NUTRIENT INTAKE AND DIGESTION BY CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND AND PLAINS BLUESTEM PASTURE

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CHAPTER I

INTRODUCTION: THE USE OF COMPLEMENTARY FORAGES

To use forages efficiently, livestock production goals must be defined so nutrient needs can be identified. No single forage type can fully meet nutrient needs of livestock throughout the grazing season (Anderson, 1991). Differences in plant growth rates and nutritional characteristics across seasons permit the use of forage combinations that will provide most of the nutrients required by grazing livestock. Using combinations of forages that can increase efficiency of animal production is most commonly called "complementary forage systems" (Lodge, 1963). Authors have coined other terms that describe this same premise include "farmed forages to complement range" (McIlvain and Shoop, 1973), "tame or seeded pasture systems" (Moore, 1970), and possibly a more ecologically correct term "agronomic ecosystem as a subsystem to the ranch ecosystem" (Lewis, 1973). The definition of "complementary" by Webster's dictionary is "mutually supplies each others lack". For two forages to fit this definition, the two forages must differ temporally in nutritional value, rate of DM production, or both.

Three factors determine the feasibility of using complementary forages (Nichols and Clanton, 1987): (1) increased production per unit of land, (2) improved forage quality for better animal performance, and (3) reduced overall production cost. In a review, Wheeler (1981) concluded that the use of complementary forages had one goal: to increase enterprise profitability. Profitability may increase as a result of higher carrying capacity or from reduced supplemental feed required to maintain optimal animal performance.

When viewed in the broadest sense of the definition of complementary forages, the literature contains an extensive number of reports on this topic. However, reports that apply to the southern Great Plains are meager (Nichols and Clanton, 1987). In two experiments conducted by McIlvain and Shoop (1973), cattle grazed native range or native range (75%) plus an area (25%) double-cropped with wheat and sudangrass. The stocking rate of each system was varied and the area of crop was on a "flexible, as-needed basis". Averaged across 6 years, gain per steer was 10% higher, gain per hectare was doubled, and net returns were increased by 260%. In a second study, a native range (90%) plus weeping lovegrass (10%) system was compared to native range (100%). Carrying capacity was increased by 82% and gain per acre was increased by 73% with the lovegrass system (McIlvain and Shoop, 1973).

Properly matching selected introduced forages and native rangeland with livestock nutrient needs enable graziers to optimize profits (Anderson, 1991). Midgrass prairie range (PRAIRIE) and Plains bluestem (*Bothriochloa ischaemum,* var. Plains; PLAINS) are the two primary grazing resources for beef production in western Oklahoma. Plains bluestem consist of a variety of introduced grasses known as "Old World Bluestems". Old World Bluestems were first introduced into the United States in 1917 to stabilize deteriorated cropland and to improve forage production on deteriorated rangeland (McCoy et al., 1992). Plains bluestem may complement PRAIRIE because of its continued growth during the summer and higher forage quality; potentially it can yield over four times the dry matter of well-managed native rangeland (Taliaferro et al., 1972; Coyne and Bradford, 1985). Consequently, PLAINS may be an ideal choice to complement native rangeland in an integrated forage-livestock system (Sims and Dewald, 1982).

In a survey conducted by McCoy et al. (1992), 93% of the respondents grazed their Old World Bluestem pastures and of these, 63% were using Old World Bluestem as a complement to native rangeland. Two of the more common problems cited by graziers were (1) forage palatability sometimes was poor and (2) forage nutrient quality sometimes was less than required by livestock. These same problems were documented by Dabo et al. (1987, 1988). These problems probably result from the pasture becoming senescent because of low stocking densities for long periods of time. Grazing Old World Bluestem more intensively should overcome this pasture quality problem.

As mentioned previously, one of the unique qualities of PLAINS is that growth begins later in the spring than native grasses and the major production period of PLAINS is in the summer and early fall (Taliaferro et al., 1972). While native grasses are dormant during the summer, PLAINS is growing so that animal growth may be maintained without the need for nutritional supplements. Also, by concentrating livestock on a smaller portion of the ranch, PLAINS will be grazed intensively, this should alleviate problems with senescent, rank forage and will allow the rangeland to rest. Finally, the use of PLAINS as a complement to native rangeland can increase ranch carrying capacity due to its higher DM yield.

To date, little information is available on the nutritive value of grazed forage from PRAIRIE and PLAINS in southwestern Oklahoma. Such information is necessary to integrate PRAIRIE and PLAINS into a complementary forage system. Also, this information will help to evaluate the necessity for and type of supplementation cattle will need when grazing either forage.

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CHAPTER II

DETERMINANTS OF FORAGE INTAKE BY GRAZING BEEF CATTLE: A LITERATURE REVIEW

When cattle consume high energy diets, they grow rapidly. Because energy intake from forage is lower, growth is less rapid and performance is lower. Performance may be measured either as weight gain or as reproductive efficiency (% calf crop, weaning weight, or both). Currently, at least two theories attempt to explain intake regulation in beef cattle consuming forage. The first addresses ruminal fill or some physical limitation of the rumen (Conrad et al., 1964). This theory suggests that the bulk of undigested particles in the gastrointestinal tract limits forage intake, so that when forage digestibility increases, intake will increase because both rate and extent of forage digestion is higher. The second theory suggests that the quantity of protein absorbed from the small intestine relative to digestible energy regulates forage intake (Egan, 1977). In the second theory, changes in protein absorption and the amount of available energy alter forage intake independent of changes in rate or extent of digestion (Egan and Doyle, 1985; Krysl et al., 1987c).

In many instances, successful supplementation program increase cattle performance as a result of increased forage intake. In order to predict or improve cattle performance, it is necessary to understand clearly which factors regulate forage intake. This literature review serves three functions: first, it describes the importance of adequate forage availability for forage intake; second, it describes how nutrient utilization in various segments of the gastrointestinal tract may regulate forage intake; and finally, it describes the effect of changing forage quality during the grazing season on site of nutrient utilization and forage intake.

Forage Availability

Performance of grazing livestock varies with stocking rate as a result of changes in herbage allowance. Numerous studies have demonstrated that an increased stocking rate decreases animal performance (Launchbaugh, 1957; Langlands and Bowles, 1974; Ellis et al., 1983). Usually, as forage becomes more limiting, animals will increase their grazing time to compensate for a smaller bite size (Ellis et al., 1983; Minson, 1990). However, such compensation becomes progressively less complete; as the animal extends its grazing time, total forage intake will be decreased. Cattle generally limit grazing time to less than 10 to 12 h/d; the remaining time is spent ruminating and resting (Minson, 1990). Hepworth et al. (1991) found that cattle stocked at heavy rates on shortgrass prairie range spent less time grazing than cattle stocked at lower rates. They concluded that at the higher stocking rate, the marginal return (nutrient intake) from an extended grazing time was insufficient so grazing time was reduced.

Rangelands and pastures are rarely uniform. Diversity benefits the animal by allowing them to graze selectively. Two major factors of forage heterogeneity can affect the relationship between intake and forage allowance: leaf versus stem and growing versus senescent tissue (Minson, 1990).

In pastures and rangelands with mature forages, large physical and chemical differences exist between leaf and stem fractions. In a summary of four studies in which the average digestibility of leaf and stem fractions of grasses differed by only 1%, intake of the leaf fraction was 15% greater (Minson, 1982). The mean retention time in the rumen of leaves and stems of 26 forages was 24 and 33 h, respectively (Laredo and Minson, 1973; Laredo and Minson, 1975; Poppi et al., 1981a,b). The most probable reason for the longer retention time and reduced intake of stems is the greater resistance of stems to mastication and slower rate of comminution (Minson, 1982). Ruminants tend to restrict their diets to leaves, even when little leaf is present in the pasture. As the leaf:stem ratio in a pasture is reduced by grazing, average bite size declines even though large quantities of stems are still available (Minson, 1990). Subsequently, the animal must spend more time searching for additional "preferred forage".

Pastures contain both growing and senescent forage, especially toward the end of the grazing season. Cattle eat only small amounts of dead forage when green leaf is available (Minson, 1990). Daily gain of sheep and cattle has been more closely related to the quantity of growing forage than total available forage (Bird et al., 1989; Minson, 1990). Heitschmidt et al. (1989) compared the nutritive quality of the available forage on midgrass prairie stocked at heavy and moderate rates. These researchers found that the nutritive quality of the standing crop was higher on the heavily stocked range than that on the moderately stocked range. Senescent forage on the moderately stocked range diluted nutrients in the standing crop. This point may lead one to believe that cows on the heavier stocking rate would perform better than cows grazing on the lighter stocking rate. However, because of reduced forage availability, intake was probably restricted even though quality was relatively high. During the winter, cows at the heavier stocking rate required 194% more supplement (20% CP) than cows at the lighter stocking rate to maintain similar levels of production/ha.

RUMINAL AND INTESTINAL FILL

Effects on intake: In the early 1960's, researchers were interested in the effects of diet digestibility on intake. The general premise was that forage intake should increase as diet digestibility increased until energy content of the forage was great enough that chemostatic mechanisms regulated intake (Fig. 2-1). Conrad et al. (1964) were among the first researchers to publish this concept. Montgomery and Baumgardt (1965) soon published data based on a similar concept. According to Conrad et al. (1964), the rate of passage of undigested particles from the rumen and the amount of undigested material in the digestive tract regulates feed intake until diet digestibility is approximately 66%. Above this percentage, intake supposedly is regulated by chemostatic mechanisms. These researchers reported a multiple correlation coefficient of .99 relating DM intake to body weight, fecal OM output per kilogram body weight, and diet digestibility. If digestibility and fecal output are known, intake may be calculated (Grovum, 1986). Because of the failure of regression analysis to account for 100% of the variation, Grovum (1986) stated that this high correlation coefficient does not support Conrad and his coworker's hypothesis. In contrast to Conrad et al. (1663), Ketelaars and Tolkamp (1992) evaluated the relationship between OM intake, digestible OM intake (DOMI) and OM digestibility of 831 forages with digestibilities ranging from 30 to 84% and nitrogen ranging from .3 to 5.6% of OM. They found that these data failed to fit the biphasic model suggested by Conrad et al. (1964). Intake failed to reach a satiation level at any point. One possible explanation for the biphasic model of Conrad et al. (1964) was that they used mixtures of forage and concentrate to adjust the digestibility of the rations. A compilation of feeding trials with sheep and cattle (Grovum, 1986) shows that digestible DMI often is lower when concentrates levels are very high rather than moderately high. Hence, intake responses observed by Conrad et al. (1964) may have been an artifact of the feedstuffs selected (Ketelaars and Tolkamp, 1992).

