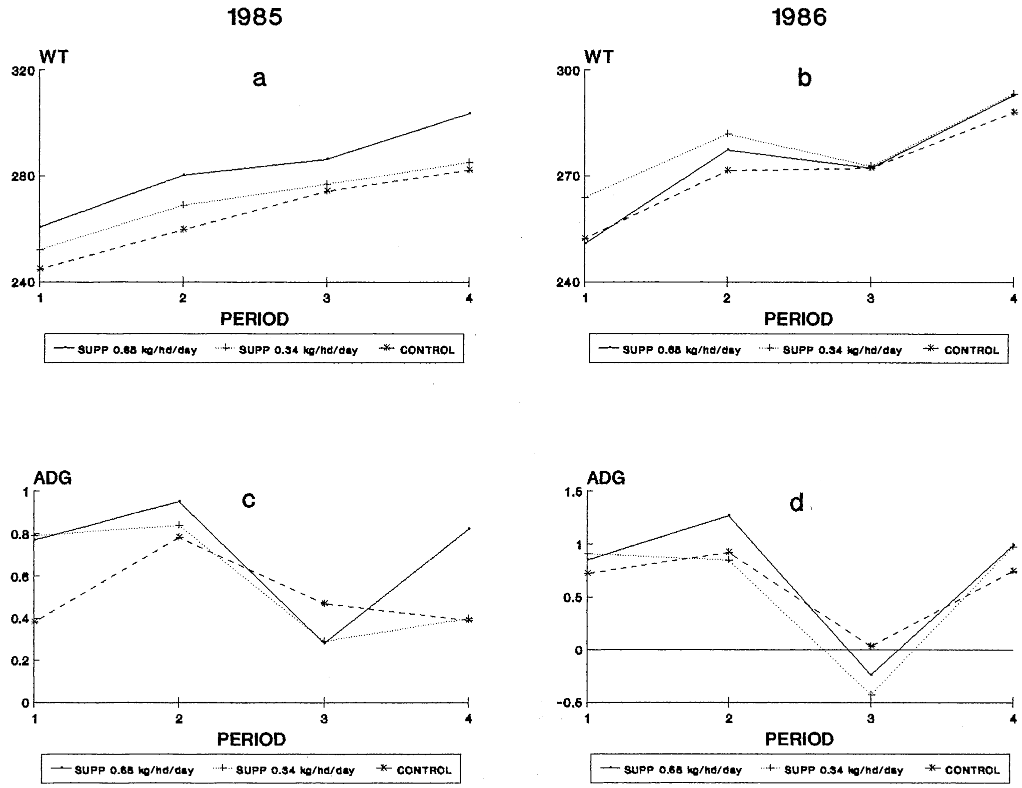

Figure 1. Weight (kg; WT) and daily gain (kg; ADG) of steers supplemented with 3 levels of cottonseed meal while grazing tobosagrass from April to July, 1985 and 1986 at the Texas Tech Experimental Ranch. (c). SUPP*PER (P<0.01); PER 1: CONTROL < 0.68, 0.34 (P<0.01); PER 4: 0.68 > 0.34, CONTROL (P<0.01); (d). SUPP*PER (P<0.01); PER 3: CONTROL > 0.68, 0.34 (P<0.05).

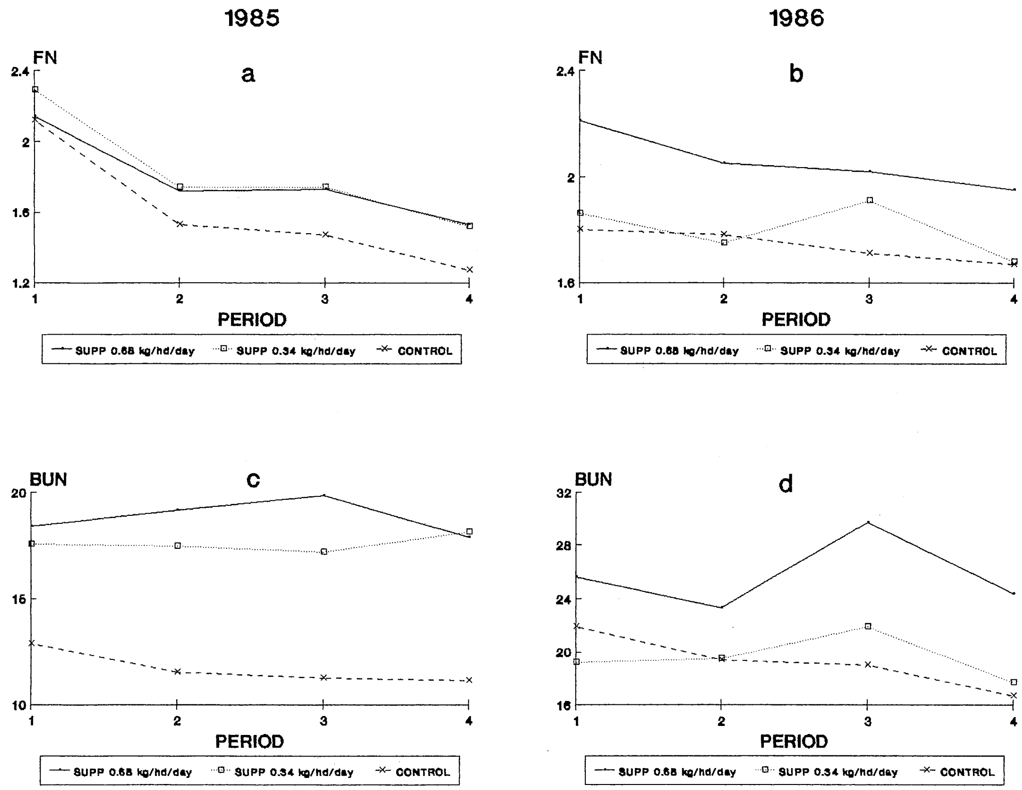

Figure 2. Fecal nitrogen (% of orgainic matter; FN) and plasma urea nitrogen (mg/100ml; BUN) of steers supplemented 3 levels of cottonseed meal while grazing tobosagrass from April to July, 1985 and 1986 at the Texas Tech Experimental Ranch. (a). SUPP ($P<0.05$); CONTROL < 0.68, 0.34 ($P<0.05$); PER ($P<0.01$); PER 1 > PER 2, PER 3, PER 4 ($P<0.01$); PER 4 < PER 2, PER 3 ($P<0.01$). (b). SUPP ($P<0.01$); 0.68 > 0.34, CONTROL ($P<0.01$); PER ($P<0.01$); PER 1 > PER 2, PER 4 ($P<0.05$); PER 3 > PER 4 ($P<0.05$). (c). SUPP ($P<0.01$); CONTROL < 0.68, 0.34 ($P<0.01$). (d). SUPP*PER ($P<0.01$); PER 1: 0.68 > 0.34, CONTROL; PER 2: 0.68 > 0.34, CONTROL ($P<0.01$); PER 3: 0.68 > 0.34, CONTROL ($P<0.01$); 0.34 > CONTROL ($P<0.05$); PER 4: 0.68 > 0.34, CONTROL ($P<0.01$).

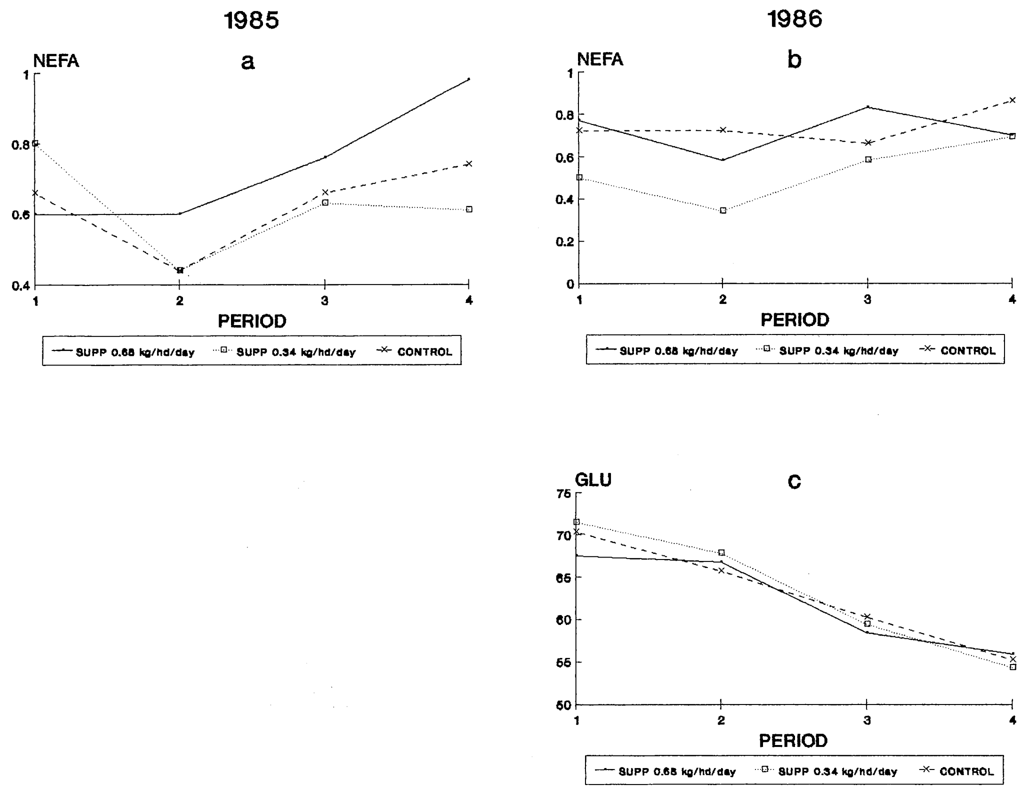

Figure 3. Plasma non-esterified fatty acids (mE/l; NEFA) and glucose (mg/dl; GLU) of steers supplemented 3 levels of cottonseed meal while grazing tobosagrass from April to July, 1985 and 1986 at the Texas Tech Experimental Ranch. (a). PER ($P<0.01$); PER 2 < PER 1, PER 3, PER 4 ($P<0.05$). (b). SUPP ($P<0.01$); 0.34 < 0.68, CONTROL ($P<0.01$); PER ($P<0.05$); PER 2 < PER 3, PER 4 ($P<0.05$). (c). PER ($P<0.01$); PER 1, PER 2 > PER 3, PER 4 ($P<0.01$).

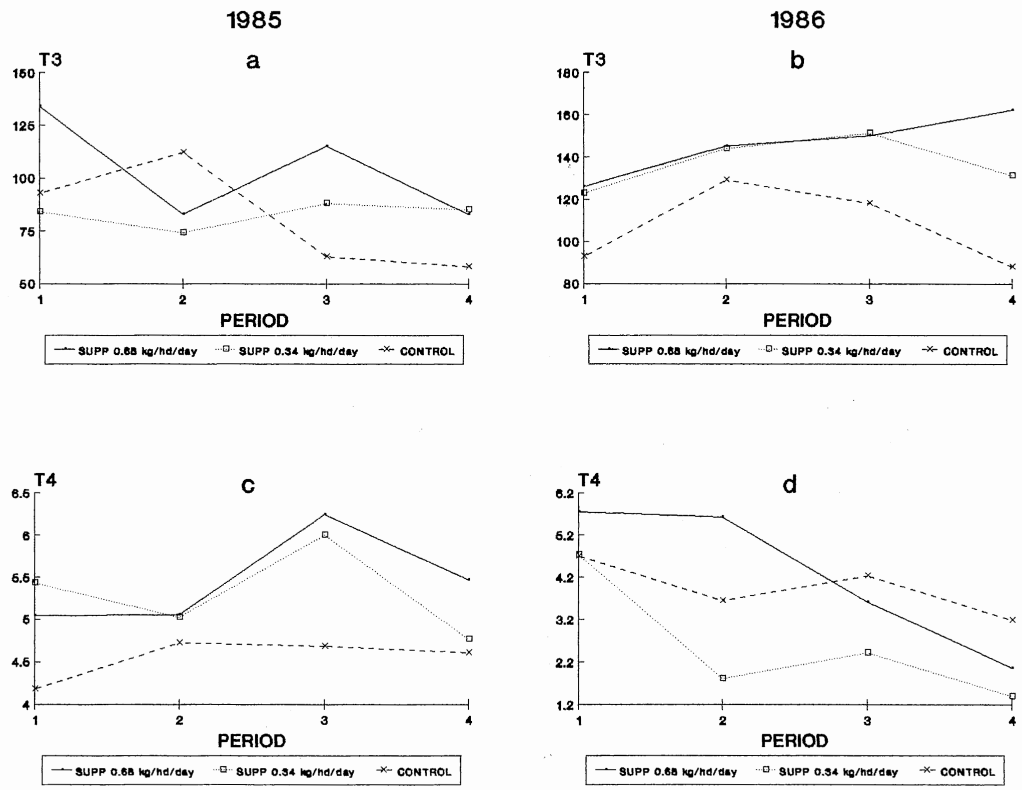

Figure 4. Plasma triiodothyronine (ng/dl; T3) and thyroxine (ug/dl; T4) of steers supplemented 3 levels of cottonseed meal while grazing tobosagrass from April to July, 1985 and 1986 at the Texas Tech Experimental Ranch. (a). SUPP*PER ($P<0.05$); PER 1: 0.68 > 0.34, CONTROL ($P<0.05$); PER 3: 0.68 > CONTROL ($P<0.01$). (b). SUPP*PER ($P<0.05$); PER 1: CONTROL < 0.68, 0.34 ($P<0.01$); PER 3: CONTROL < 0.68, 0.34 ($P<0.01$); PER 4: 0.68 > 0.34, CONTROL ($P<0.05$); 0.34 > CONTROL ($P<0.05$). (c). SUPP ($P<0.01$); CONTROL < 0.68, 0.34 ($P<0.01$); PER ($P<0.05$); PER 3 > PER 1, PER 2, PER 4 ($P<0.05$). (d). SUPP*PER ($P<0.01$); PER 1: 0.68 > 0.34, CONTROL ($P<0.05$); PER 2: 0.68 > 0.34, CONTROL ($P<0.01$); CONTROL > 0.34 ($P<0.01$); PER 3: 0.34 < 0.68, CONTROL ($P<0.01$); PER 4: CONTROL > 0.68, 0.34 ($P<0.05$).