Egan (1974) fed sheep seventeen different forages, ranging in OM digestibility from 49 to 79% and ruminal apparent OM digestibility from 28 to 45%. The relationship between voluntary forage intake and ruminal OM digestion was weak (r^2=.23; Egan, 1977). This relationship suggested that factors in addition to digestibility were regulating forage intake and changed with forage quality (e.g., N content, ruminal fill, passage rate, level of satiety, rate of digestion, microbial protein synthesis).

Some investigators have suggested that the capacity of the postruminal tract limits emptying rate of the rumen. In 1947, one Australian worker stated that "intake of a sheep is governed not so much by the size of its mouth but by the size of its anus" (Owens et al., 1991). Similarly, other researchers have suggested that fecal output is relatively constant in cattle (Conrad et al., 1964; Ellis et al., 1983; McCollum and Galyean, 1985b; Grovum, 1986).

If fecal bulk limits intake, then an increase in fecal bulk should reduce intake. Grovum and Phillips (1978) used duodenal infusions of methylcellulose as a bulk laxative to test this hypothesis. The sheep fed chopped alfalfa (*Medicago sativa*) hay ad libitum and receiving 300 g methylcellulose/d more than doubled wet fecal output (from 2000 to 4500 g/d) but maintained their previous level of forage intake. Obviously, these sheep had a large excess capacity to transport bulk in the intestines. Later, the infusion of the methylcellulose was doubled (600 g/d) to estimate the upper limit to transport bulk. After initiation of the infusion, intake was reduced to prevent over loading of the intestines. In conclusion, intestinal transport of bulk was not limiting intake. Grovum and Phillips (1978) concluded that the bottleneck probably was at the reticulo-omasal orifice.

Some researchers have suggested that cattle eat to a constant fecal output. Ellis et al. (1983) reported that cattle grazing annual ryegrass (*Lolium multiflorum*) consumed forage to a constant fecal output (.84 g/kg BW). These data suggest that fecal output was constant, but the observations were made within a narrow range of forage digestibilities (65 to 75%) with cattle grazing a monoculture. This premise may not apply to cattle grazing lower quality forages or to cattle grazing a forage resource of mixed species. Based on data adapted from McCollum and Galyean (1985a), supplementation of cottonseed meal to cattle consuming a low quality hay increased fecal output. This response is consistent with regression equations developed by Owens et al. (1991). Owens and his coworkers found that higher nitrogen content in the total diet had a positive effect on total fecal output.

Feces produced by nitrogen deficient animals usually are dry. This dryness probably is due to reduced nitrogen and fluid influx from the body because of reduced osmotic pressure of the digesta (Owens et al., 1991). The conservation of nitrogen and subsequently water may be one of the factors regulating fecal output. Wet feces may flow through the intestines with greater ease and at a faster rate. However, intake of low-quality forages also might be depressed by an absolute nitrogen deficiency at the tissue level.

The intestinal capacity of sheep apparently does not limit intake. In grazing beef cattle, intestinal capacity probably does not limit intake although less data to support this conclusion exists.

Seasonal Effects: Cattle grazing rangeland in New Mexico had faster particle passage rate (%/h) and a shorter total tract mean retention time (h) in March than in February, while total intake tended to be lower in March than February (Judkins et al., 1987). The factor that allowed these cattle to maintain a high level of intake in February presumably was a tendency for greater gastrointestinal fill. In similar research, Krysl et al. (1987a), McCollum and Galyean (1985b), and Funk et al. (1987a) all noted that during periods characterized by slower particle passage rate, cattle tended to maintain intake by increasing gastrointestinal fill. Although information concerning digesta kinetics in grazing cattle is limited, these findings suggests that gastrointestinal fill may be a result, not a cause of level of intake. This information suggests that cattle will attempt to maintain intake and compensate for reduced particle passage rate by increasing gastrointestinal fill.

Fecal output varies greatly among diets that differ in forage quality. Krysl et al. (1987a) reported that cattle grazing blue grama rangeland in New Mexico had fecal outputs that ranged from 5.1 to 12.5 g OM/kg BW. McKown et al. (1991) reported that fecal outputs from cattle grazing midgrass prairie in central Texas ranged from 4.9 to 12.0 g OM/kg BW. In both reports, investigators associated high fecal output with high forage quality. McCollum and Galyean (1985b) noted that fecal output remained fairly constant over the entire grazing season (7.9 g OM/kg BW). The only exception was noted during late October (10.9 g OM/kg BW). These authors suggested that cattle consumed forage to a constant fecal output. The elevated fecal output during October was associated with a 76% increase in forbs in the diet (McCollum et al., 1985). Ingalls et al. (1966) suggested that because forbs and legumes fragment easily during comminution, digesta may pack more densely in the digestive tract and allow fill to increase at a similar volume. In the study by McCollum and Galyean (1985b), fecal volume may have been similar among months, while feces differed in density. Wet fecal volume rather than dry weight may be a controlling factor.

In the first year of a two year study conducted with steers grazing tallgrass prairie in Oklahoma from May through September, fecal output (% of BW) increased as the forage became more mature and less digestible (Campbell, 1989). However, during the second year of this study (Campbell, 1989), no change in fecal output was observed. Additionally, fecal output appeared to be greater (% of BW) for year 1 (.98) than year 2 (.77). Average body weight of the steers differed between years (Year 1, avg = 333 kg; Year 2, avg = 546 kg). Because, these cattle were in two different physiological states (growing vs. mature), they may have responded differently to changes in forage maturity.

RUMINAL FERMENTATION

Effects on intake: Ruminal microbes have specific nutrient requirements as do the host animals. A nutrient of major concern is nitrogen; it can be acquired from various sources: ammonia-nitrogen (NH_3N), amino acids, peptides, dipeptides, and various other non-protein nitrogen compounds. Ammonia-nitrogen is a key nutrient for ruminal bacteria. Many species fail to grow with amino acids as their sole nitrogen source (Bladen et al., 1961). Three potential responses to inadequate ruminal NH_3N concentrations include: 1) reduced rate of digestion, 2) reduced extent of digestion, and 3) reduced microbial protein synthesis. Models describing grazed forage intake constructed by Ellis (1978) suggest that rumen fill, particle passage rate, and rate of digestion regulate forage intake. When inadequate rumen NH_3N limits the rate of digestion, forage intake is reduced. Egan (1977) demonstrated that the yield of metabolizable N from the rumen also may affect intake. Thereby, reduced microbial protein synthesis may depress intake.

Several estimates of the minimum concentration of ruminal NH_3N have been published. Satter and Slyter (1974) determined that 2 to 5 mg/dl of NH_3N was needed for maximizing microbial protein synthesis. However, other researchers have reported optimums ranging from 2 to 22.1 mg/dl of NH_3N in vivo (Hume et al., 1970; Satter and Slyter, 1974; Allen and Miller, 1976; Slyter et al., 1979; Boniface et al., 1986). This wide range of values probably results from differences in criteria and substrates used to quantify these values. The estimate that is commonly quoted, 2 to 5 mg/dl of NH_3N (Satter and Slyter, 1974), was estimated in vitro and represents the value necessary for maximal microbial protein production. Recent work by Australian workers found that in situ digestion was optimal at 4.5 mg/dl of NH_3N (Boniface et al., 1986). Other researchers found that metabolizable nitrogen flow was maximized between 13 and 22 mg NH_3N/dl (Hume et al., 1970; Allen and Miller, 1976).

Studies from Australia have indicated that the minimum level of ruminal NH_3N needed to maximize voluntary intake of a low-quality forage is greater than the amount needed to maximize ruminal OM digestion. Boniface et al. (1986) adjusted NH_3N levels in the rumen of cattle by infusing urea. Forage digestibility (in situ) was maximized when NH_3N was below 10 mg/dl. However, forage intake continued to increase until ruminal NH_3N reached 20 mg/dl. The rate and potential digestibility of a forage plays an important role in forage intake regulation (Minson, 1982). Perhaps microbial protein synthesis (g/kg DOM) increased as ruminal NH_3N was elevated to 20 mg/dl. The additional flow of protein into the small intestine may have stimulated intake (Egan and Moir, 1965). Such an increase in microbial protein production may be particularly important for young growing ruminants that have higher protein requirements (Orskov, 1982).

Seasonal effects: Ruminal NH_3N during the grazing season decreases as forage matures (McCollum et al., 1985; McMeniman et al., 1986b; Funk et al., 1987a; Krysl et al., 1987b; Campbell, 1989). Early in the growing season, ruminal NH_3N appeared to be adequate in most studies reviewed (range: 6 to 24 mg/dl). However, as the grazing season advanced, NH_3N often decreased to levels below those suggested as necessary for optimal fiber digestion and microbial protein synthesis and far below levels that may be necessary to maximize forage intake (Satter and Slyter, 1974; Boniface et al. 1986).

Ruminal NH_3N originates from three sources: degradation of feed proteins, salivary urea, and flux across the rumen wall. Recycled nitrogen (salivary and ruminal influx) contributes to the total nitrogen available for microbial protein synthesis. The Subcommittee on Nitrogen Usage in the Ruminant (NRC, 1985) assumed that a mean of 15% of consumed nitrogen is recycled. This value was selected by fitting data from lactating dairy cows. However, it does not fit well with data from beef cattle consuming diets of 5 to 8% CP (NRC, 1985). With low-quality diets, the amount of nitrogen recycling should be much higher, although precise estimates are unavailable (Kennedy and Milligan, 1980). Additionally, nitrogen recycling may be reduced by the various metabolic pools or "sinks" for amino acids (for example, milk, animal, or fetal tissue).

In cases where cattle, especially growing and lactating cattle, are consuming forages low in CP, ruminal NH_3N may become limiting due to both a low supply of forage nitrogen and to increased sequestering of amino acids in specific metabolic pools. Reduced nitrogen recycling (g/d) to the rumen make the ruminal bacteria more dependent on nitrogen from degradation of forage protein. Scott (1987) noted that ruminal NH_3N concentration increased as dietary nitrogen increased (r = .91). Hume and Purser (1974), McMeniman et al. (1986b), and Barton et al. (1992) reported similar relationships between forage nitrogen content and ruminal NH_3N concentration. In addition to a reduced nitrogen content of more mature forages, ruminal nitrogen availability is limited further by a reduced ruminal nitrogen degradability (Scott, 1987; Campbell, 1989; Messman et al., 1992). If nitrogen in the rumen is insufficient relative to energy, bacteria may engage in a process referred to as "energy spilling" (Nocek and Russell, 1988). In this process ATP is no longer used efficiently for synthesis of bacterial cells.

POSTRUMINAL FACTORS

Effect of protein/energy ratio on intake: In some studies of protein supplementation, forage intake was increased without any change in rate or extent of ruminal digestion, particle passage rate, or both (Egan and Moir, 1965; Egan and Doyle, 1985; Krysl et al., 1987b; Hunt et al., 1989). Egan and Doyle (1985) and Krysl et al. (1987b) noted that the greater forage intake by protein-supplemented sheep was associated with increased ruminal fill. DelCurto et al. (1990) reported that ruminal DM fill increased 55% when protein was supplemented to cows consuming low-quality forage (.4% nitrogen). The volume of digesta in the rumen can change markedly along with lactation (Balch and Campling, 1962; Tolluh, 1966; Weston, 1982), improved nitrogen status (Egan and Moir, 1965; Egan, 1970; Garza et al., 1991), and longer day length (Milne et al., 1978; Forbes et al., 1981; Weston, 1982). If tension receptors in the rumen wall regulate intake, one would not expect fill to increase despite an altered physiological or nutritional status (Grovum, 1986). Instead, the balance between supply and demand for nutrients may regulate intake.

Protein supplementation can alter metabolizable nitrogen yield from the rumen. When protein supplements were included as 12% of a bromegrass hay (.7% nitrogen) diet for beef cows, non-ammonia nitrogen flow from the rumen increased 22% (Moberg et al., 1989). Nitrogen flowing to the duodenum and OM intake increased linearly when cows consuming prairie hay (.6% nitrogen) were supplemented with four different levels of protein (39 to 121 g nitrogen; Scott, 1992). The lowest amount of supplementation (39 g nitrogen/d) increased the flow of microbial protein from the rumen; higher amounts up to 121 g nitrogen/d failed to increase microbial protein flow (Scott, 1992). The lack of a continuous response possibly was due to limited energy availability in the rumen. When Egan and Doyle (1985) infused urea into the rumen of sheep consuming a low-quality oat hay (.8% nitrogen), ruminal fill increased 35% even though ruminal digestion was unchanged. They attributed this increase in ruminal fill to a 59% increase in non-ammonia nitrogen flowing to the small intestine.

One proposed mode of action by which the protein/energy (P/E) ratio may stimulate intake is through an increased efficiency of metabolizable energy use (MacRae and Lobley, 1982). Efficient use of acetate requires adequate amounts of glucogenic substrates (Egan, 1965; Annison and Armstrong, 1970; Tyrrell et al., 1978). Propionate and amino acids will provide glucogenic carbon chains required for glycerol synthesis and reduction of NADP to $NADPH_2$ (Zubay, 1989). Infusing protein into the small intestine or feeding escape protein has improved energetic efficiency (Barry et al., 1982; MacRae et al., 1985; Hoagland et al., 1988). Although the underlying mechanisms are not understood, they may involve reduced heat loss from futile cycling (Tolkamp and Ketelaars, 1992) and increased tissue protein synthesis stimulated by the elevated amino acid supplies (Barry et al., 1982; Orskov, 1982; Gill et al., 1984). In models constructed by Tolkamp and Ketelaars (1992), additional nitrogen increased the predicted intake of forages with similar ME. The authors suggested that this increase in intake probably was due to more efficient use of ME.

These studies indicate that metabolizable nitrogen yield from the rumen may play an important role in the regulation of intake. Forage intake and animal performance responses to increased metabolizable nitrogen supply may result from the correction of a P/E imbalance in absorbed nutrients (McCollum and Horn, 1990). As forage matures, nitrogen content declines, the P/E ratio in absorbed products usually decreases and forage intake declines.

The P/E balance in absorbed products appears to be important in the regulation of intake (Leng, 1990). Increasing the P/E ratio of metabolites absorbed from the intestine has increased intake (Egan and Moir, 1965; Egan, 1977). In a study examining intake of 17 different forages that varied widely in quality, the P/E ratio, expressed as grams protein digested in the small intestine/MJ DE, accounted for more of the variation (r^2=0.85) in forage intake by sheep than did OM digestibility (r^2=0.67; Egan, 1974). The greatest rate of change in intake, occurred at P/E ratios between 4 and 7.

An unbalanced P/E ratio may be corrected by providing a ruminal degradable supplement to stimulate microbial protein production or by supplementing with a ruminal escape protein. Casein infused into the duodenum of sheep increased intake when the basal forage diets produced between 3 and 6 g metabolizable protein/MJ DE absorbed (Fig. 2-2). The P/E in the basal forages ranged from 3.4 to 8.4 g protein/MJ DE. Final P/E ratios, adjusted for both infused casein and additional forage intake, ranged from 7.4 to 9.3 (Fig. 2-3). Based on these findings, Egan (1977) concluded that if forages have P/E ratios lower than 6.0, protein absorption was inadequate which in turn suppressed forage intake and nitrogen retention. Increasing the postruminal protein supply should improve animal performance by elevating forage intake. At ratios greater than 7.5, it may be possible to improve performance by supplying additional protein to the small intestine but the response increment would be smaller due to the lack of a substantial increase in forage intake.

The concepts of Egan (1977) can partially explain the variation in forage intake response to supplementation. The varied intake responses following protein supplementation of forages with similar protein concentrations probably is associated with varied degrees of energy and protein availability (McCollum and Horn, 1990). As the forage protein content increases, the P/E ratio will approach 7.5. As forage matures, the nitrogen content drops more than digestibility;

hence, the P/E ratio will decline as content of the forage declines. The lack of response to supplemental protein on some low-quality forages also may be explained by low digestible OM (DOM) content of the forage yielding P/E ratios near or above 7.5 despite a low protein content.

The greatest problem limiting the application of the concepts of Egan (1977) to grazing animals is a lack of sufficient data relative to energy and protein yields from native and introduced forages. Few studies have quantified the variables used by Egan (1977) in a grazing environment. Most of the work conducted in the United States on nitrogen digestion and ruminal nitrogen yields has been conducted with diets containing large amounts of concentrates or on forages of a higher quality than normally available on range or pasture. Some recent research has characterized forage composition/nutrient flow relationships in cattle and sheep grazing pasture and rangelands (McMeniman et al., 1986a,b,c; Funk et al., 1987a,b; Campbell, 1989).

Seasonal effect on P/E ratios: Limited information is available on site and extent of digestion of range and pasture forages in grazing livestock. To estimate the effect of absorbed P/E ratios on forage intake, two variables must be quantified: non-ammonia nitrogen flow from the rumen and digestible energy intake.

To predict non-ammonia nitrogen flowing from the rumen, one must know microbial protein yields from the rumen. Several relationships have been developed and used in nitrogen requirement models (NRC, 1985; ARC, 1980). Some field studies are available that allow more specific applications and development of the regression models (McCollum, 1991; Funk et al., 1987a,b; McMeniman et al., 1986a,b,c).

Presented in Tables 2-1 and 2-2 are the P/E ratios from three experiments (Funk et al, 1987b; Campbell, 1989; Scott, 1992). To calculate these ratios, three assumptions were made: first, 1 kg of digestible OM equals 1 kg of TDN (NRC, 1985); second, 1 kg of TDN equals 4.4 Mcal of DE (Schneider and Flatt, 1975); finally, in Table 2-1, digestibility of non-ammonia nitrogen was assumed to be 58.9% (Funk et al., 1987b).

The P/E ratios absorbed by cattle grazing blue grama rangeland were fairly constant among months (Table 2-1). These ratios were in the range absorbed protein should limit intake.

Egan (1977) developed this range of ratios with sheep in confinement. Grazing ruminants may tolerate a lower P/E ratio because of their higher energy requirements for maintenance (McMeniman et al., 1986b). If a grazing animal used a higher percentage of absorbed energy for maintenance, protein requirements would be reduced because less energy is available for gain (NRC, 1984).

Cattle grazing tallgrass prairie (Table 2-1) had much higher P/E ratios than cattle on blue grama rangeland. Unlike the cattle grazing blue grama rangeland, these cattle had P/E ratios well above 7.4. Egan (1977) suggested that this point is where the positive forage intake response to protein supplementation diminishes. One other item to note in Table 2-1 is that September, forage intake decreased even though the P/E ratio increased. This increase in the P/E ratio is the result of a reduced DE intake. If forage intake by cattle grazing tallgrass prairie during the summer follows the hypothesis of Egan (1977), improved gain associated with protein supplementation (McCollum and Lusby, 1989) may not result from increase forage intake but result from increased efficiency of ME utilization.