CHAPTER V

RELATIONSHIPS AMONG NUTRIENT INTAKE AND BLOOD AND FECAL CONSTITUENTS IN GRAZING STEERS

Abstract

In 1986 and 1987, 12 beef steers (230 kg) were randomly allocated to 1 of 3 treatment groups. Each group was fed either 0.00, 0.34, or 0.68 kg/hd/day cottonseed meal from April to July. Cattle were maintained on a common 32 ha of native tobosagrass range. At the end of April, May, and June of each year, forage intake was estimated for each steer using Yb-marker based fecal output estimates and in vitro digestibility estimates. Diet samples were collected from esophageal cannulated steers during each trial (6 samples/trial). At the end of each trial, weights and blood samples were taken from each steer after overnight fasting. Blood serum was analyzed for urea nitrogen, glucose, non-esterfied fatty acids, triiodothyronine, and thyroxine. Feces were analyzed for nitrogen. Extrusa samples and supplement samples were analyzed for crude protein and in vitro digestibility. Total diet digestibility, percent total crude protein,

total dry matter intake (g/kg BW), total digestible dry matter intake (g/kg BW), and total crude protein intake (g/kg BW) were determined. Responses of blood and fecal metabolites to supplementation were inconsistent. Responses of energy intake parameters were also inconsistent. Crude protein intake was increased ($P<0.05$) with supplementation. Significant relationships among blood and fecal components and intake parameters were observed, however, useful models predicting nutritional status of steers could not be developed.

Introduction

Optimal performance from grazing livestock is primarily dependent on dietary quality and intake. In periods of low forage quality, grazing cattle may require supplementary protein or energy to maintain satisfactory gains. In times where profit margins are slight, deviations from an optimal feeding level may mean the difference in profit or loss. Overfeeding of supplements is costly and difficult to determine. Underfeeding of supplements, detectable by cattle condition and reduced performance, is often recognized too late. A rapid means of assessing nutrient intake at any point in time would be invaluable in refining feeding programs for grazing steers as forage condition changes through the year.

Relationships have been observed between dietary nitrogen and fecal nitrogen (FN) in beef steers (Hinnant 1979, Squires and Siebert 1983), deer, and elk (Leslie and Starkey 1985). Wofford et al. (1985) found FN values below 1.7% indicated a dietary nitrogen deficiency. Hinnant (1979) observed a range in FN of 1.2 to 1.9% depending on nitrogen intake with 6% dietary crude protein corresponding to 1.4% FN in growing steers.

Preston et al. (1965) reported that serum urea nitrogen (BUN) levels over 10.0 mg/100 ml in sheep fed high energy rations indicated adequate dietary nitrogen for rapid growth. Torell et al. (1974) reported correlations between BUN and supplemental nitrogen (r=0.99) in sheep.

Seal et al. (1978) observed increasing non-esterified fatty acid (NEFA) levels coincidental with decreasing energy intake in deer. A range of 242 to 667 uM/l was observed as feed digestible energy density declined from 3000 to 2700 kcal/kg. A depression in NEFA was observed by Rhind et al. (1984) when lambs were fed supplements increasing ME intake from 12.3 to 13.0 MJ/day.

Blood glucose levels (GLU) should be inversely related to NEFA levels (Rowlands 1980). Other studies have shown relationships between GLU and energy intakes below maintenance (Russel and Wright 1983) but responses of GLU to energy intake above maintenance are not well documented.

Baccari et al. (1983) reported correlations between triiodothyronine (T3) and weight gain in heifers (r=0.91). Relationships between growth rate and thyroid hormone levels were observed in weaned sheep (Rhind et al. 1984) with thyroxine (T4) yielding the stongest relationship.

The relationships described above suggest that predictive models could be developed that would be useful in estimating nutrient status of grazing steers at a specific point in time. The objectives of this study were to observe the effects of different levels of protein and energy intake on these blood and fecal components over time and develop predictive models to estimate nutrient intake.

Materials and Methods

This study was conducted at the Texas Tech Experimental Ranch in Garza County, Texas in 1986 and 1987. The study site consisted of 32 ha of native mesquite (*Prosopis glandulosa* var. *glandulosa* Torr.)/tobosagrass (*Hilaria mutica* [Buckl.] Benth.) range. Vegetation and climate of the area are described by Pitts (1989a).

In April of each year, 12 mixed breed steers (primarily *Bos taurus* crosses) were allocated to 1 of 3 feeding groups (0.00, 0.34, or 0.68 kg/hd/day of cottonseed meal (CSM)). In 1986, steers arrived on 6 March at 227 kg from native blue grama (*Bouteloua gracilis* [H.B.K.] Lag.)

range in eastern New Mexico. Average weight at the beginning of the trial (7 April) was 230 kg. In 1987, steers were wintered on tobosagrass range with supplemental CSM. These animals were moved to the study area on 13 March weighing 195 kg. At the time the trial began (14 April) these cattle weighed 223 kg.

Steers were fed alfalfa hay in addition to native range from the time they arrived on the study area until they had been trained to feed in individual stalls (approx. 1 week). Feeding was then changed to 200 g of cottonseed hull, milo, and molasses mix 3 days per week (30% DDM and 8.6% CP in 1986; 37% DDM and 8.6% CP in 1987). Steers received this mix throughout the trial. Cottonseed meal cubes (44.8% CP) were fed on the same day at rates of 0.00, 0.34, or 0.68 kg/hd/day. All feed was offered in individual stalls at 1100 hours; there were no refusals.

Five days before the end of April (PER 1), May (PER 2), and June (PER 3) of each year, 100 g of Yb-labeled cottonseed hulls (Teeter et al. 1984) were fed daily for 7 days in the cottonseed hull-milo-molasses mix. On day 6 and 7, fecal samples were collected from each steer as follows: Day 6- 1100 h and 1500 h; Day 7- 0300 h, 0700 h, 1900 h, and 2300 h. This schedule resulted in a sample every 4 h of a 24-h period. Feces were composited for each steer and frozen.

After the 2300 h sampling on day 7, steers were penned off feed and water until the following morning. At 0700 hours on day 8, the cattle were individually weighed and two 10 ml blood samples were collected via jugular puncture. Blood samples were refrigerated and allowed to coagulate. After coagulating, the samples were centrifuged at 3000 rpm for 10 min and the serum was extracted and frozen.

On days 5 and 6 during trials in 1986, forage diet samples were obtained from 3 esophageally cannulated steers (6 samples total). These steers were fasted overnight prior to sample collection. The steers were allowed to graze 30 min during each collection period. Two cannulated steers were used in 1987 and collection was extended 1 day to obtain 6 diet samples. Diet samples were individually bagged and frozen. In both years, the cannulated steers were kept in an adjoining pasture of similar vegetation type.

Fecal samples were dried in a forced-air oven at 40 C and analyzed for DM, ash, and Kjeldahl nitrogen (AOAC 1980). Feces were analyzed for Yb concentration by atomic absorption spectrometry after extraction with ethylenediaminetetraacetic acid (Hart and Polan 1984). Serum samples were analyzed for BUN, GLU, NEFA, T3, and T4. Analyses were described by Pitts (1989b).

Esophageal masticate samples were dried in a forced-air oven at 40° C and analyzed for DM, ash, Kjeldahl nitrogen (AOAC 1980), and in vitro dry matter digestibility (Tilley and Terry 1963). Cottonseed meal and the cottonseed hull mix were analyzed for DM, ash, Kjeldahl nitrogen, acid detergent lignin, and in vitro dry matter digestibility. Composition of feed and masticate samples are shown in Tables 1 and 2.

Forage dry matter intake, total dry matter intake (TDMI), and total diet dry matter digestibility (DMD), were determined using equations presented by Kartchner (1981). In vitro dry matter digestibility of forage samples replaced lignin ratio digestibility in the equations.

Blood samples from PER 3 in 1987 were damaged and GLU and T4 analysis from this period are not presented. Data were analyzed initially with treatment (TRT) and period (PER) as main effects and year as a repeated measure. Model components were TRT, PER, TRT*PER, YEAR, YEAR*TRT, YEAR*PER, and YEAR*TRT*PER. A YEAR*PER interaction was observed and data were subsequently analyzed within year. Treatment, PER, and TRT*PER were tested.

Results and Discussion

Diet digestibility increased with level of supplementation (Fig. 1, Appendix tables 14-19). Differences resulted from the addition of supplement of higher digestibility than the forage on offer (Table 1, 2). Digestibility of CSM was 72% compared to forage digestibilities of 36 to 60%. Seasonal decline ($P<0.01$) in DMD in 1986 of 53 to 40% was observed for the high supplement (0.68 kg/hd/day CSM; HS) group with similar decline for the other 2 groups (Fig. 1). Greater values for DMD were observed in 1987. Diet digestibility for the HS steers was 61% in PER 1 and decreased to 55% by PER 2 ($P<0.05$) (Fig. 1). No further decline in DMD was observed.

Total dietary CP also reflected level of supplementation (Fig. 1). Average CP for all treatments in 1986 declined from 15.4% to 13.6% between PER 1 and PER 3 ($P<0.05$). A seasonal decline in CP was also observed in 1987 ($P<0.05$). Average CP fell from 14.8 to 12.5 from PER 1 to PER 3.

Supplementation significantly ($P>0.05$) affected TDMI in both years of the study (Fig. 2). However, the effect was not consistent for both years. Steers in the low supplement (0.34 kg/hd/day CSM; LS) group had greater TDMI through 1986 and steers in the HS group had greater TDMI in PER 1 and PER 3 of 1987. Values for TDMI in 1986, averaged across treatments, declined from 18.5 to 12.8 g/kg BW from PER 1 to PER 3 (P<0.01) (Fig. 2). A similar response was observed in 1987. Intake declined from 19.4 g/kg BW in PER 1 to 13.5 g/kg BW in PER 3 (P<0.01). Reeves (1987) reported forage intake by steers grazing tobosagrass declining from 15.0 to 13.0 g/kg BW over the same period. Heavy rain during PER 2 and PER 3 of 1987 may have actually depressed intake. Fecal output of steers during 1986 and PER 1 of 1987 fell within the range 0.8 to 0.9% of BW. Fecal output at PER 2 and PER 3, 1987 was 0.7% and 0.6% of BW, respectively.

Total digestible dry matter intake followed the same pattern of TDMI (Fig. 2). Effect of supplementation was not consistent in 1986 and 1987. Steers receiving LS had greater TDDMI than those in the HS or control (CON) group in 1986 (P<0.05) and steers in the HS group in 1987 had greater TDDMI than LS or CON steers (P<0.05). A reason for this inconsistency was not apparent. Raymond (1969) indicated forage digestibility may not be enhanced by protein supplements when diet CP levels are above 6.0-8.0% CP. Dietary forage CP remained above 10.5% throughout 1986 and in vitro dry matter digestibility of forage declined to 36%. If digestibility was increased through supplementation, lower TDDMI intakes in the HS group are a result of computation with estimated digestibility below actual values.

Crude protein intake in 1986 was similar for the HS and LS steers as a result of high TDMI for the LS group (Fig. 3). Average CPI for these 2 groups decreased from 3 g/kg BW in PER 1 to 1.93 g/kg BW in PER 3. According to NRC (1984) requirements, this level of CPI, in the presence of adequate energy intake, should have produced gains of 1.0 kg/hd/day in PER 1 and 0.4 kg/hd/day in PER 3. Actual gains were 0.94 kg and 1.1 kg, respectively, for the 2 periods. Gains were greater in PER 3 than can be attributed to protein intake. Some compensatory growth may have occurred during this period after poor gains in PER 2, or gains in PER 3 may be inflated because of reduced fill when steers were weighed at PER 2. Control steers had lower ($P<0.01$) CPI ranging from 2.53 to 1.32 g/kg BW for PER 1 and PER 3, respectively. Differences ($P<0.01$) in CPI occurred for all treatments in 1987 with greatest levels for the HS group followed by LS and finally CON. A decline in CPI was observed from PER 1 to PER 3 ($P<0.01$; Fig. 3). Average CPI for PER 1 and PER 2 was 2.81 and 1.82 g/kg BW. Corresponding gains for those periods were 1.69 and 0.71 kg/hd/day, respectively. Early gains in 1987 were higher than would be expected according to NRC (1984) requirements. Compensatory growth by these steers after wintering on native range could account for these abnormally high gains.