The last study reviewed was conducted by Scott (1992; Table 2-2). This study differs from Funk et al. (1987a,b) and Campbell (1989) because it was conduced with cattle fed hay in confinement. Scott (1992) fed the cattle a low-quality forage (.6% nitrogen), supplemented with combinations of soybean meal and soybean hulls so that equal weights of supplement provided either 39, 65, 95, or 121 g of nitrogen. The control cattle received no supplement. When the cattle were given 39 g nitrogen, intake increased so that the P/E ratio was unchanged. However, as the supplement was increased from 39 to 121 g of N, the P/E ratio increased from 4.53 to 6.59. Scott (1992) also reported a linear (P=.0001) increase in total OM intake. In this study, the cattle were responsive to changes in the P/E ratio. Also, these P/E ratios are much lower than those in Tables 2-1.

CONCLUSIONS

Ruminal fill may be important in the regulation of forage intake. But, cattle and sheep probably will not consume forage to a point of maximum rumen fill unless the amount of protein and energy in absorbed nutrients are adequate.

A low P/E ratios can be corrected by protein supplementation. More research is needed to determine the proper P/E ratios to maximize intake and rumen microbial protein yields in cattle grazing different forages. Additionally, the microbial protein yields from range and pasture forages require further investigation. Quantitative measures of the effect of both forage maturity and forage type on microbial protein yield are lacking. With a better understanding of these variables, more appropriate supplements can be designed.

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TABLE 2-1. VARIABLES AFFECTING INTAKE BY CATTLE GRAZING BLUE GRAMA (Funk et al., 1987b) AND TALLGRASS PRAIRIE (Campbell, 1989) RANGELAND DURING THE SUMMER

	Month			
Item	Early-June	Late-June	July	August
Blue grama rangeland				
OM intake, g/kg BW	25.0	27.0	26.0	26.7
DOMI[a], g/kg BW	15.9	15.5	16.4	17.4
DE intake, MJ/kg BW	.292	.285	.302	.319
CP absorbed from the small intestine, g/kg BW	1.53	1.68	1.36	1.83
P/E ratio[b]	5.24	5.89	4.50	5.74
Tallgrass prairie rangeland	Month			
	May	June	August	September
OM intake, g/kg BW	20.5	21.1	20.9	18.7
DOMI[a], g/kg BW	12.0	11.8	10.8	7.6
DE intake, MJ/kg BW	.220	.217	.199	.139
CP absorbed from the[c] small intestine, g/kg BW	2.06	1.74	1.73	1.34
P/E ratio	9.36	8.01	8.69	9.64

[a] Digestible OM intake.
[b] Grams of protein absorbed from the small intestine/MJ DE.
[c] Metabolizable protein flowing from the rumen was assumed to be 58.9% digestible in the small intestine (Funk et al., 1987b).

TABLE 2-2. VARIABLES AFFECTING INTAKE BY CATTLE SUPPLEMENTED WITH FOUR LEVELS OF NITROGEN (Scott, 1992)

Item	g · Supplemental Nitrogen^{-1} · d^{-1}				
	Control	39	65	95	121
OM intake, g/d	3861.8	6954.4	7997.3	9090.8	8676.4
DOMI[a], g/d	1818.8	3797.6	4510.1	5252.4	5066.0
DE intake, MJ/d	33.5	69.9	83.0	96.7	93.3
CP absorbed from the small intestine, g/d	160.0	316.8	468.8	558.1	615.0
P/E ratio[b]	4.77	4.53	5.64	5.77	6.59

[a] Digestible OM intake.
[b] Grams of protein absorbed from the small intestine/MJ DE.

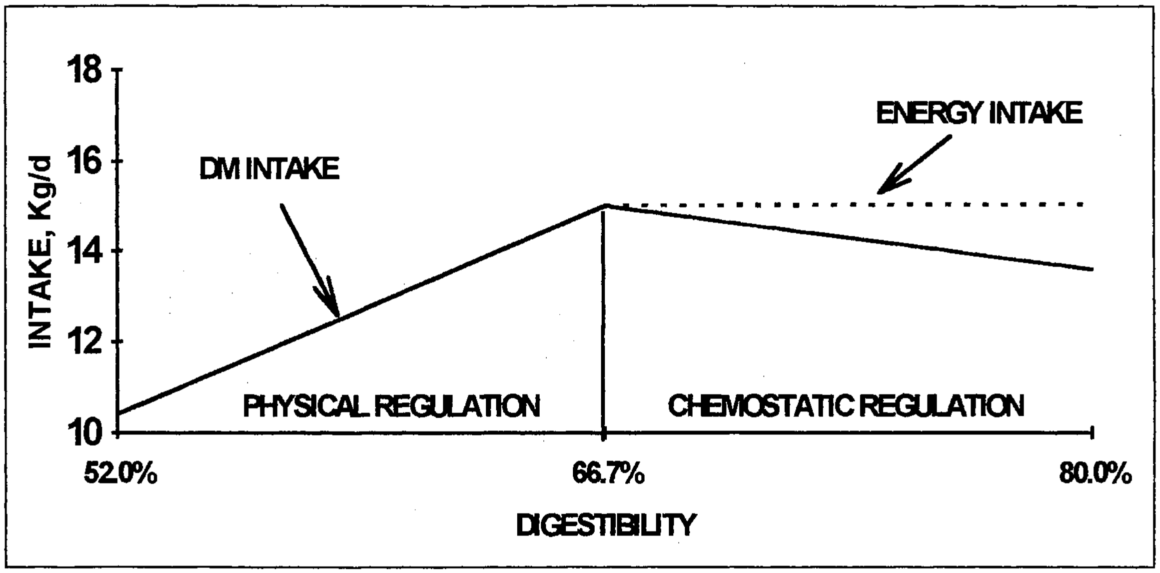

Figure 2-1. Effect of increasing diet digestibility on voluntary intake by ruminants (adapted from Conrad et al., 1964). Point of inflection is at 66.7% digestibility.

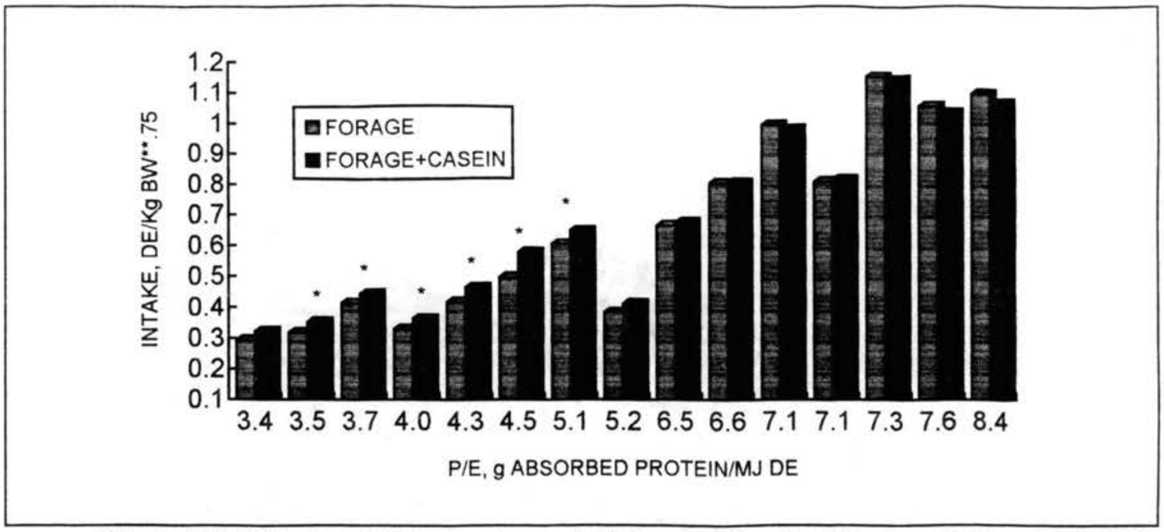

Figure 2-2. Voluntary intake by sheep, before and after the infusion of 40 g casein into the duodenum, of forages providing different ratios of protein and energy absorbed in the small intestine (adapted from Egan, 1977).

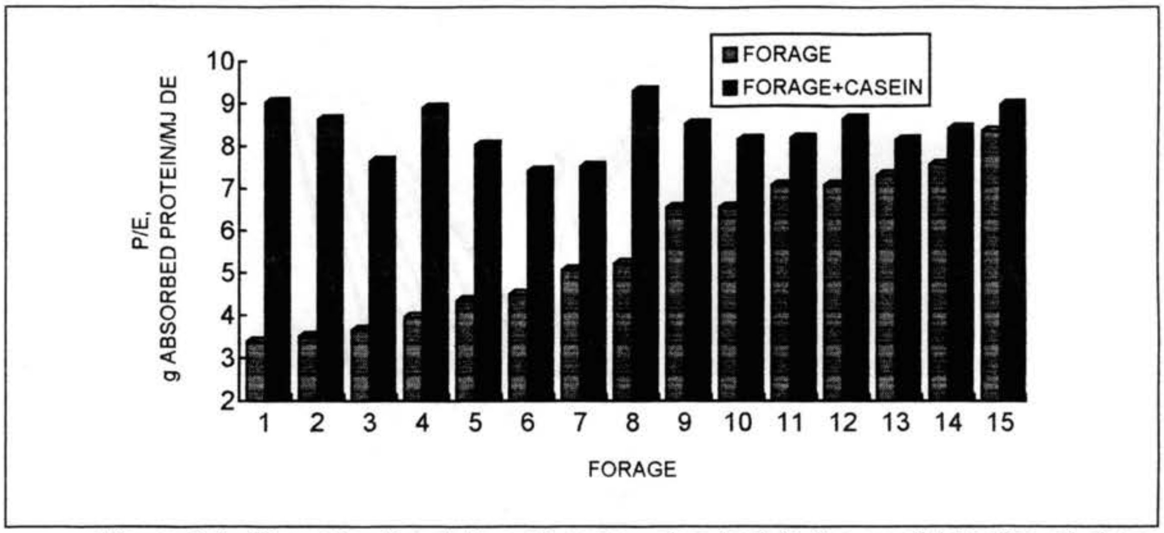

Figure 2-3. The ratio of protein and energy absorbed in the small intestine of sheep consuming forage at will before and after infusing 40 g of casein into the duodenum (adapted from Egan, 1977).

CHAPTER III

DIET QUALITY AND RUMINAL DIGESTION IN BEEF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND AND PLAINS BLUESTEM THROUGHOUT THE SUMMER[1]

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ABSTRACT: Beef cattle fitted with esophageal (4 hd/pasture) or ruminal cannulae (6 hd/pasture; beginning avg BW=274) grazed either midgrass prairie rangeland (PRAIRIE) or Plains bluestem (*Bothriochloa ischaemum* var. Plains) pasture (PLAINS) during mid-May, late June, mid-August, and mid-October of 1990 and 1991. The range site was in excellent range condition. The PLAINS contained approximately 10% Russian thistle during 1990; however, during 1991 the thistle content was negligible. Nitrogen (N) in masticate samples collected from PRAIRIE was lowest ($P<.05$) in June and August across both years. However, during 1990 the N in PLAINS masticate peaked ($P<.05$) in August, but during 1991 N content was lowest ($P<.05$) in August. The detergent fiber content of masticate from both sites increased ($P<.05$) as the grazing season advanced from May through August. In some instances, fall regrowth in October resulted in a small reduction ($P<.05$) in the fiber content of masticate. Over the grazing season, in vitro OM disappearance (IVOMD) followed a pattern similar to N content in masticate samples. The IVOMD of PLAINS masticate was always greater ($P<.05$) than for PRAIRIE

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[1] Journal article No. XXXX of the Oklahoma Agricultural Experiment Station.
[2] Animal Science Department.
[3] We thank Maria Mottola for assistance with the laboratory analysis and Matt Cravey, Jackie Hogue, Mike Lohman, Twig Marston, Juan Mieres, Mike Van Koevering, and Gary Zeihe for assistance with the collection of the samples.
[4] Department of Agronomy, Range Scientist.

masticate. Ruminal ammonia N (NH_3N; mg/dl) in cattle grazing PRAIRIE was different ($P<.05$) from other months in August and October of 1991 (1.2 and 8.3, respectively); the remaining months were similar ($P>.05$; avg=2.8). The ruminal NH_3N in cattle grazing PLAINS during 1990 was highest ($P<.05$) in August (9.0) and lowest ($P<.05$) in June (3.6). During 1991, ruminal NH_3N was highest ($P<.05$) in May (7.1) then decreased ($P<.05$) through October (1.0). The ruminal NH_3N in cattle grazing PLAINS usually was higher ($P<.05$) than in cattle grazing PRAIRIE. The extent of in situ OM and N disappearance was usually lowest ($P<.05$) during June and August when masticate quality was poorest except for PLAINS during 1990 which peaked ($P<.05$) in August. The rate of in situ OM disappearance was similar ($P>.05$) among months and among forages except for PRAIRIE being higher ($P<.05$) in May of 1990. The rumen degradable N:rumen digestible OM ratio estimated from in situ digestion suggested that cattle grazing PRAIRIE during both years and PLAINS during 1991 may have benefited from rumen degradable N supplementation from June through August. Plains bluestem would be preferred for mid-summer grazing, while PRAIRIE appears to be preferable in the spring and fall.

(KEY WORDS: Rangelands, Grazing, Nitrogen, Rumen Digestion, Cattle)

Introduction

Native range and Old World Bluestems are the two primary forage resources for beef cattle production in southwestern Oklahoma. Plains bluestem (*Bothriochloa ischaemum* var. Plains; PLAINS) was introduced to the Southern Plains in 1972 and has been promoted as a complementary forage to native range for integrated forage-livestock systems (Taliaferro et al., 1972; Sims and Dewald, 1987). One unique quality of PLAINS is that spring growth begins later than midgrass prairie (PRAIRIE) and the majority of growth occurs in the summer when PRAIRIE growth has slowed (Taliaferro et al., 1972).

Cattle grazing native and introduced grasses may require nutrient supplementation to optimize animal performance during mid- to late-summer (Campbell, 1989; Funk et al., 1987; McCracken et al., 1990; Park et al., 1989; Torell et al., 1991; Brandyberry et al., 1992).

Considering the differences in growth curves for PRAIRIE and PLAINS, having cattle graze PLAINS rather than PRAIRIE during the summer (July through August) may be an economical alternative to supplementation. In addition, using PLAINS as a complement to PRAIRIE would increase carrying capacity. Further, well-managed seedings of Old World Bluestems can produce four times more forage than native rangeland (Coyne and Bradford, 1985).

This study was conducted to evaluate differences between PRAIRIE and PLAINS in diet quality, ruminal fermentation, and in situ disappearance of OM and nitrogen (N) in cattle.

Material and Methods

Research Site: This study was conducted at the Marvin Klemme Range Research Station in Washita County, OK (35° 22' N, 99° 04' W). The station is located in the Rolling Red Plains resource area (SCS, 1982). Soils on the range area were in the Cordell Series and are mapped as Red Shale range sites. The 48.6 ha of PRAIRIE never has been cultivated. The 6.5 ha of PLAINS was established in 1989 on a site with a St. Paul silt loam soil. Precipitation from January through October at Clinton, OK, approximately 16.1 km north of the station, was 77 cm (Fig. 3-1a; avg=70 cm) in 1990 and 63 cm (Fig. 3-1b) in 1991.

Fertilization of the PLAINS was the only pasture management practice implemented. In 1990, the PLAINS was fertilized on July 26 with 68 kg of N and 49 kg of phosphorus/ha. During 1991, 47 kg of N/ha was applied on May 1.

Sampling Procedures: Four trials were conducted in 1990 and 1991. Trial dates during 1990 were in mid-spring (9 May to 20 May), mid-growing season (20 June to 1 July), mid-summer dormancy (8 August to 19 August) and fall growing season (8 October to 19 October). Because of winter kill in 1990, the PLAINS was allowed to recover until mid-June before grazing was initiated. Therefore, the mid-spring trial in 1990 does not include PLAINS. Trial dates during 1991 were 10 May to 21 May, 22 June to 2 July, 12 August to 22 August, and 5 October to 15 October.

Standing crop was estimated during each sampling period by clipping forage to the ground inside 0.1 m quadrats (n=40, PRAIRIE; n=20, PLAINS) along paced transects. Herbage samples were individually weighed in the field then dried to a constant weight. Four samples from each pasture were hand separated into live and dead fractions and processed as described above. Live:dead ratios in the remaining clipped samples were estimated using simultaneous equations relating total sample DM to DM of the live and dead fractions (Gillen and Tate, 1993). The dry weight-rank method (Gillen and Smith, 1986) was used to estimate species composition of both pastures. Russian thistle was included in measurements on the PLAINS pasture in June and August of 1990. Cattle readily consumed the plant during these trials. In October, Russian thistle had matured and cattle did not graze it. Therefore, it was not included in estimates of available forage during October of 1990.

Four steers fitted with esophageal cannulae were allowed to graze each pasture for 1 wk before diet sampling. Masticate samples were obtained from each pasture on two consecutive days, starting on d-1 of each sampling period. The steers were fitted with screen-bottom collection bags and allowed to graze for 30 to 45 minutes. Steers were herded as they grazed in order to obtain a more uniform sampling of the entire pasture. After collection, samples were mixed by hand and a 20% aliquot was stored frozen in a plastic bag. Prior to laboratory analysis, these aliquots were composited across days within steer, lyophilized[5], and ground in a Wiley mill through a 2-mm screen. The remaining masticate samples were composited across steers and days and used for substrates for in situ digestibility measurements. This masticate was dried in a forced air oven at 30° C. The samples were spread thinly and mixed frequently during drying to reduce artifact lignin formation (Broesder et al., 1991). After drying, the masticate was ground in a Wiley mill through a 2-mm screen.

Six ruminally and duodenally cannulated cattle (1990, British x British heifers, avg initial BW=274 kg; 1991, British x British steers, avg initial BW=259 kg) were allowed to graze

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[5] Virtis Freeze Drier. Model 10-100V, Virtis Corp., Gardiner, NY.

PRAIRIE and PLAINS during the entire grazing season. Cattle had ad libitum access to water and mineralized salt[6].

Samples of ruminal contents were obtained on d 5 and 6. Samples were taken at sunrise, midday and dusk with times alternating by pasture. Ruminal pH was determined then all samples were strained through four layers of cheese cloth, acidified with 1 ml of 7.2 N H_2SO_4/100 ml of ruminal fluid, and stored frozen.

Beginning on d 8, duplicate 10 x 20 cm polyester bags (pore size = 53$\pm$10 microns) containing 5 g of esophageal masticate were suspended in the rumen of each animal for 72, 48, 36, 24, 16, 12 and 6 h. Following removal on d-11, bags were rinsed with cold tap water until effluent was clear; bags were dried at 100^{o} C

Laboratory Analyses: Masticate samples were analyzed for DM and ash (AOAC, 1991), NDF and ADF (Goering and Van Soest, 1970) and Kjeldahl N (AOAC, 1991). Nitrogen content was fractioned into soluble and insoluble N by pepsin digestion (AOAC, 1991). Residue remaining in polyester bags after in situ digestion was analyzed for DM, ash and N. In vitro organic matter disappearance (IVOMD) from masticate was determined as described by Tilley and Terry (1962). Incubation tubes were inoculated with a 50:50 mixture of rumen fluid and McDougall's buffer containing urea. Ruminal fluid was collected from ruminally cannulated heifers maintained on a 50% alfalfa:50% prairie hay diet. Ruminal samples were thawed at room temperature and centrifuged at 10,000 x g for 10 min. Supernatant was analyzed for NH_3N by the procedure of Broderick and Kang (1980).