The CPI/TDDMI ratio increased ($P<0.05$) from PER 1 to PER 3 in 1986 (Fig. 3). Supplementation at either level increased this ratio ($P<0.01$). The HS treatment had the greatest ratio ($P<0.05$) which increased from 34% to 42% from PER 1 TO PER 3. Increased ratios are primarily a function of decreasing TDDMI levels through the season. Crude protein intake decreased through this period but TDDMI decreased more rapidly (Fig. 2, 3). A slight downward trend was observed for CPI/TDDMI in 1987 ($P<0.05$). Supplementation positively affected the ratio ($P<0.01$) (Fig. 3). Lower ratio values in 1987 compared to 1986 are largely a function of greater TDDMI in 1987, CPI values for the 2 years were similar. A positive relationship was observed between CPI/TDDMI and BUN. Increases in BUN would be expected as CPI increases relative to TDDMI (Richardson 1984).

Daily gain did not differ ($P<0.05$) between treatments in either year of the study (Fig. 4). In 1986, ADG declined ($P<0.01$) from 1.00 kg/hd/day in PER 1 to 0.15 kg/hd/day in PER 2. Gains increased ($P<0.01$) in PER 3 (1.14 kg/hd/day) to a level similar to PER 1 (Fig. 4). The decrease in ADG corresponded to a depression in TDDMI and CPI and the increase in ADG in PER 3 corresponded to a decrease in the rate of decline in both TDDMI and CPI (Fig.

2, 3). Daily gain in 1987 declined ($P<0.01$) throughout the study period (Fig. 4). Average gain for all treatments was 1.69 kg/hd/day in PER 1 and 0.71 kg/hd/day in PER 3. Changes in ADG generally reflect the decline in TDDMI and CPI in 1987.

Fecal nitrogen was correlated with ADG, TDDMI, and CPI (Table 4). Other studies have noted positive relationships between FN and ADG ($r=0.82$) (Squires and Siebert 1983), organic matter intake ($r=0.66$), and diet CP ($r=0.91$) (Holechek et al. 1982). Although treatments were not significantly different ($P>0.05$), the HS steers tended to have greater FN values than LS or CON groups. Average FN for all treatments in 1986 was 2.36% at PER 1, declined ($P<0.01$) to 1.89% at PER 2, and increased to 2.15% at PER 3 following the same general trend as ADG. Squires and Siebert (1983) reported 0.00 weight gain with FN of 1.4% which is lower than in the current study. Gains approached 0.00 during PER 2, 1986 when FN was greater than 1.8%. Low DMD may have been responsible for elevated FN in this study. Higher FN values in 1987 corresponded to better gains and higher CP levels. Fecal nitrogen declined ($P<0.01$) from a high in PER 1 of 2.91% to 1.76% by PER 3 (Fig. 5).

Serum urea nitrogen was not significantly affected by supplement ($P>0.05$) in 1986 (Fig. 5). No consistent trend was evident. In the HS group, BUN levels increased from 19.0 mg/100 ml in PER 1 to 21.6 in PER 2 and declined to 21.4 by PER 3 (P>0.05). In the LS and CON groups, BUN declined throughout the season. Level of BUN in the LS group declined from 19.8 mg/100 ml at PER 1 to 18.4 in PER 3. Steers in the CON group followed the same trend with values of 22.0 and 20.4 mg%, respectively. In 1987, BUN was higher in HS and LS steers than CON steers (P<0.01). It is not known why this relationship varied between years. Ratios of CPI/TDDMI were lower in 1987 compared to 1986 (Fig. 3) and may explain the reduced BUN levels (Richardson 1984). Serum urea nitrogen would be expected to increase as CPI increases (Preston 1965), but BUN would fall as energy intake increased relative to CPI (Waldo 1968, Richardson 1984). Negative relationships were observed between BUN and DMD and TDDMI possibly as a result of increasing CPI/TDDMI ratio.

Serum NEFA was not affected by treatment either year. Serum NEFA followed the same trend as GLU in 1986, increasing from PER 1 to PER 2 then declining in PER 4 (Fig. 6). An inverse relationship was found between NEFA and FN (Table 3). Concentration of NEFA in 1987 was very low, possibly reflecting greater TDDMI and compensatory growth of these steers.

Serum GLU levels did not differ among treatments in either year (P>0.05). In 1986, average GLU increased from 64.8 mg/dl in PER 1 to 68.8 mg/dl in PER 2 and then declined sharply (P<0.01) to 52.6 mg/dl in PER 3 (Fig. 6). Glucose exibited a positive relationship to TDMI, TDDMI, and CPI. In deer fawns (Odocoileus virginianus), serum GLU was lower with high-protein, moderate-energy diets and low-protein, low-energy diets. Blood GLU increased with high-protein, low-energy diets and low-protein, moderate-energy diets (Seal et al. 1978). Richardson (1984) reported a similar pattern in growing steers (Bos taurus and Bos indicus) consuming diets comprised of veld hay, maize-meal and CSM. Serum GLU in 1987 (Fig. 6) was in excess of 70 mg/dl while serum GLU never surpassed 70 mg/dl in 1986. Average GLU for all treatments at PER 1 was 83.0 mg/dl and declined to 74.4 mg/dl by PER 2 (P<0.05). Although not significant (P>0.10), GLU remained constant across the summer in the HS steers and declined for the other two groups (Fig. 6).

Serum T3 was higher (P<0.01) in the 2 supplemented herds in 1986 (Fig. 7). Serum T3 declined (P<0.05) in all treatments as the trial progressed. Serum T3 was positively correlated with TDMI, TDDMI, and CPI (Table 4). Positive relationships between energy intake and T3 have been observed in deer fawns (Seal et al. 1978). Level of T3 did not differ (P>0.05) among treatments in 1987.

Average T3 for all supplement groups declined from 108.4 to 73.1 ng/dl from PER 1 to PER 3.

Supplementation did not affect serum T4 in either year (Fig. 7). A positive correlation between T3 and T4 occurred in 1986. No decrease in T4 was observed ($P>0.05$) in 1987 when T3 declined ($P<0.01$) during the first 2 periods. Previous work with calves found that the ratio of T4:T3 increased as growth rate increased (Kahl et al. 1977). Rhind et al. (1984) observed a positive relationship between T4 and energy intake of lambs on pasture. Serum T3 was negatively influenced by energy supplement.

The expected separation in performance and dietary parameters among supplementation groups was not observed. Diet CP remained above 9.8% through trials in both years. Precipitation was above average during both years and CP did not reach low levels reported in the literature (Britton and Steuter 1983). Rittenhouse et al. (1970) indicated that positive effects of protein supplementation on digestion and intake may not be observed when diet CP is above 6.0-8.0%. Egan (1977) suggested that intake would not be improved through protein supplementation if the protein to energy ratio (g protein / MJ digestible energy) was greater than 7.5. Other studies have indicated that intake and gain response may not occur when diet CP / DMD ratios are greater than 0.13 (Lusby and Horn 1983, McCollum and Galyean 1985, Smith and Warren 1986). In 1986, this ratio increased from 0.25 to 0.30 and no response to the HS level was observed. This ratio was lower in 1987 (0.19-0.22) and a small intake response was observed.

Closer relationships between intake variables and these blood and fecal constituents have been observed in pen studies. General trends among TDDMI and CPI and FN, GLU, BUN, T3, and T4 are similar to those reported in the literature (Seal et al. 1978, Rhind et al. 1984, Richardson 1984). Significant relationships were observed among the intake parameters and blood and fecal components. However, lack of separation among treatment groups in performance and intake parameters led to inconsistencies in response of blood and fecal constituents to supplementation. Models were developed to predict DMD (r^2=0.91), CP (r^2=0.38), TDMI (r^2=0.43), TDDMI (r^2=0.68), CPI (r^2=0.64), and CPI/TDDMI (r^2=0.54) (Appendix tables 20-26). However, the error associated with predictions was great and the usefulness of the models is questioned.

Performance of steers in this study was not improved through supplementation indicating CP was not limiting. During years of normal precipitation or during late summer or winter months, forage CP may be deficient (Britton and Steuter 1983, Kiesling et al. 1969). Protein supplementation at that time may illicit a positive response and relationships among intake parameters and blood and fecal components may improve. Refinement of techniques for estimation of actual intakes and inclusion of variables related to environmental conditions may also enhance relationships among these variables.

Table 1. Composition of supplements (dry matter basis) fed to steers grazing tobosagrass at the Texas Tech Experimental Ranch from April to July, 1986 and 1987.

Supplement	CP	DMD	ADL[1]
		%	
Cottonseed meal	44.8	71.6	5.4
Cottonseed hull mix	13.3	50.6	10.1
Cottonseed hulls	3.9	16.1	19.4

[1]CP = crude protein, DMD = dry matter digestibility, ADL = acid detergent lignin.

Table 2. Crude protein (% of dry matter) and digestible dry matter (%) of esophageal masticate samples collected from steers grazing tobosagrass at the Texas Tech Experimental Ranch from April to July, 1986 and 1987.

	1986		1987	
Period[1]	CP	DMD	CP	DMD
1	13.2	52.08	12.9	59.85
2	11.9	44.28	9.8	51.57
3	10.5	35.52	10.0	52.36

[1] Period 1 ended 1 May, period 2 ended 1 June, period 3 ended 1 July.

Table 3. Correlation matrix of blood and fecal constituents of steers grazing tobosagrass at the Texas Tech Experimental Ranch from April to July, 1986 and 1987.

	FN[1]	GLU[2]	NEFA[3]	BUN[4]	T3[5]
1986					
GLU	-0.22				
NEFA	-0.39*	0.27			
BUN	0.39*	0.10	-0.20		
T3	0.26	0.11	0.04	-0.22	
T4[6]	-0.19	0.10	0.64*	-0.38*	0.33*
1987					
GLU	0.49*				
NEFA	-0.01	0.16			
BUN	-0.33	-0.53*	-0.26		
T3	0.43*	0.30	0.02	-0.34	
T4	-0.37	0.10	0.08	0.10	-0.01

[1] FN = fecal nitrogen (organic matter basis).
[2] GLU = serum glucose.
[3] NEFA = serum non-esterified fatty acids.
[4] BUN = serum urea nitrogen.
[5] T3 = serum triiodothyronine.
[6] T4 = serum thyroxine.
* Significant ($P<0.05$).

Table 4. Correlation matrix of nutritional parameters and blood and fecal components of steers grazing tobosagrass at the Texas Tech Experimental Ranch from April to July, 1986 and 1987.

	Blood and feces					
Diet	FN[1]	BUN[2]	GLU[3]	NEFA[4]	T3[5]	T4[6]
CP[7]	0.35*	0.30*	0.18	0.24*	0.45*	0.07
DMD[8]	0.45*	-0.63*	0.20	-0.49*	0.06	0.45*
TDMI[9]	0.49*	-0.19	0.36*	-0.13	0.41*	-0.04
TDDMI[10]	0.56*	-0.41*	0.34*	-0.32*	0.31*	0.15
CPI[11]	0.55*	0.02	0.35*	0.03	0.54*	-0.06
CPI/TDDMI	0.01	0.67*	0.02	0.52*	0.35*	0.38*

[1] FN = fecal nitrogen (organic matter basis).
[2] BUN = serum urea nitrogen.
[3] GLU = serum glucose.
[4] NEFA = serum non-esterified fatty acids.
[5] T3 = serum triiodothyronine.
[6] T4 = serum thyroxine.
[7] CP = percent crude protein in total diet (dry matter basis).
[8] DMD = dry matter digestibility.
[9] TDMI = total dry matter intake.
[10] TDDMI = total digestible dry matter intake.
[11] CPI = crude protein intake.
* Significant ($P<0.05$).

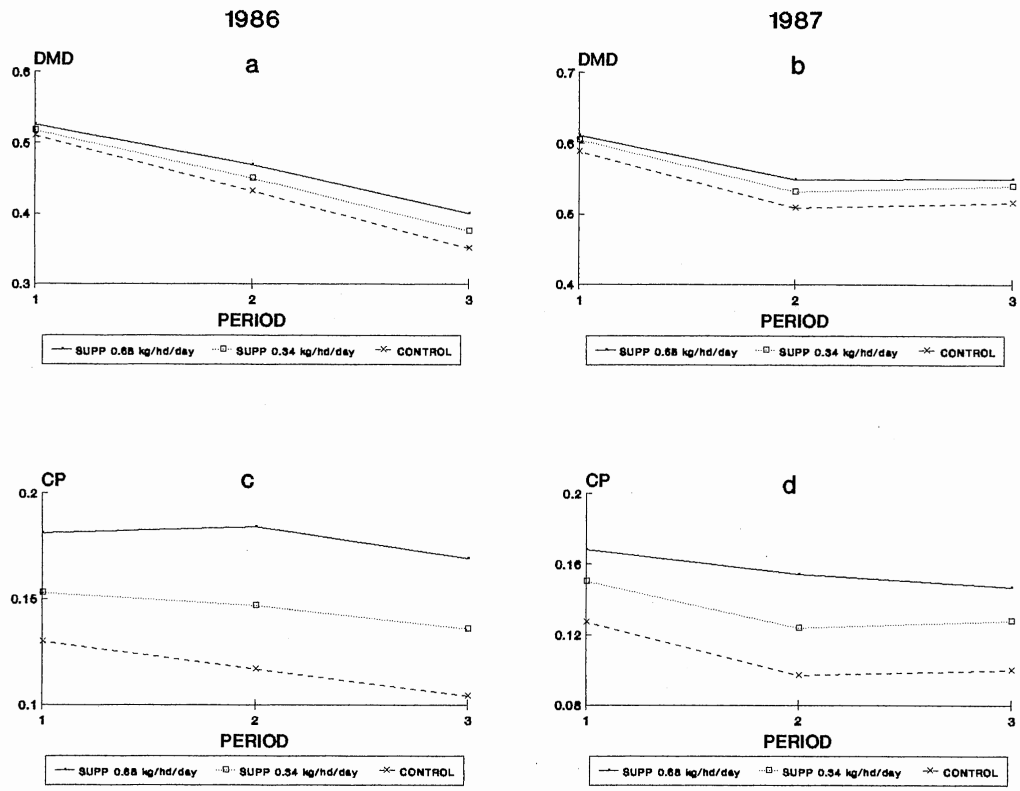

Figure 1. Total diet dry matter digestibility (g/g DM; DMD) and crude protein (g/g DM; CP) of the diets of steers supplemented 3 levels of cottonseed meal while grazing tobosagrass from April to July, 1986 and 1987 at the Texas Tech Experimental Ranch. (a). SUPP*PER (P<0.01); All periods: 0.68 > 0.34 > CONTROL (P<0.01). (b). SUPP*PER (P<0.01); All periods: 0.68 > 0.34 > CONTROL (P<0.01). (c). SUPP*PER (P<0.01); All periods: 0.68 > 0.34 > CONTROL (P<0.01). (d). SUPP*PER (P<0.01); All periods: 0.68 > 0.34 > CONTROL (P<0.01).

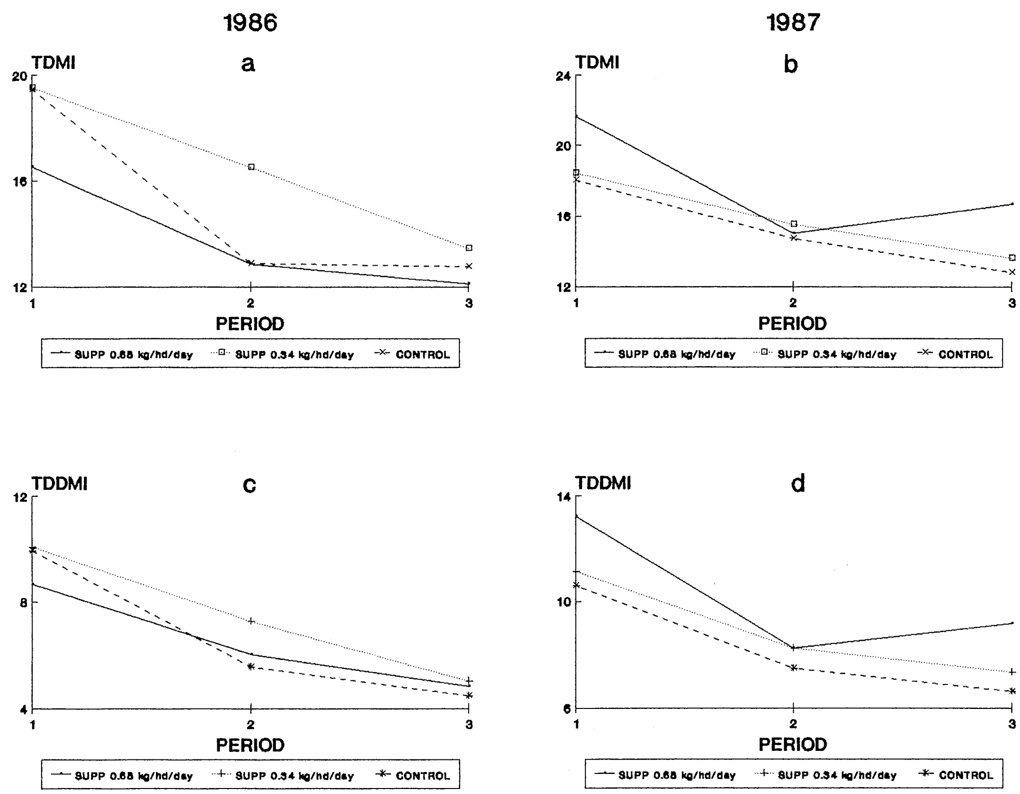

Figure 2. Total dry matter intake (g/kg BW; TDMI) and total digestible dry matter intake (g/kg BW; TDDMI) by steers supplemented 3 levels of cottonseed meal while grazing tobosagrass from April to July, 1986 and 1987 at the Texas Tech Experimental Ranch. (a). SUPP ($P<0.05$); 0.34 > 0.68 ($P<0.01$); PER ($P<0.01$); PER 1 > PER 2, PER 3 ($P<0.01$). (b). SUPP ($P<0.01$); 0.68 > 0.34, CONTROL ($P<0.01$); PER ($P<0.01$); PER 1 > PER 2, PER 3 ($P<0.01$). (c). SUPP ($P<0.05$); CONTROL < 0.68, 0.34 ($P<0.05$); PER ($P<0.01$); PER 1 > PER 2 > PER 3 ($P<0.01$). (d). SUPP ($P<0.01$); 0.68 > 0.34, CONTROL ($P<0.01$); PER ($P<0.01$); PER 1 > PER 2, PER 3 ($P<0.01$).

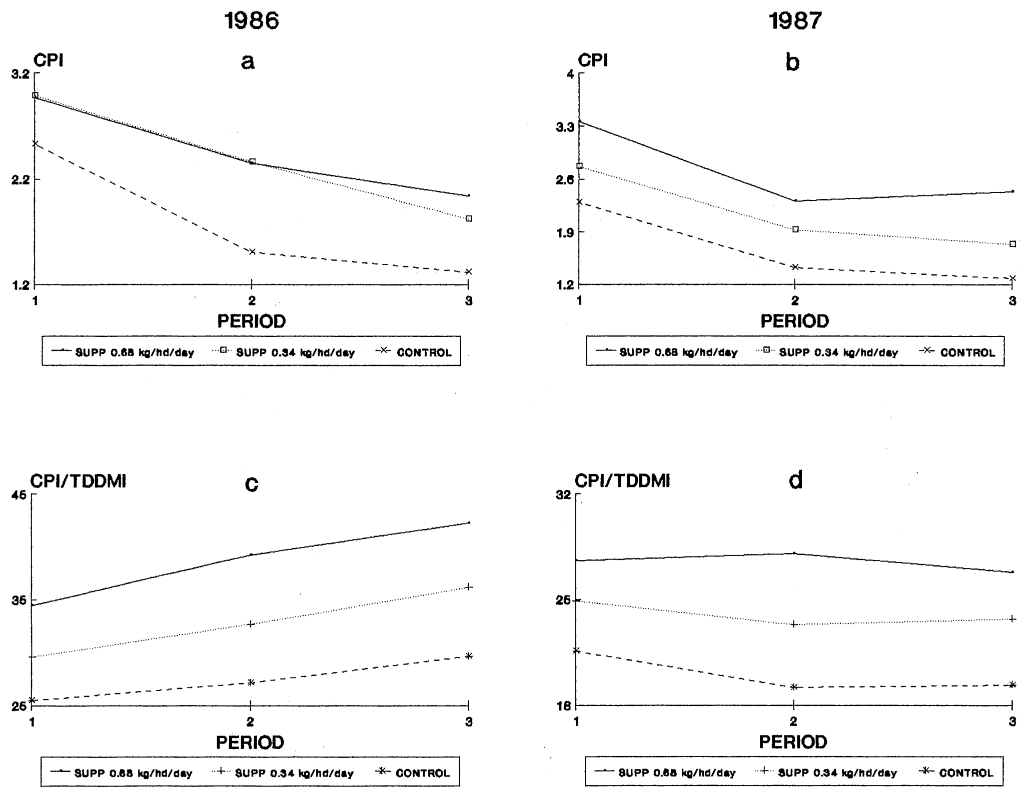

Figure 3. Crude protein intake (g/kg BW; CPI) and the ratio of crude protein intake to total digestible dry matter intake (CPI/TDDMI) by steers supplemented 3 levels of cottonseed meal while grazing tobosagrass from April to July, 1986 and 1987 at the Texas Tech Experimental Ranch. (a). SUPP (P<0.01); 0.68 > 0.34 > CONTROL (P<0.05); PER (P<0.01); PER 1 > PER 2, PER 3 (P<0.01). (b). SUPP (P<0.01); 0.68 > 0.34 > CONTROL (P<0.01); PER (P<0.01); PER 1 > PER 2, PER 3 (P<0.01). (c). SUPP*PER (P<0.01); All periods: 0.68 > 0.34 > CONTROL (P<0.01); (d). SUPP*PER (P<0.01); All periods: 0.68 > 0.34 > CONTROL (P<0.01).

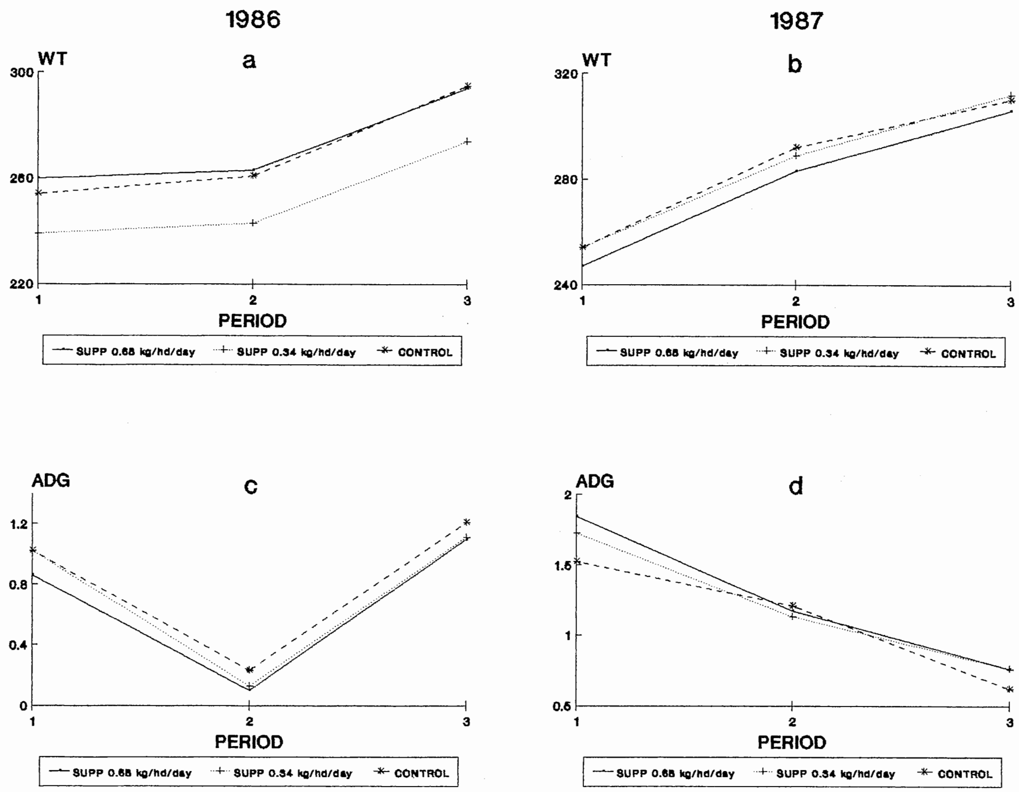

Figure 4. Weight (kg; WT) and daily gain (kg; ADG) of steers supplemented 3 levels of cottonseed meal while grazing tobosagrass from April to July, 1986 and 1987 at the Texas Tech Experimental Ranch.
(c). PER ($P<0.01$); PER 2 < PER 1, PER 3 ($P<0.01$).
(d). PER ($P<0.01$); PER 1 > PER 2 > PER 3 ($P<0.01$).