Calculations: In situ rate of OM and N digestion was calculated using the methodology described by Mertens and Loften (1980). Rate of digestion and diet composition data were analyzed as a split-plot; the model contained year and pasture in the main-plot and period in the sub-plot. The error term used for year and pasture was year x pasture and the residual error

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[6] Contained (% of DM): 20.5% NaCl, 16.5% Ca, 8% P, .02% I, trace minerals, 44,000 IU vit. A/kg, and 22,000 IU vit D_3/kg.

term was used to test the remaining factors (Lentner and Bishop, 1986). Least squares means were separated using the lsd procedure (Lentner and Bishop, 1986).

Results and Discussion

Standing Crop: Standing crop on PRAIRIE increased from May until August, then decreased slightly in October during both years (Table 3-1). Residual standing crop estimates were higher than the average range site potential (between 672 and 1568 kg/ha; SCS, 1982). Forage availability should not have limited intake during any month.

Total standing crops on the PLAINS in June and August were similar to that available on PRAIRIE (Table 3-1) with exception of June of 1991. This difference in June probably resulted from the fertilizer application in May. In the fall, standing crop on PLAINS tended to be greater than on PRAIRIE. This characteristic probably resulted from the higher growth rate of Plains bluestem plants than midgrass prairie plants in the fall (Taliaferro et al., 1972).

Species Composition: Species composition of the PRAIRIE indicated the site was in excellent range condition (Table 3-1). Forbs composed 12 to 27% of the total standing crop until October. The reduction of total forbs in October would be the result senescence as the plant community entered early dormancy. Purple locoweed (*Astragalus mollissimus*) accounted for only 1% of the total available herbage in May, but the esophageal masticate contained 23% locoweed (Gunter et al., 1993). Ralphs et al. (1986) reported that cattle preferentially grazed White locoweed (*Oxytropis sericea*), especially the pods and flowers, from high mountain pastures in Utah.

In 1990, live:dead ratios on PRAIRIE decreased as the grazing season advanced from May until August (Table 3-1). In October, live:dead ratios increased slightly due to fall regrowth. However, in 1991, the live:dead ratios remained relatively constant through the entire grazing season.

In October 1990, the large increase for Plains bluestem to the pasture composition probably was due to the recovery from winter kill and exclusion of Russian thistle from standing crop estimates. In 1991, the forb content of the pasture decreased as the grazing season advanced.

This decline probably was due to the ability of Plains bluestem plants to successfully compete with other plant species (Dalrymple, 1990). Live:dead ratios on PLAINS increased as the grazing season advanced (Table 3-1) in 1990 but decreased in 1991. This change probably was due to the application of N in 1990 in July while N was applied in May during 1991.

Masticate Composition: The N content of PRAIRIE masticate decreased ($P<.05$) from May to mid-summer during both years (Fig. 3-2) then increased ($P<.05$) in October. The N requirement of a 272 kg medium-frame steer gaining .9 kg/d is 1.7% of DM (NRC, 1984). Percent N in the PRAIRIE masticate met this NRC requirement every month except in June of 1990 and August of 1991. Stocker steers (205 kg initial wt) grazing adjacent PRAIRIE gained .8 kg/d from May until July 15 and .9 kg/d from July 16 until September 15 during 1990 (McCollum and Gillen, unpublished data).

Plains bluestem masticate contained more ($P<.05$) N than PRAIRIE during all months in 1990. Masticate N content on PLAINS peaked ($P<.05$) in August (Fig. 3-2). During 1991, PLAINS masticate N followed a pattern similar to PRAIRIE. However, PLAINS provided more ($P<.05$) N during all months except October. The dissimilar pattern of N between years resulted from two factors. First, Russian thistle was prevalent in June and August of 1990 (Table 3-1). Based on hand-clipped samples, Russian thistle contained 4.3 and 4.4% N in June and August of 1990, respectively. The concentration of Russian thistle in the masticate samples appeared disproportionately high. Second, fertilizer was applied 20 d before diet sampling in August of 1990 and May of 1991. The N content of growing forage peaks about 3 wk after fertilizer is applied (Minson, 1990).

Pepsin insoluble N (PIN) is an index of N digestibility and heat damage (Goering et al., 1972; Beever et al., 1976). In June of 1990, the level of PIN in the masticate (Table 3-2) exceeded 50% of the total N for both forage types. Before this collection, daily temperatures had exceeded 30° C (Fig. 3-1). Researchers have shown that drying clipped forages samples at high temperatures will reduce N digestibility (Beever et al., 1976: Goering et al., 1972). Perhaps this same reaction can occur at high environmental temperatures while plants are becoming senescent. Pepsin insoluble N, as a percent of total N, was not related ($r = -.12$) to total N. Correlation analysis showed that PIN accounted for 80% of the variation of in situ N disappearance at 24 h of incubation. The regression relationship between the extent of in situ N disappearance at 24 h (EXT) and PIN was ($s_{y \cdot x}$=9.3, r^2=.64):

$$EXT = 133 - 1.66\ PIN$$

This equation implies that for each gram of added PIN, in situ N availability decreased by 1.66 g.

During both years, NDF and ADF on PRAIRIE followed similar patterns as the grazing season advanced. Both fractions increased ($P<.05$) from May through June then remained constant ($P>.05$) for the remainder of the grazing season (Table 3-2). During 1990, PLAINS masticate contained less ($P<.05$) NDF and ADF than PRAIRIE in all months except October ($P>.05$). During 1991, the fiber content was similar ($P>.05$) between forages.

In vitro OM disappearance from PRAIRIE masticate (Fig. 3-3) was moderately correlated with ADF content ($r = -.63$). In vitro OM disappearance decreased ($P<.05$) 8 percentage units from May to June, then remained constant ($P>.05$) throughout the rest of the grazing season (Table 3-2). Acid detergent fiber content of PRAIRIE masticate was 7% higher in June than May. Plains bluestem pasture masticate was more ($P<.05$) digestible in vitro than PRAIRIE masticate during both years (Fig. 3-3). These differences in digestibility suggest that cattle grazing PLAINS may perform better than cattle grazing PRAIRIE. At the Marvin Klemme Range Research Station, steers grazing PLAINS grained weight 29% faster than steers grazing PRAIRIE (.9 vs. .7 kg/d, respectively) despite the fact that steers grazing PLAINS were stocked at a higher rate (.6 vs. 1.8 ha/steer, respectively; McCollum and Gillen, unpubl. data).

Ruminal fermentation: During 1990, ruminal NH_3N concentration in heifers grazing PRAIRIE was similar ($P>.05$) across months (Table 3-3). However, during 1991, ruminal NH_3N was depressed ($P<.05$) in August but increased ($P<.05$) in October. During 1990, ruminal NH_3N concentration on PLAINS peaked ($P<.05$) during August when masticate N was highest. During 1991, ruminal NH_3N concentration decreased as the grazing season advanced. The levels of ruminal NH_3N were within ranges suggested to be optimal for microbial protein synthesis

(Peterson, 1987; Hoover, 1986; Slyter et al., 1979). Total diet N (% of OM) was poorly related to ruminal NH_3N concentration (r = -.10). The low ruminal NH_3N noted in cattle grazing PLAINS in October of 1991 possibly resulted from high utilization in the rumen due to the higher forage digestibility (NRC, 1985).

Ruminal pH remained fairly constant and near an optimum for fiber digestion over the entire grazing season for cattle grazing either forage (Table 3-3; Orskov, 1982; Van Soest, 1982; Hoover, 1986). Ruminal pH was similar to values reported by other researchers (McCollum et al., 1985; Funk et al., 1987; Krysl et al., 1987). Hoover et al. (1984), in an in vitro continuous culture system, found that a pH of 6.5 was optimal for extent of fiber and OM digestion.

In situ OM disappearance from PRAIRIE masticate was greatest ($P<.05$) during May (Table 3-4). As the grazing season progressed, in situ OM disappearance decreased (Fig. 3-4). However in October, fall regrowth contributed to an increase ($P<.05$) in in situ OM digestibility. During 1990, in situ OM disappearance from PLAINS masticate increased ($P<.05$) from June to August (Fig. 3-4). However, during 1991, in situ OM digestibility decreased ($P<.05$) from June to August. This disagreement between years probably resulted from differences between N and NDF contents of the masticate that are associated with timing of N fertilization (Fig. 3-2; Table 3-2). Also, with the exception of October, in situ OM disappearance from PLAINS masticate generally was higher than from PRAIRIE masticate. This potential for a higher ruminal digestibility would increase the ruminal requirement for rumen degradable N (RDN; NRC, 1985; Owens et al., 1991).

The in situ degradability of N in PRAIRIE masticate followed a pattern similar to in situ OM disappearance (Table 3-5; Fig. 3-5). Degradability at 16 h was similar to values reported by Nebraska researchers for cattle diets collected from mixed stands of big bluestem and switchgrass (48%; Hafley et al., 1990), but somewhat lower than for bromegrass hay (71%; Wilkerson and Klopfenstein, 1991). Karges et al. (1992) reported that in Nebraska the N disappearance from masticate collected by cattle grazing sandhills rangeland from June through August was 79.1% at 16 h. Nitrogen degradability from tallgrass prairie masticate tended to be lower than our estimates (Campbell, 1989). During June of 1990, the in situ N degradability was severely depressed. The decrease at that time may have resulted from the extremely hot weather (Fig. 3-1). Burritt et al. (1988) and Broesder et al. (1992) reported that the heating of masticate decreased its N solubility and IVOMD because of Maillard product formation. Daily high temperatures before this sampling period exceeded 39° C, Maillard product formation can occur in samples at temperatures as low as 40° C (Van Soest, 1982). Perhaps this same reaction occurs in unclipped plants. In support of this view, in August of 1991, even though the N content of masticate was lower than in June of 1990, in situ N degradability was higher (Fig. 3-5). Average daily temperatures preceding this period had been lower than temperatures in June of 1990 (Fig 3-1).