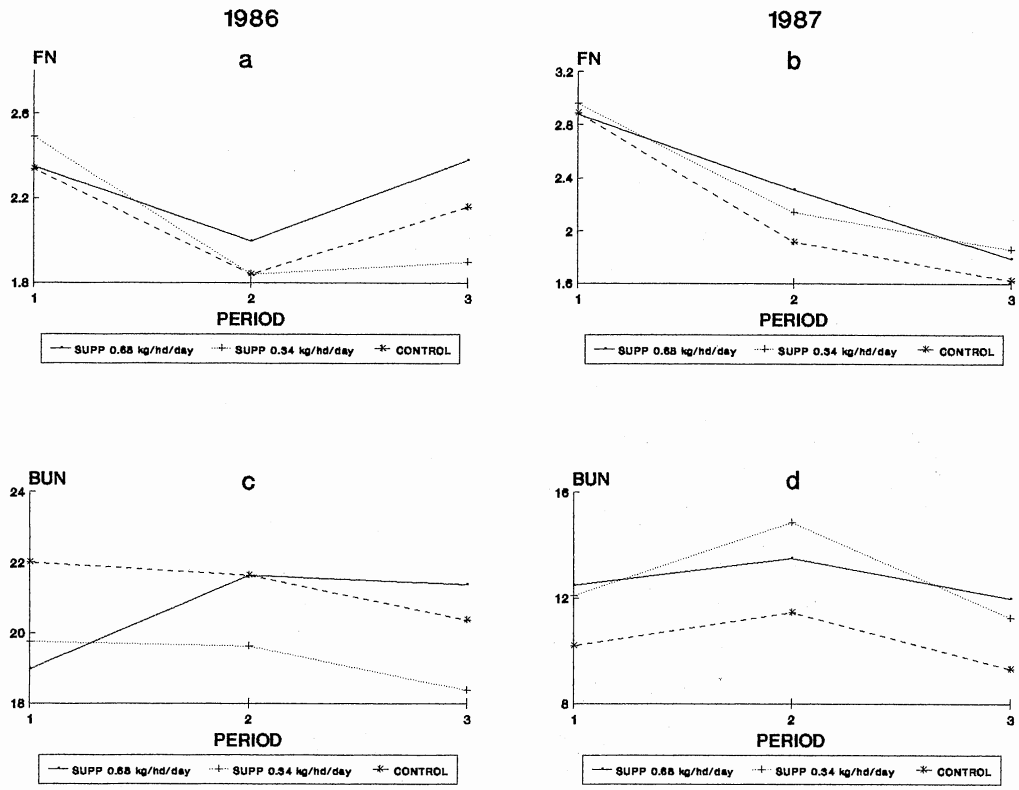

Figure 5. Fecal nitrogen (% of organic matter; FN) and plasma urea nitrogen (mg/100ml; BUN) of steers supplemented 3 levels of cottonseed meal while grazing tobosagrass from April to July, 1986 and 1987 at the Texas Tech Experimental Ranch.
(a). PER (P<0.01); PER 1 > PER 3 > PER 2 (P<0.05).
(b). PER (P<0.01); PER 1 > PER 2 > PER 3 (P<0.01).
(d). SUPP (P<0.01); CONTROL < 0.68, 0.34 (P<0.01); PER (P<0.01); PER 2 > PER 1, PER 3 (P<0.05).

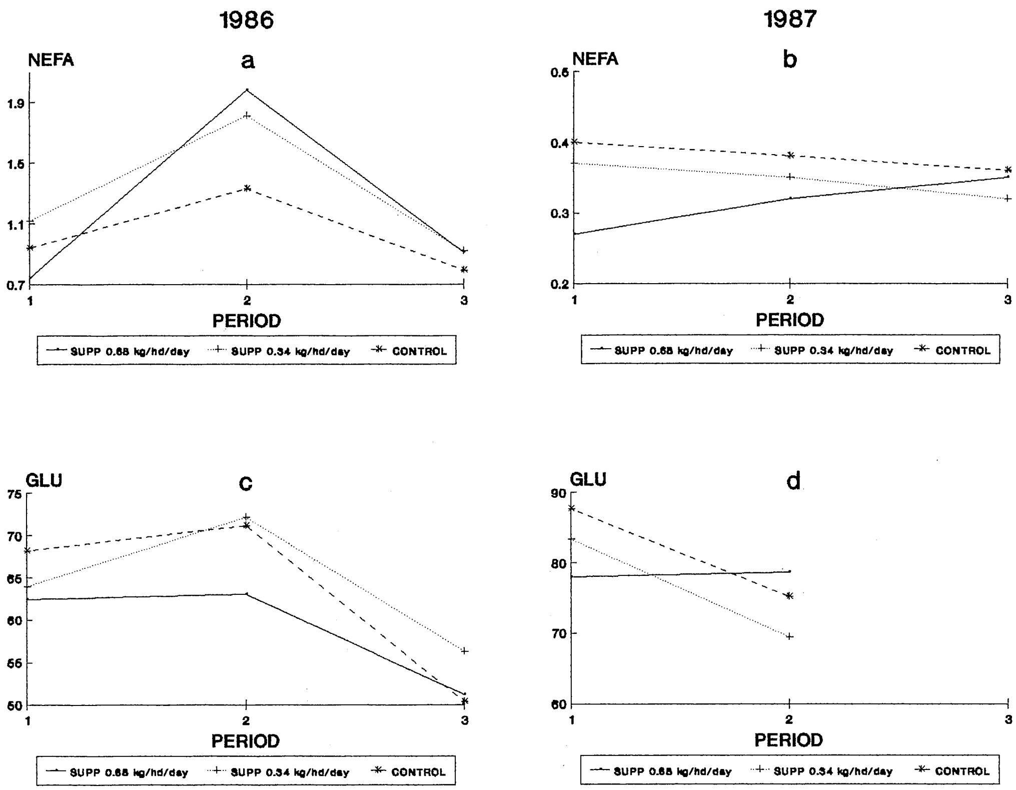

Figure 6. Plasma non-esterified fatty acids (mE/l; NEFA) and glucose (mg/dl; GLU) of steers supplemented 3 levels of cottonseed meal while grazing tobosagrass from April to July, 1986 and 1987 at the Texas Tech Experimental Ranch. (a). PER (P<0.01); PER 2 > PER 1, PER 3 (P<0.01). (c). PER (P<0.01); PER 3 < PER 1, PER 2 (P<0.01). (d). SUPP*PER (P<0.05).

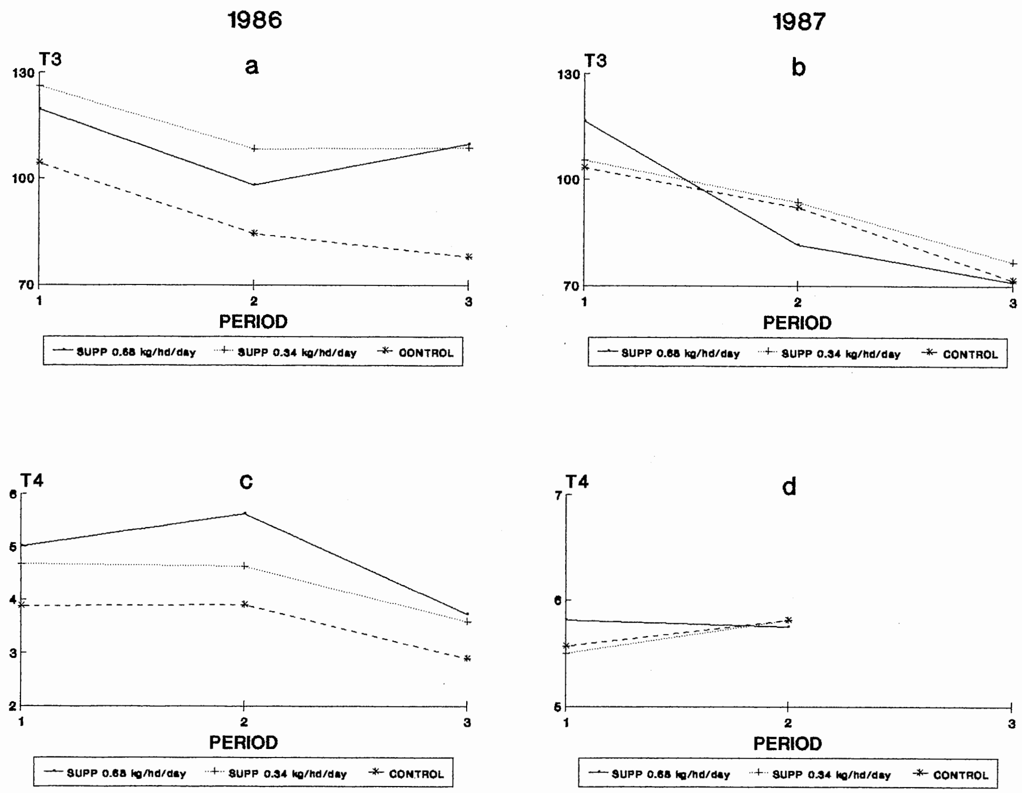

Figure 7. Plasma triiodothyronine (ng/dl; T3) and thyroxine (ug/dl; T4) of steers supplemented 3 levels of cottonseed meal while grazing tobosagrass from April to July, 1986 and 1987 at the Texas Tech Experimental Ranch. (a). SUPP (P<0.01); CONTROL < 0.68, 0.34 (P<0.01); PER (P<0.05); PER 1 > PER 2, PER 3 (P<0.05). (b). PER (P<0.01); PER 1 > PER 2 > PER 3 (P<0.01). (c). PER (P<0.05); PER 3 < PER 1, PER 2 (P<0.05).

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APPENDIX

Table 1. Weights (kg) of unsupplemented steers grazing tobosagrass at the Texas Tech Experimental Ranch, 1985.

Steer	23 April	14 May	4 June	2 July	23 July
326	490	507	527	559	558
327	476	497	541	563	557
328	493	500	535	550	545
329	529	538	571	606	610
330	504	513	555	571	585
332	583	577	631	635	659
333	463	472	499	529	547
334	477	482	508	536	505
335	558	567	605	620	620
336	518	529	551	571	566
337	433	456	485	521	524
338	623	602	637	675	656
339	490	509	512	579	556
340	522	532	581	620	614
341	555	570	611	633	659
342	556	568	605	605	616
343	483	491	531	565	565
344	580	587	605	634	614
345	469	495	523	562	584
346	475	496	528	555	543
347	498	501	528	535	546
348	502	523	567	579	602
349	580	595	641	652	662
350	456	475	505	531	543
351	528	538	561	595	589
352	490	515	535	565	561
353	541	554	578	578	595
354	515	567	600	654	661
355	554	557	585	619	621
356	625	639	666	692	679
357	537	571	600	622	628
358	591	604	650	696	673
359	517	522	528	563	578
360	579	581	616	651	658
361	509	529	559	585	600
362	550	545	582	620	626
363	432	438	483	526	526
364	499	532	566	611	589
365	586	600	648	690	688
366	545	546	573	601	605
367	416	437	475	504	508
368	565	575	608	630	669
370	490	525	558	601	600
371	496	525	552	592	590
372	524	565	588	629	638

Table 1. (Continued).

Steer	23 April	14 May	4 June	2 July	23 July
373	490	498	541	567	600
374	476	477	490	504	525
375	548	567	585	614	609
MEAN	519	533	565	594	597

Table 2. Weights (kg) of steers supplemented with 0.34 kg/hd/day of cottonseed meal while grazing tobosagrass at the Texas Tech Experimental Ranch, 1985.

Steer	23 April	14 May	4 June	2 July	23 July
226	497	508	545	563	567
227	456	454	492	504	492
228	524	520	557	575	589
229	505	524	563	582	572
230	559	571	609	626	603
231	475	495	532	549	564
232	567	619	657	662	697
233	502	532	564	574	565
234	528	560	593	618	625
235	432	438	465	484	489
236	527	568	604	618	606
237	543	609	654	691	716
238	489	494	544	558	540
239	478	476	544	600	600
240	538	556	583	614	618
241	542	582	618	631	648
242	472	485	512	524	530
243	514	551	588	605	611
244	515	520	562	584	596
245	603	623	673	688	695
246	550	577	610	639	660
247	547	574	617	640	645
248	374	405	447	475	463
249	544	566	606	624	626
250	526	531	584	587	588
251	472	492	534	558	559
252	497	516	580	592	611
253	491	512	553	575	574
254	513	548	564	572	610
255	525	563	612	630	638
256	472	465	499	528	526
257	494	511	538	544	558
258	426	468	516	547	546
259	491	508	551	559	559
260	591	596	632	645	641
261	511	559	591	600	617
262	512	531	565	578	590
263	503	522	570	600	603
264	513	531	575	600	608
265	470	488	518	528	540
266	505	525	575	607	604
267	499	525	565	586	594
268	536	565	621	671	681
270	505	498	520	541	538
271	505	493	542	574	595

Table 2. (Continued).

Steer	23 April	14 May	4 June	2 July	23 July
272	456	463	513	547	547
273	474	494	532	552	563
274	458	474	512	554	537
275	610	619	675	710	710
MEAN	507	527	567	588	593

Table 3. Weights (kg) of steers supplemented with 0.68 kg/hd/day of cottonseed meal while grazing tobosagrass at the Texas Tech Experimental Ranch, 1985

Steer	23 April	14 May	4 June	2 July	23 July
126	550	571	625	629	681
127	552	600	639	640	712
128	472	508	531	569	623
129	462	500	537	549	590
131	445	472	517	544	570
132	508	558	600	632	689
133	486	502	529	554	578
134	496	512	545	570	590
135	463	479	532	530	584
136	570	606	642	669	695
137	467	496	523	530	580
138	576	600	655	670	706
139	501	494	553	554	585
140	513	557	595	619	642
141	499	548	596	610	643
142	480	512	542	545	581
143	504	541	563	587	610
144	487	513	560	562	600
145	610	656	707	712	740
146	536	572	629	612	680
147	490	518	537	553	602
148	557	580	635	656	699
149	546	580	600	618	655
150	482	515	563	575	610
151	486	520	550	566	593
152	586	610	645	666	710
153	504	537	587	594	615
154	516	545	586	578	633
155	550	556	599	581	587
156	485	504	555	567	608
157	560	567	607	612	665
158	488	535	566	576	583
159	510	555	596	616	633
160	500	519	559	555	621
161	541	575	600	611	661
162	540	587	624	621	630
163	550	572	623	625	665
164	533	551	604	612	675
165	477	481	513	495	558
166	538	580	617	620	670
167	514	556	613	609	646
168	608	638	693	730	762
169	564	605	655	668	741
170	559	607	642	640	687
171	498	531	566	583	628

Table 3. (Continued).

Steer	23 April	14 May	4 June	2 July	23 July
172	482	507	542	551	616
173	577	616	638	660	711
174	474	501	567	573	634
175	524	551	579	600	643
MEAN	519	549	589	600	641

Table 4. Weights (kg) of unsupplemented steers grazing tobosagrass at the Texas Tech Experimental Ranch, 1986.

Steer	7 April	28 April	19 May	9 June	30 June
5	510	529	586	591	634
6	649	686	720	724	752
7	577	596	631	619	664
8	492	536	561	566	600
9	538	558	600	594	637
10	472	517	545	555	586
11	490	517	565	555	586
12	507	560	588	612	645
13	458	488	544	548	586
14	524	563	634	625	647
15	511	547	591	576	625
16	481	534	558	579	620
17	375	432	464	499	544
18	485	531	562	569	625
19	506	540	586	583	614
20	581	625	671	680	727
21	476	520	570	580	641
22	558	586	617	635	681
23	503	526	565	571	609
24	576	600	632	654	685
25	453	460	490	486	527
26	522	545	584	604	611
27	512	538	565	565	603
28	589	634	690	642	730
29	540	576	607	626	656
30	551	586	630	638	682
31	471	522	534	543	597
32	542	594	617	640	695
33	550	612	589	610	657
34	529	563	610	622	657
35	480	527	549	559	600
36	550	582	619	629	656
MEAN	517	554	590	596	637

Table 5. Weights (kg) of steers supplemented with 0.34 kg/hd/day of cottonseed meal while grazing tobosagrass at the Texas Tech Experimental Ranch, 1986.

Steer	7 April	28 April	19 May	9 June	30 June
5	521	570	627	600	656
6	530	574	602	577	621
7	600	651	676	642	706
8	476	518	567	552	589
9	606	630	654	650	706
10	538	570	615	586	622
11	505	544	575	572	588
12	481	521	558	535	591
13	634	689	735	705	751
14	494	537	590	580	620
15	497	526	570	570	618
16	579	596	675	660	717
17	456	503	555	555	608
18	600	665	705	702	765
19	517	536	566	581	602
20	438	464	513	498	552
21	588	641	683	671	716
22	450	482	558	549	587
23	544	593	619	645	697
24	538	579	618	610	660
25	479	522	568	573	615
26	598	659	708	714	772
MEAN	530	571	615	606	653

Table 6. Weights (kg) of steers supplemented with 0.68 kg/hd/day of cottonseed meal while grazing tobosagrass at the Texas Tech Experimental Ranch, 1986.

Steer	7 April	28 April	19 May	9 June	30 June
5	586	635	696	670	736
6	561	597	661	629	666
7	405	449	506	499	534
8	445	475	525	521	575
9	564	600	667	660	695
10	552	604	657	649	695
11	480	510	581	556	611
12	466	512	565	561	610
13	563	592	660	657	706
14	498	539	583	586	615
15	625	674	754	756	789
16	472	495	557	554	588
17	473	485	537	555	582
18	505	537	582	586	635
19	483	504	565	570	612
20	610	618	701	694	742
21	488	528	606	574	631
22	555	580	635	650	675
23	529	557	635	626	682
24	533	551	621	600	637
25	610	629	694	676	747
MEAN	524	556	618	611	655

Table 7. Weights (kg) of unsupplemented steers grazing tobosagrass at the Texas Tech Experimental Ranch, 1987.

Steer	11 April	2 May	23 May	13 June	4 July
305	475	530	592	600	658
306	511	563	625	643	692
307	449	505	558	560	616
308	477	517	566	584	654
309	496	564	632	650	683
310	456	503	578	516	593
311	498	552	627	600	665
312	480	549	602	633	694
313	446	486	547	557	602
314	502	549	600	596	639
315	526	560	637	663	717
316	530	549	638	655	701
317	393	449	508	535	584
318	448	478	555	574	635
319	435	471	554	571	638
320	409	455	522	538	595
321	512	557	639	665	711
322	471	508	593	616	656
323	486	540	615	637	682
324	507	547	628	654	678
325	563	609	705	719	783
326	493	543	629	664	711
327	452	460	511	522	570
328	583	624	712	716	784
329	529	562	628	662	707
330	427	446	527	536	583
331	431	450	541	561	629
332	409	433	503	519	581
333	397	441	505	527	591
334	421	449	515	544	591
335	421	431	496	531	570
336	422	454	531	527	585
337	463	490	583	610	650
338	461	503	571	598	656
339	430	445	526	545	602
340	470	511	587	624	679
341	403	437	530	552	611
MEAN	467	506	579	595	648

Table 8. Weights (kg) of steers supplemented with 0.34 kg/hd/day of cottonseed meal while grazing tobosagrass at the Texas Tech Experimental Ranch, 1987.

Steer	11 April	2 May	23 May	13 June	4 July
205	542	614	659	672	729
206	476	555	593	586	673
207	469	530	572	595	645
208	518	585	650	676	733
209	526	578	650	650	722
210	462	530	583	609	658
211	385	449	494	507	558
212	435	512	553	572	623
213	386	460	500	505	563
214	570	643	700	709	763
215	431	500	578	600	669
216	517	587	645	667	718
217	501	554	600	637	702
218	440	587	538	547	600
219	486	542	617	642	707
220	444	527	568	606	659
221	422	509	553	588	655
222	466	552	608	659	711
223	515	588	635	667	735
224	527	611	695	737	804
225	437	503	544	582	617
227	488	550	614	634	695
228	506	566	632	661	721
229	509	561	622	664	717
230	416	458	545	544	587
231	434	481	522	562	610
232	461	510	570	598	656
233	326	363	423	446	504
234	465	515	570	600	668
235	415	447	499	513	554
236	420	460	520	531	600
237	481	538	608	629	694
238	417	489	539	585	653
239	431	494	541	588	638
240	475	523	596	619	673
241	550	597	666	695	745
242	515	595	654	704	761
243	498	545	617	631	660
244	417	480	536	572	636
245	451	500	557	572	624
MEAN	466	530	584	609	666

Table 9. Weights (kg) of steers supplemented with 0.68 kg/hd/day of cottonseed meal while grazing tobosagrass at the Texas Tech Experimental Ranch, 1987.

Steer	11 April	2 May	23 May	13 June	4 July
105	523	597	654	665	716
105	513	605	650	681	704
107	518	590	650	655	721
108	481	567	607	613	654
109	484	560	620	646	684
111	379	455	492	516	556
112	484	560	604	609	653
113	451	511	548	565	605
114	435	515	565	558	611
115	533	619	665	695	755
116	546	624	680	701	756
117	478	565	626	641	698
118	480	536	607	623	671
119	479	520	605	624	691
120	388	453	519	542	610
121	495	550	609	620	695
122	414	474	545	573	655
123	416	479	532	564	600
124	419	484	552	559	624
125	506	551	607	623	686
126	466	536	600	623	701
127	451	521	575	600	663
128	450	493	563	585	620
129	435	513	600	617	659
130	417	476	527	543	600
131	437	502	550	564	632
132	479	546	615	634	695
133	468	516	592	604	654
MEAN	465	533	591	609	663

Table 10. Average daily gain (kg) of steers fed three levels of protein supplement while grazing tobosagrass at the Texas Tech Experimental Ranch.

Period	Supplement level 0 [1] Mean	SD	0.34 [2] Mean	SD	0.68 [3] Mean	SD
1985						
4/23 to 5/14	0.30	0.27	0.43	0.35	0.65	0.28
5/14 to 6/4	0.69	0.23	0.87	0.22	0.88	0.25
6/4 to 7/2	0.47	0.22	0.33	0.18	0.23	0.28
7/2 to 7/23	0.07	0.33	0.11	0.27	0.92	0.42
1986						
4/7 to 4/28	0.79	0.28	0.89	0.28	0.69	0.27
4/28 to 5/19	0.77	0.36	0.95	0.32	1.36	0.25
5/19 to 6/9	0.14	0.33	-0.21	0.33	-0.16	0.30
6/9 to 6/30	0.88	0.30	1.02	0.27	0.96	0.27
1987						
4/11 to 5/2	0.83	0.34	1.33	0.31	1.46	0.30
5/2 to 5/23	1.58	0.28	1.23	0.28	1.27	0.29
5/23 to 6/13	0.37	0.30	0.54	0.31	0.37	0.20
6/13 to 7/4	1.14	0.23	1.23	0.23	1.18	0.31

1 0 = control group, 1985 N = 50, 1986 N = 32, 1987 N = 37.

2 0.34 = 0.34 kg/hd/day cottonseed meal, 1985 N = 50, 1986 N = 22, 1987 N = 40.

3 0.68 = 0.68 kg/hd/day cottonseed meal, 1985 N = 50, 1986 N = 21, 1987 N = 28.

Table 11. Average daily gain and blood and fecal constituent levels of steers grazing tobosagrass at the Texas Tech Experimental Ranch in 1985.

Item[1]	4/23 to 5/14		5/14 to 6/4		6/4 to 7/2		7/2 to 7/23	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Control (no supplement)								
Average daily gain (kg/hd)	0.4	0.4	0.8	0.2	0.5	0.2	0.4	0.3
Weight (kg/hd)	245	19	260	22	274	19	282	21
Fecal nitrogen (% OM)	2.1	0.5	1.5	0.3	1.5	0.3	1.3	0.2
Urea nitrogen (mg/dl)	12.9	2.1	11.6	1.6	11.3	2.1	11.1	2.2
Free fatty acid (mE/l)	0.7	0.2	0.4	0.2	0.7	0.4	0.7	0.3
Triiodothyronine (ng/dl)	93	63	112	43	63	34	58	24
Thyroxine (ug/dl)	4.2	0.5	4.7	0.7	4.7	0.8	4.6	0.8
0.34 kg/hd/day cottonseed meal								
Average daily gain (kg/hd)	0.8	0.3	0.8	0.4	0.3	0.2	0.4	0.2
Weight (kg/hd)	252	20	269	20	277	24	285	26
Fecal nitrogen (% OM)	2.2	0.3	1.7	0.5	1.7	0.3	1.5	0.2
Urea nitrogen (mg/dl)	17.5	4.3	17.5	3.0	17.2	4.0	18.1	4.1
Free fatty acid (mE/dl)	0.8	0.3	0.4	0.1	0.6	0.2	0.6	0.2
Triiodothyronine (ng/dl)	84	35	74	34	88	26	85	36
Thyroxine (ug/dl)	5.4	1.6	5.0	2.0	6.0	1.7	4.7	1.3
0.68 kg/hd/day cottonseed meal								
Average daily gain (kg/hd)	0.8	0.3	0.9	0.2	0.3	0.3	0.8	0.4
Weight (kg/hd)	260	21	280	24	286	27	303	25
Fecal nitrogen (% OM)	2.1	0.4	1.7	0.2	1.7	0.4	1.5	0.2
Urea nitrogen (mg/dl)	18.4	5.2	19.2	5.0	19.9	5.9	17.9	4.3
Free fatty acid (mE/l)	0.6	0.2	0.6	0.3	0.8	0.2	1.0	0.4
Triiodothyronine (ng/dl)	134	46	83	32	115	56	83	25
Thyroxine (ug/dl)	5.0	1.0	5.1	1.4	6.2	1.0	5.5	0.7

1 N = 10 for all treatments.

Table 12. Average daily gain and blood and fecal constituent levels of steers grazing tobosagrass at the Texas Tech Experimental Ranch in 1986.