Rate of OM disappearance from masticate was similar ($P>.05$) between years, forage types and among most months (Table 3-4). One exception was the faster rate observed for PRAIRIE diets in May of 1990. The lack of a difference in rate of disappearance also has been reported by Campbell (1989) and Funk et al. (1987). The rate of N disappearance (Table 3-5) was moderately correlated ($r = .67$) with extent of N disappearance.

Ratios of RDN to rumen digestible OM (RDOM) were calculated from the in situ data (Gunter and McCollum, 1991; Fig. 3-6). The NRC (1985) suggested that 26 g RDN/kg RDOM is required to optimize microbial protein synthesis. Ratios estimated for PRAIRIE ranged from 9 to 21 while PLAINS ranged from 11 to 31. These estimates do not include recycled N. Ratios are higher than estimates reported for cattle grazing tallgrass prairie (Gunter and McCollum, 1991). The higher ratio for PLAINS suggests that the amount of supplemental RDN needed is lower than for PRAIRIE. Cattle grazing forages with ratios below 20 may benefit from increased fiber digestion and increased microbial protein synthesis if a RDN source is provided. Despite conservation of urea from the kidney and its transfer to the rumen and hydrolysis to ammonia, animals on low N diets (i.e., <20 g N/kg RDOM) may have an insufficient capacity to recycle N (McMeniman and Armstrong, 1977; Nolan et al., 1986).

The PLAINS appears to complement PRAIRIE during the summer grazing season. These two forages fit the nutritional requirements of complementary forages (Nichols and Clanton, 1987). In June and August while PRAIRIE is in summer dormancy, PLAINS provided more dietary N and N that was more available in the rumen. Also, during this same period, PLAINS provided a more digestible diet than PRAIRIE. The higher ruminal OM disappearance along with higher ruminal N availability should supply more metabolizable N for grazing cattle.

Complementing the summer characteristics of PLAINS, PRAIRIE provided diets in May and October that were high in N and IVOMD. Nutrients in these diets were readily degraded in the rumen and should provide adequate amounts for the microbial population.

Implications

Managers using PRAIRIE and PLAINS as complements, should graze PRAIRIE during the spring and fall and graze PLAINS during the mid-summer. This grazing schedule would use the higher nutritional value of PLAINS during the mid-summer and allow the PRAIRIE to rest. This should reduce supplementation costs and improve animal performance.

Supplements for cattle grazing either forage type should focus on energy, but provide sufficient RDN. Energy in the total diet appears low in relation to protein (Allden, 1981). Therefore, energy supplementation may improve the performance of cattle grazing either forage type. The in situ digestion data suggest that the ruminal bacteria in cattle grazing either forage type were N deficient during June through August (Nolan et al., 1987). Supplements for the cattle must contain an adequate RDN/RDOM to maintain optimal microbial protein synthesis. When protein is high relative to energy in the diet, protein will be metabolized for energy (Clanton and Zimmerman, 1971). Additional energy should promote N retention and increase gain efficiency as long as supplement levels are maintained at a low enough rate to avoid substitution (Lake et al., 1974).

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TABLE 3-1. STANDING CROP AND SPECIES COMPOSITION OF MIDGRASS PRAIRIE RANGELAND AND PLAINS BLUESTEM PASTURE

	Month							
Species	May		June		August		October	
Year	1990	1991	1990	1991	1990	1991	1990	1991
Midgrass prairie rangeland								
Total available DM, kg/hectare	1685	2161	1924	1984	2369	2145	1723	1974
	%							
Sideoats grama	21	13	28	19	26	28	28	21
Blue/Hairy grama	17	25	11	22	21	18	17	35
Buffalograss	14	17	15	19	14	16	17	11
Little bluestem	T[a]	5	T	8	3	3	3	0
Other grasses	12	10	26	15	15	18	30	13
Annual grasses	6	8	0	0	0	0	0	0
Forbs	27	15	18	14	20	12	4	13
Locoweed	1	T	0	0	0	0	0	0
Half shrub	2	7	2	3	1	5	1	7
Live:dead ratio	2.5	1.8	1.3	2.6	.3	2.2	.9	1.8
Plains bluestem pasture								
Total available DM, kg/hectare	---	2650	1840	5080	2375	2850	2197	3490
	%							
Plains bluestem	---	64	66	79	69	96	96	94
Shortgrasses	---	1	1	0	4	0	0	0
Other grasses	---	5	14	2	6	T	1	5
Forbs[b]	---	30	19	18	21	4	3	T
Live:dead ratio	---	12.2	.6	5.2	2.0	.7	24.0	2.8

a T denotes trace amounts, less than 1% of the total DM.

b Standing crop estimates exclude russian thistle during October of 1990 because of lack of use by the cattle.

TABLE 3-2. COMPOSITION OF ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) AND PLAINS BLUESTEM PASTURE (PLAINS)

Item	Forage	Year	May	June	August	October	SE[a]
			Month				
			% of total N				
Insoluble N	PRAIRIE	1990	37.6[ci]	56.9[fgi]	50.3[egi]	44.3[d]	2.1
		1991	31.9[cgj]	51.1[ej]	56.7[fgj]	42.1[d]	2.7
	PLAINS	1990	---	44.6[dh]	36.4[chi]	44.0[d]	1.5
		1991	38.7[ch]	49.1[d]	49.1[dhj]	43.0[c]	1.4
		Mean	---	46.9	42.8	43.5	
			% of OM				
NDF, % of OM	PRAIRIE	1990	68.2[ci]	80.6[dg]	81.2[dg]	77.7[dg]	1.4
		1991	57.4[cgj]	77.5[e]	80.8[e]	76.0[d]	2.6
	PLAINS	1990	---	66.8[chi]	61.9[dhi]	73.7[eh]	1.8
		1991	65.5[ch]	76.6[ej]	77.9[ej]	74.1[d]	1.3
		SE[b]	1.6	1.4	2.2	.6	
ADF, % of OM	PRAIRIE	1990	36.0[ci]	38.9[dg]	40.3[dgi]	38.8[d]	.5
		1991	33.8[cj]	38.2[d]	43.4[ej]	38.2[d]	1.0
	PLAINS	1990	---	31.8[chi]	29.8[chi]	36.9[d]	.9
		1991	33.9[c]	37.1[dj]	41.8[ej]	38.1[d]	.8
		SE	.4	.6	1.4	.4	

[a] n=16, except on PLAINS during 1990, n=12.
[b] n=16, except during May, n=12.
[c-f] Row means with uncommon superscripts differ (P<.05).
[g,h] Pasture means within year with uncommon superscripts differ (P<.05).
[i,j] Year by forage type means with uncommon superscripts differ (P<.05).

TABLE 3-3. RUMINAL AMMONIA NITROGEN (NH_3N) AND pH IN CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) AND PLAINS BLUESTEM PASTURE (PLAINS)

Item	Forage	Year	Month: May	June	August	October	SE[a]
NH_3N, mg/dl	PRAIRIE	1990	2.8	2.6	3.6^{fh}	3.3^{fh}	.15
		1991	2.1^{cf}	2.5^{c}	1.2^{cfi}	8.3^{dfi}	.53
	PLAINS	1990	---	3.6^{c}	9.0^{egh}	5.9^{dgh}	.41
		1991	7.1^{eg}	2.2^{cd}	2.5^{dgi}	1.0^{cgi}	.33
		SE[b]	.37	.17	.47	.41	
pH	PRAIRIE	1990	6.31^{d}	6.47^{dh}	6.21^{ch}	6.33^{d}	.02
		1991	6.30	6.34^{fi}	6.43^{i}	6.48^{f}	.02
	PLAINS	1990	---	6.42^{d}	6.32^{cdh}	6.25^{ch}	.02
		1991	6.26^{c}	6.49^{dg}	6.51^{di}	6.56^{dig}	.02
		SE	.03	.02	.03	.02	

a n=72, except on PLAINS during 1990, n=54.
b n=72, except during May, n=54.
c-e Row means with uncommon superscripts differ ($P<.05$).
f,g Pasture means within year with uncommon superscripts differ ($P<.05$).
h,i Year by forage type means with uncommon superscripts differ ($P<.05$).

TABLE 3-4. EXTENT AND RATE OF IN SITU OM DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) AND PLAINS BLUESTEM PASTURE (PLAINS)

			Month				
Item	Forage	Year	May	June	August	October	SE[a]
Hours of incubation, % of OM							
12	PRAIRIE	1990	51.7^{e}	21.6^{cgi}	28.3^{dg}	31.8^{dgi}	2.5
		1991	50.5^{e}	35.5^{dgj}	29.1^{c}	42.2^{ej}	1.8
	PLAINS	1990	---	43.4^{ch}	57.5^{dhi}	40.6^{ch}	2.2
		1991	50.8^{d}	46.0^{dh}	33.2^{cj}	38.9^{c}	1.8
		SE[b]	1.4	2.1	2.6	1.3	
16	PRAIRIE	1990	64.2^{di}	35.3^{cg}	36.8^{cg}	40.5^{c}	2.9
		1991	57.0^{ej}	39.9^{cdg}	36.9^{c}	46.3^{d}	1.6
	PLAINS	1990	---	54.9^{ch}	64.7^{dhi}	53.2^{c}	1.8
		1991	60.0^{e}	55.4^{eh}	39.6^{cj}	46.8^{d}	1.8
		SE	1.2	2.3	2.6	1.7	
36	PRAIRIE	1990	75.3^{ei}	52.8^{cgi}	56.9^{cg}	61.9^{dg}	2.1
		1991	69.1^{egj}	62.9^{dgj}	56.0^{cg}	65.6^{de}	1.2
	PLAINS	1990	---	66.2^{chi}	77.4^{dhi}	68.7^{ch}	1.4
		1991	75.8^{eh}	73.8^{ehj}	64.7^{chj}	70.3^{d}	1.1
		SE	1.0	1.8	2.0	1.1	
Rate of OM disappearance, %/h							
	PRAIRIE	1990	9.0^{di}	5.0^{c}	5.4^{c}	6.6^{c}	.3
		1991	6.3^{j}	6.3	5.4	5.6	.2
	PLAINS	1990	---	7.0	7.5	7.5	.3
		1991	6.9	7.3	5.5	6.3	.4
		SE	.6	.4	.4	.4	

a n=24, except on PLAINS during 1990, n=18.
b n=24, except during May, n=18.
c-f Row means with uncommon superscripts differ ($P<.05$).
g,h Pasture means within year with uncommon superscripts differ ($P<.05$).
i,j Year by forage type means with uncommon superscripts differ ($P<.05$).