Item[1]	4/7 to 4/28 Mean	SD	4/28 to 5/19 Mean	SD	5/19 to 6/9 Mean	SD	6/9 to 6/30 Mean	SD
Control (no supplement)								
Average daily gain (kg/hd)	0.7	0.3	0.9	0.3	0.0	0.2	0.8	0.2
Weight (kg/hd)	252	25	272	24	272	24	288	23
Fecal nitrogen (% OM)	1.8	0.3	1.8	0.2	1.7	0.2	1.7	0.2
Urea nitrogen (mg/dl)	21.9	3.9	19.4	2.1	19.0	2.4	16.7	1.5
Free fatty acid (mE/l)	0.7	0.3	0.7	0.4	0.7	0.2	0.9	0.3
Triiodothyronine (ng/dl)	93	25	128	30	118	24	88	10
Thyroxine (ug/dl)	4.7	0.8	3.6	0.9	4.2	0.6	3.2	0.6
0.34 kg/hd/day cottonseed meal								
Average daily gain (kg/hd)	0.9	0.2	0.9	0.3	-0.4	0.2	1.0	0.3
Weight (kg/hd)	264	26	282	25	273	23	293	26
Fecal nitrogen (% OM)	1.9	0.2	1.7	0.2	1.9	0.3	1.7	0.2
Urea nitrogen (mg/dl)	19.2	1.8	19.5	3.1	21.9	2.2	17.7	1.9
Free fatty acid (mE/dl)	0.5	0.2	0.3	0.1	0.6	0.1	0.7	0.3
Triiodothyronine (ng/dl)	123	25	144	20	150	38	131	35
Thyroxine (ug/dl)	4.7	0.8	1.8	0.6	2.4	0.8	1.3	0.5
0.68 kg/hd/day cottonseed meal								
Average daily gain (kg/hd)	0.9	0.2	1.3	0.2	-0.2	0.3	1.0	0.2
Weight (kg/hd)	251	29	277	30	272	28	293	30
Fecal nitrogen (% OM)	2.2	0.2	2.0	0.2	2.0	0.2	1.9	0.2
Urea nitrogen (mg/dl)	25.6	3.7	23.3	3.6	29.7	5.2	24.5	4.1
Free fatty acid (mE/l)	0.8	0.3	0.6	0.3	0.8	0.2	0.7	0.3
Triiodothyronine (ng/dl)	126	21	146	22	150	15	162	22
Thyroxine (ug/dl)	5.7	1.1	5.6	1.3	3.6	1.5	2.1	0.6

1 N = 10 for all treatments.

Table 13. Models predicting weight gain (kg/day) of steers grazing tobosagrass at the Texas Tech Experimental Ranch, 1985 and 1986.

	Sy.x	R^2
Period 1 (Late April-Early May) [1]		
ADG=0.227+0.0000078(WT^2)	0.31	0.09
ADG=0.026+0.0000061(WT^2)+0.016(BUN)	0.30	0.15
ADG=0.037+0.0000062(WT^2)+0.019(BUN)-0.0000057(T3^2)	0.30	0.18
Period 2 (Late May-Early June)		
ADG=0.056+0.003(WT)	0.28	0.08
ADG=-0.703+0.002(WT)+0.558(FN)	0.24	0.37
ADG=-0.600+0.002(WT)+0.450(FN)+0.010(BUN)	0.23	0.38
ADG=0.137+0.002(WT)+0.500(FN)-0.082(BUN)+0.003(BUN^2)	0.22	0.43
ADG=-0.081+0.002(WT)+0.458(FN)-0.071(BUN)+0.002(BUN^2)+0.024(T4)	0.22	0.45
Period 3 (Mid June-Late June)		
ADG=-0.031+0.183(NEFA^2)	0.40	0.04
ADG=0.490+0.218(NEFA^2)-0.005(T3)	0.33	0.33
ADG=0.893+0.251(NEFA^2)-0.013(T3)+0.000031(T3^2)	0.32	0.39
ADG=0.493+0.199(NEFA^2)-0.011(T3)+0.000026(T3^2)+0.072(T4)	0.30	0.48
Period 4 (Early July-Mid-July)		
ADG=-0.543+0.004(WT)	0.34	0.09
ADG=-1.247+0.004(WT)+0.589(FN)	0.30	0.31
ADG=-1.373+0.003(WT)+0.614(FN)+0.122(NEFA)	0.30	0.32
ADG=-1.709+0.004(WT)+0.623(FN)+0.707(NEFA)-0.302(NEFA^2)	0.30	0.33
ADG=-1.744+0.003(WT)+0.383(FN)+1.020(NEFA)-0.453(NEFA^2)+0.020(BUN)	0.29	0.39
ADG=-2.149+0.003(WT)+0.381(FN)+0.887(NEFA)-0.394(NEFA^2)+0.089(BUN) -0.002(BUN^2)	0.28	0.42
ADG=-1.757+0.003(WT)+0.214(FN)+1.006(NEFA)-0.438(NEFA^2)+0.085(BUN) -0.002(BUN^2)-0.054(T4)	0.27	0.47

1 ADG = average daily gain (kg/hd), WT = weight (kg/hd), BUN = serum urea nitrogen (mg/dl), T3 = triiodothyronine (ng/dl), FN = fecal nitrogen (% OM) T4 = thyroxine (ug/dl), NEFA = non-esterified fatty acids (mE/l).

Table 14. Average daily gain, blood and fecal constituent levels, and intake parameters of steers grazing tobosagrass at the Texas Tech Experimental Ranch in 1986.

Item	4/10 to 5/1		5/1 to 6/2		6/2 to 6/30	
	Mean	SD	Mean	SD	Mean	SD
Weight (kg/hd)[1]	254	8.5	261	8.0	295	6.5
Average daily gain (kg/hd)	1.0	0.1	0.2	0.1	1.2	0.2
Fecal nitrogen (% OM)	2.3	0.2	1.8	0.2	2.2	0.3
Glucose (mg/dl)	68.2	9.5	71.1	7.7	50.3	5.5
Free fatty acid (mE/l)	0.9	0.1	1.3	0.3	0.8	0.2
Urea nitrogen (mg/dl)	22.0	2.4	21.6	1.1	20.4	2.8
Triiodothyronine (ng/dl)	104.3	13.4	84.4	16.1	78.0	5.7
Thyroxine (ug/dl)	3.9	0.4	3.9	0.4	2.9	0.6
Crude protein (% of diet DM)	13.0	0.0	11.7	0.0	10.4	0.0
Dry matter digestibility (%)	51.0	0.0	43.2	0.0	35.1	0.0
Dry matter intake (g/kg BW)	19.4	3.1	12.9	1.0	12.8	1.5
Digestible dry matter intake (g/kg BW)	9.9	1.6	5.6	0.4	4.5	0.5
Crude protein intake (g/kg BW)	2.5	0.4	1.5	0.1	1.3	0.2

1 N = 4.

Table 15. Average daily gain, blood and fecal constituent levels, and intake parameters of steers fed 0.34 kg/hd/day of cottonseed meal while grazing tobosagrass at the Texas Tech Experimental Ranch in 1986.

Item	4/10 to 5/1 Mean	4/10 to 5/1 SD	5/1 to 6/2 Mean	5/1 to 6/2 SD	6/2 to 6/30 Mean	6/2 to 6/30 SD
Weight (kg/hd)[1]	239	23.6	243	15.3	274	15.3
Average daily gain (kg/hd)	1.0	0.2	0.1	0.3	1.1	0.1
Fecal nitrogen (% OM)	2.4	0.2	1.8	0.3	1.9	0.1
Glucose (mg/dl)	63.9	3.0	72.1	3.1	56.3	12.1
Free fatty acid (mE/l)	1.1	0.4	1.8	0.6	0.9	0.1
Urea nitrogen (mg/dl)	19.8	1.3	19.6	1.3	18.3	1.4
Triiodothyronine (ng/dl)	126.1	20.8	108.3	21.9	108.7	18.0
Thyroxine (ug/dl)	4.7	1.4	4.6	1.0	3.6	1.2
Crude protein (% of diet DM)	15.3	0.0	14.7	0.0	13.6	0.0
Dry matter digestibility (%)	51.7	0.0	45.0	0.0	37.5	0.0
Dry matter intake (g/kg BW)	19.5	1.5	16.1	3.4	13.4	1.2
Digestible dry matter intake (g/kg BW)	10.1	0.8	7.3	1.5	5.0	0.4
Crude protein intake (g/kg BW)	3.0	0.2	2.4	0.4	1.8	0.1

1 N = 4.

Table 16. Average daily gain, blood and fecal constituent levels, and intake parameters of steers fed 0.68 kg/hd/day of cottonseed meal while grazing tobosagrass at the Texas Tech Experimental Ranch in 1986.

Item	4/10 to 5/1 Mean	4/10 to 5/1 SD	5/1 to 6/2 Mean	5/1 to 6/2 SD	6/2 to 6/30 Mean	6/2 to 6/30 SD
Weight (kg/hd)[1]	260	7.2	263	8.5	294	8.3
Average daily gain (kg/hd)	0.9	0.4	0.1	0.2	1.1	0.1
Fecal nitrogen (% OM)	2.4	0.3	2.0	0.3	2.4	0.2
Glucose (mg/dl)	62.4	3.5	63.0	7.9	51.2	8.0
Free fatty acid (mE/l)	0.7	0.2	2.0	1.0	0.9	0.3
Urea nitrogen (mg/dl)	19.0	2.4	21.6	3.8	21.4	4.6
Triiodothyronine (ng/dl)	119.6	13.6	98.1	14.9	109.7	19.1
Thyroxine (ug/dl)	5.0	1.3	5.6	2.6	3.7	1.5
Crude protein (% of diet DM)	18.1	0.0	18.4	0.0	16.9	0.0
Dry matter digestibility (%)	52.5	0.0	46.9	0.0	40.1	0.0
Dry matter intake (g/kg BW)	16.5	2.6	12.9	1.3	12.1	0.7
Digestible dry matter intake (g/kg BW)	8.7	1.4	6.0	0.6	4.9	0.2
Crude protein intake (g/kg BW)	3.0	0.3	2.4	0.1	2.0	0.1

1 N = 4.

Table 17. Average daily gain, blood and fecal constituent levels, and intake parameters of steers grazing tobosagrass at the Texas Tech Experimental Ranch in 1987.

Item	4/14 to 5/1		5/1 to 6/1		6/1 to 7/1	
	Mean	SD	Mean	SD	Mean	SD
Weight (kg/hd)[1]	254	10.7	292	17.0	310	19.8
Average daily gain (kg/hd)	1.5	0.2	1.2	0.3	0.6	0.3
Fecal nitrogen (% OM)	2.9	0.2	1.9	0.3	1.6	0.2
Glucose (mg/dl)	87.6	5.2	75.2	6.6		
Free fatty acid (mE/l)	0.4	0.1	0.4	0.2	0.4	0.1
Urea nitrogen (mg/dl)	10.2	1.7	11.5	2.0	9.3	0.9
Triiodothyronine (ng/dl)	103.3	19.0	92.1	5.3	71.6	11.6
Thyroxine (ug/dl)	5.6	0.4	5.9	0.4		
Crude protein (% of diet DM)	12.7	0.0	9.7	0.0	10.0	0.0
Dry matter digestibility (%)	58.8	0.0	50.9	0.0	51.6	0.0
Dry matter intake (g/kg BW)	18.0	1.1	14.7	2.9	12.8	1.6
Digestible dry matter intake (g/kg BW)	10.6	0.7	7.5	1.5	6.6	0.9
Crude protein intake (g/kg BW)	2.3	0.1	1.4	0.3	1.3	0.2

1 N = 4.

Table 18. Average daily gain, blood and fecal constituent levels, and intake parameters of steers fed 0.34 kg/hd/day of cottonseed meal while grazing tobosagrass at the Texas Tech Experimental Ranch in 1987.

Item	4/14 to 5/1		5/1 to 6/1		6/1 to 7/1	
	Mean	SD	Mean	SD	Mean	SD
Weight (kg/hd)[1]	254	10.8	289	10.2	312	15.2
Average daily gain (kg/hd)	1.7	0.3	1.1	0.1	0.8	0.2
Fecal nitrogen (% OM)	3.0	0.2	2.1	0.3	1.9	0.1
Glucose (mg/dl)	83.4	2.7	69.4	4.5		
Free fatty acid (mE/l)	0.4	0.2	0.4	0.1	0.3	0.1
Urea nitrogen (mg/dl)	12.1	1.6	14.9	1.9	11.3	0.8
Triiodothyronine (ng/dl)	105.4	14.8	93.6	8.5	76.7	4.2
Thyroxine (ug/dl)	5.5	0.4	5.8	0.6		
Crude protein (% of diet DM)	15.0	0.0	12.4	0.0	12.8	0.0
Dry matter digestibility (%)	60.4	0.0	53.2	0.0	54.0	0.0
Dry matter intake (g/kg BW)	18.4	0.6	15.5	0.5	13.6	1.5
Digestible dry matter intake (g/kg BW)	11.1	0.4	8.3	0.6	7.3	0.8
Crude protein intake (g/kg BW)	2.8	0.1	1.9	0.1	1.7	0.2

[1] N = 4.

Table 19. Average daily gain, blood and fecal constituent levels, and intake parameters of steers fed 0.68 kg/hd/day of cottonseed meal while grazing tobosagrass at the Texas Tech Experimental Ranch in 1987.

Item	4/14 to 5/1		5/1 to 6/1		6/1 to 7/1	
	Mean	SD	Mean	SD	Mean	SD
Weight (kg/hd)[1]	247	10.3	283	10.3	306	12.9
Average daily gain (kg/hd)	1.8	0.1	1.2	0.1	0.8	0.1
Fecal nitrogen (% OM)	2.9	0.2	2.3	0.1	1.8	0.2
Glucose (mg/dl)	78.0	4.7	78.7	8.3		
Free fatty acid (mE/l)	0.3	0.1	0.3	0.2	0.4	0.1
Urea nitrogen (mg/dl)	12.5	0.2	13.5	1.3	12.0	2.0
Triiodothyronine (ng/dl)	116.6	10.8	81.5	7.1	71.1	5.9
Thyroxine (ug/dl)	5.8	0.5	5.8	0.5		
Crude protein (% of diet DM)	16.8	0.0	15.4	0.0	14.7	0.0
Dry matter digestibility (%)	61.1	0.0	54.9	0.0	55.0	0.0
Dry matter intake (g/kg BW)	21.6	0.7	15.0	1.0	16.7	3.0
Digestible dry matter intake (g/kg BW)	13.2	0.4	8.2	0.5	9.2	1.6
Crude protein intake (g/kg BW)	3.6	0.1	2.3	0.1	2.4	0.3

1 N = 4.

Table 20. Models predicting diet dry matter digestibility (g/g of dry matter) of steers grazing tobosagrass at the Texas Tech Experimental Ranch during April, May, and June, 1986 and 1987.

Model[1]	Sy.x	R^2
DMD=0.172+0.005(GLU)[2]	0.05	0.54
DMD=0.056+0.004(GLU)+0.08(FN)	0.04	0.70
DMD=0.018+0.003(GLU)+0.083(FN)+0.021(T4)	0.04	0.80
DMD=-0.290+0.012(GLU)+0.092(FN)+0.021(T4)-0.000068(GLU^2)	0.03	0.82
DMD=-0.291+0.013(GLU)+0.078(FN)+0.023(T4)-0.000083(GLU^2)-0.027(NEFA)	0.03	0.86
DMD=0.132+0.01(GLU)+0.06(FN)+0.027(T4)-0.001(WT)-0.041(NEFA)[4] -0.000064(GLU^2)	0.03	0.91
Model[3]		
DMD=0.655-0.01(BUN)	0.06	0.40
DMD=0.568-0.009(BUN)+0.016(FN^2)	0.05	0.58
DMD=0.847-0.009(BUN)+0.007(FN^2)+0.052(SUPP)-0.001(WT)-0.026(NEFA)[4]	0.04	0.67

1 Models include variables from periods 1, 2, and 3 in 1986 and periods 1 and 2 in 1987.

2 GLU = glucose (mg/dl), FN = fecal nitrogen (% OM), T4 = thyroxine (ug/dl) NEFA = non-esterified fatty acids (mE/l), WT = weight (kg/hd), BUN = serum urea nitrogen (mg/dl), SUPP = supplement level (0, 0.34, or 0.68 kg/hd/day).

3 Models include variables from all periods of 1986 and 1987. GLU and T4 were excluded.

4 WT and SUPP were included in variable list.

Table 21. Models predicting diet crude protein (g/g of dry matter) of steers grazing tobosagrass at the Texas Tech Experimental Ranch during April, May, and June, 1986 and 1987.

Model[1]	Sy.x	R^2
[2]		
CP=0.07+0.00056(T3)	0.02	0.17
CP=0.063+0.00051(T3)+0.032(FN)	0.02	0.21
CP=0.039+0.00041(T3)+0.022(FN)+0.014(NEFA)	0.02	0.28
CP=0.016+0.00042(T3)+0.024(FN)+0.010(NEFA)+0.001(BUN)	0.02	0.31
CP=-0.019+0.00039(T3)+0.024(FN)+0.003(NEFA)+0.003(BUN)+0.0007($T4^2$)	0.02	0.38
[4]		
CP=0.139+0.80(SUPP)-0.0000006(WT^2)+0.000032(BUN^2)+0.002(FN^2)	0.01	0.92
Model[3]		
CP=0.084+0.00057(T3)	0.02	0.21
CP=0.067+0.00047(T3)+0.012(FN)	0.02	0.24
CP=0.051+0.00038(T3)+0.015(FN)+0.0012(BUN)	0.02	0.29
CP=0.050+0.00031(T3)+0.018(FN)+0.0010(BUN)+0.0029($NEFA^2$)	0.02	0.32
[4]		
CP=0.134+0.077(SUPP)-0.0000005(WT^2)+0.000028(BUN^2)+0.0015(FN^2)	0.01	0.92

1 Models include variables from periods 1, 2, and 3 in 1986 and periods 1 and 2 in 1987.

2 T3 = triiodothyronine (ng/dl), FN = fecal nitrogen (%OM), NEFA = non-esterified fatty acids (mE/l), BUN = serum urea nitrogen (mg/dl), T4 = thyroxine (ug/dl), SUPP = supplement level (0, 0.34, or 0.68 kg/hd/day), WT = weight (kg/hd).

3 Models include variables from all periods of 1986 and 1987. GLU and T4 were excluded.

4 WT and SUPP were included in variable list.

Table 22. Models predicting total dry matter intake (g/kg of body weight) of steers grazing tobosagrass at the Texas Tech Experimental Ranch during April, May, and June, 1986 and 1987.

Models [1]	Sy.x	R^2
[2]		
$TDMI=11.65+0.794(FN^2)$	2.88	0.23
$TDMI=7.35+0.608(FN^2)+0.077(GLU)$	2.78	0.30
$TDMI=1.70+0.472(FN^2)+0.084(GLU)+0.058(T3)$	2.57	0.41
$TDMI=-11.50+0.456(FN^2)+0.078(GLU)+0.237(T3)-0.001(T3^2)$	2.54	0.43
Models [3]		
$TDMI=11.70+0.792(FN^2)$	2.80	0.25
$TDMI=12.77+0.770(FN^2)-0.003(BUN)$	2.76	0.28
$TDMI=9.25+0.555(FN^2)-0.005(BUN)+0.053(T3)$	2.61	0.37

1 Models include variables from periods 1, 2, and 3 in 1986 and period 1 and 2 in 1987.

2 FN = fecal nitrogen (% OM), GLU = glucose (mg/dl), T3 = triiodothyronine (ng/dl), BUN = serum urea nitrogen (mg/dl).

3 Models include variables from all periods of 1986 and 1987. GLU and T4 were excluded.

Table 23. Models predicting dry matter intake (g/kg of body weight) by steers grazing tobosagrass at the Texas Tech Experimental Ranch during April, May, and June, 1986 and 1987.

Model[1]	Sy.x	R^2
TDDMI=3.507+0.843(FN^2)[2]	2.07	0.40
TDDMI=-1.56+0.623(FN^2)+0.091(GLU)	1.81	0.55
TDDMI=-4.986+0.541(FN^2)+0.095(GLU)+0.035(T3)	1.70	0.61
TDDMI=-5.225+0.566(FN^2)+0.074(GLU)+0.031(T3)+0.421(T4)	1.63	0.64
TDDMI=-14.03+0.632(FN^2)+0.346(GLU)+0.028(T3)+0.418(T4)-0.002(GLU^2)	1.60	0.66
TDDMI=-14.57+0.547(FN^2)+0.384(GLU)+0.032(T3)+0.457(T4)-0.002(GLU^2)-0.686(NEFA)	1.58	0.68
TDDMI=19.557+0.384(FN^2)-0.061(WT)+0.828(T4)-1.384(NEFA)[4]	1.36	0.75
Model[3]		
TDDMI=4.376+0.722(FN^2)	2.03	0.34
TDDMI=6.177+0.686(FN^2)-0.006(BUN^2)	1.82	0.48
TDDMI=4.261+0.569(FN^2)-0.006(BUN^2)+0.029(T3)	1.75	0.52
TDDMI=23.394+0.295(FN^2)-0.005(BUN^2)-0.051(WT)-2.721(NEFA)+0.629($NEFA^2$)[4]	1.57	0.63

1 Models include variables from periods 1, 2, and 3 in 1986 and periods 1 and 2 in 1987.

2 FN = fecal nitrogen (% OM), GLU = glucose (mg/dl), T3 = triiodothyronine (ng/dl), T4 = thyroxine (ug/dl), BUN = serum urea nitrogen (mg/dl), WT = weight (kg/hd), NEFA = non-esterified fatty acids (mE/l).

3 Models include variables from all periods of 1986 and 1987. GLU and T4 were excluded.

4 WT and SUPP were included in variable list.

Table 24. Models predicting crude protein intake (g/kg of body weight) by steers grazing tobosagrass at the Texas Tech Experimental Ranch during April, May, and June, 1986 and 1987.

Model[1]	Sy.x	R^2
[2]		
CPI=0.397+0.019(T3)	0.56	0.29
CPI=-0.032+0.015(T3)+0.139(FN^2)	0.49	0.45
CPI=-0.367+0.015(T3)+0.132(FN^2)+0.094(T4)	0.48	0.49
CPI=-1.152+0.014(T3)+0.155(FN^2)+0.151(T4)+0.029(BUN)	0.47	0.51
CPI=-3.781+0.013(T4)+0.193(FN^2)+0.147(T4)+0.343(BUN)-0.009(BUN^2)	0.44	0.58
CPI=-7.971+0.085(T3)+0.195(FN^2)+0.144(T4)+0.407(BUN)-0.011(BUN^2)-0.0003($T3^2$)	0.43	0.62
CPI=-9.182+0.083(T3)+0.187(FN^2)+0.128(T4)+0.472(BUN)-0.012(BUN^2)-0.0003($T3^2$) +0.011(GLU)	0.42	0.64
CPI=2.434-0.000026(WT^2)+0.928(SUPP)+0.091(FN^2)+0.076(T4)+0.005(T3)[4]	0.32	0.78
Model[3]		
CPI=0.386+0.829(FN)	0.55	0.31
CPI=-0.318+0.603(FN)+0.012(T3)	0.50	0.43
CPI=11.533-0.063(WT)+1.174(SUPP)+0.077(FN^2)-0.001(BUN^2)+0.000022($T3^2$) +0.000094(WT^2)[4]	0.33	0.77

1 Models include variables from periods 1, 2, and 3 in 1986 and periods 1 and 2 in 1987.

2 T3 = triiodothyronine (ng/dl), FN = fecal nitrogen (% OM), T4 = thyroxine (ug/dl), BUN = serum urea nitrogen (mg/dl), GLU = glucose (mg/dl), WT = weight (kg/hd), SUPP = supplement level (0, 0.34, or 0.68 kg/hd/day).

3 Models include variables from all periods of 1986 and 1987. GLU and T4 were excluded.

4 WT and SUPP were included in variable list.

Table 25. Models predicting the ratio of crude protein intake/total digestible dry matter intake of steers grazing tobosagrass at the Texas Tech Experimental Ranch during April, May, and June, 1986 and 1987.

Model[1]	Sy.x	R^2
[2]		
CPI/DDMI=51.35-0.319(GLU)	5.04	0.38
CPI/DDMI=45.093-0.268(GLU)+3.269(NEFA)	4.69	0.47
CPI/DDMI=38.566-0.209(GLU)+2.463(NEFA)+0.010(BUN^2)	4.57	0.51
CPI/DDMI=32.441-0.212(GLU)+2.150(NEFA)+0.010(BUN^2)+0.063(T3)	4.45	0.54
CPI/DDMI=64.635+15.645(SUPP)-0.967(GLU)+10.613(NEFA)-3.87(T4)+0.006(GLU^2) -2.429($NEFA^2$)+0.289($T4^2$)[4]	1.94	0.92
Model[3]		
CPI/DDMI=14.256+0.874(BUN)	4.74	0.45
CPI/DDMI=15.028+0.713(BUN)+2.406(NEFA)	4.62	0.49
CPI/DDMI=10.962+0.680(BUN)+2.111(NEFA)+0.050(T3)	4.55	0.51
CPI/DDMI=11.471+0.511(BUN)+13.415(SUPP)+7.33(NEFA)-1.599($NEFA^2$)[4]	2.85	0.81

1 Models include variables from periods 1, 2, and 3 in 1986 and periods 1 and 2 in 1987.

2 GLU = glucose (mg/dl), NEFA = non-esterified fatty acids (mE/l), BUN = serum urea nitrogen (mg/dl), T3 = triiodothyronine (ng/dl), SUPP = supplement level (0, 0.34, or 0.68 kg/hd/day), T4 = thyroxine (ug/dl).

3 Models include variables from all periods of 1986 and 1987. GLU and T4 were excluded.

4 WT and SUPP were included in variable list.

Table 26. Models predicting weight gain (kg/hd/day) of steers grazing tobosagrass at the Texas Tech Experimental Ranch during April, May, and June, 1986 and 1987.

Model[1]	Sy.x	R^2
[2]		
ADG=1.572-0.652(NEFA)	0.36	0.56
ADG=0.926-0.508(NEFA)+0.097(FN^2)	0.32	0.66
ADG=1.221-0.974(NEFA)+0.083(FN^2)+0.161($NEFA^2$)	0.30	0.70
Model[3]		
ADG=0.159+0.162(FN^2)	0.40	0.41
ADG=0.631+0.130(FN^2)-0.412(NEFA)	0.32	0.62
ADG=0.393+0.112(FN^2)-0.463(NEFA)+0.0038(T3)	0.31	0.64
ADG=0.484+0.105(FN^2)-0.811(NEFA)+0.0047(T3)+0.125($NEFA^2$)	0.30	0.66

1 Models include variables from periods 1, 2, and 3 in 1986 and periods 1 and 2 in 1987.

2 ADG = average daily gain (kg/hd), NEFA = non-esterified fatty acids (mE/l), FN = fecal nitrogen (% OM), T3 = triiodothyronine (ng/dl).

3 Models include variables from all periods of 1986 and 1987. GLU and T4 were excluded.

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VITA

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Candidate for the Degree of

Doctor of Philosophy

Thesis: EFFECT OF PROTEIN SUPPLEMENTATION ON RELATIONSHIPS AMONG PERFORMANCE, NUTRIENT INTAKE, AND BLOOD AND FECAL COMPONENTS OF STEERS GRAZING TOBOSAGRASS

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