TABLE 3-5. EXTENT AND RATE OF IN SITU NITROGEN DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) AND PLAINS BLUESTEM PASTURE (PLAINS)

			Month				
Item	Forage	Year	May	June	August	October	SE[a]
Hours of incubation, % of total nitrogen							
12	PRAIRIE	1990	56.0[f]	11.6[cgi]	32.6[dg]	40.7[ei]	3.5
		1991	54.5[d]	37.1[cj]	36.8[c]	50.9[dgj]	1.8
	PLAINS	1990	---	45.2[ch]	62.0[dhi]	42.9[c]	2.7
		1991	55.8[e]	43.3[d]	35.7[cj]	43.6[dh]	2.0
		SE[b]	1.5	3.1	2.7	1.4	
16	PRAIRIE	1990	64.4[f]	20.3[cgi]	31.5[dgi]	43.6[egi]	3.9
		1991	61.8[d]	38.3[cgj]	41.1[cj]	55.4[dj]	2.3
	PLAINS	1990	---	52.5[ch]	69.3[dhi]	55.4[ch]	2.5
		1991	65.9[e]	56.9[dh]	44.2[cj]	53.9[d]	1.9
		SE	1.0	3.6	3.1	1.9	
36	PRAIRIE	1990	78.0[fi]	44.1[cgi]	61.7[dgi]	68.1[eg]	2.9
		1991	71.6[egj]	65.0[dgj]	50.9[cgj]	70.8[de]	1.9
	PLAINS	1990	---	63.7[chi]	83.1[ehi]	74.5[dh]	2.3
		1991	83.8[eh]	76.0[dhj]	61.3[chj]	73.1[d]	1.8
		SE	1.3	2.8	2.5	1.1	
Rate of N disappearance, %/h							
	PRAIRIE	1990	5.8[di]	3.6[ci]	4.3[cdg]	5.0[cd]	.3
		1991	3.5[cgj]	7.4[dj]	4.5[c]	5.0[c]	.4
	PLAINS	1990	---	4.6[ci]	6.9[dh]	7.1[d]	.6
		1991	8.0[dh]	8.8[dj]	5.6[c]	6.3[cd]	.5
		SE	.5	.6	.5	.4	

a n=24, except on PLAINS during 1990, n=18.
b n=24, except during May, n=18.
c-f Row means with uncommon superscripts differ (P<.05).
g,h Pasture means within year with uncommon superscripts differ (P<.05).
i,j Year by forage type means with uncommon superscripts differ (P<.05).

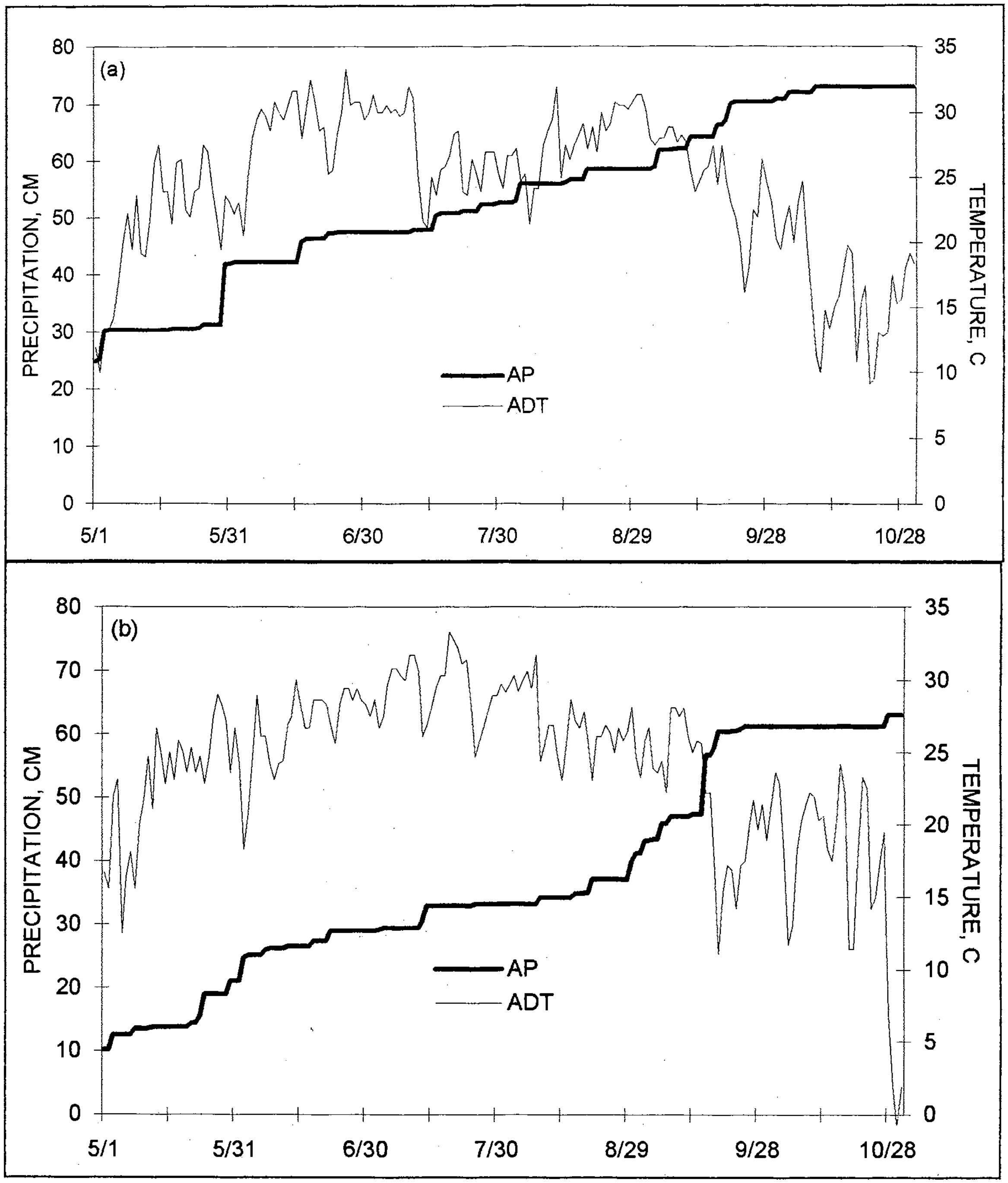

Figure 3-1. Accumulated precipitation (AP, cm) and average daily temperature (ADT, C°) from May Through October of 1990 (a) and 1991 (b) at Clinton, Oklahoma.

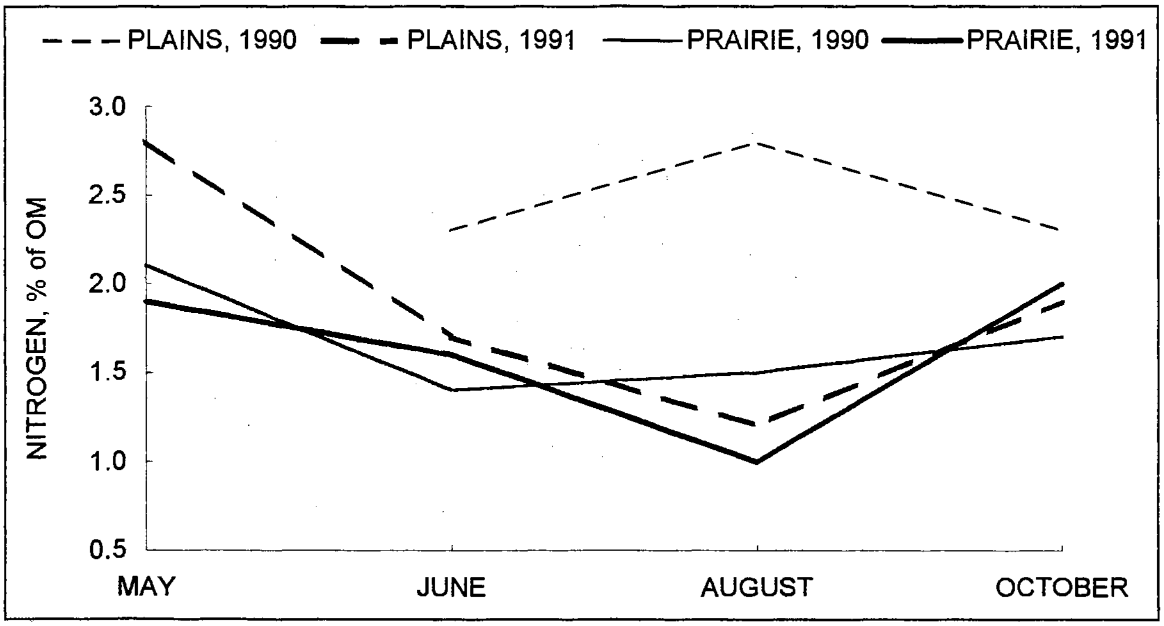

Figure 3-2. Nitrogen content of masticate samples collected from midgrass prairie rangeland (PRAIRIE) and Plains bluestem pasture (PLAINS). Pooled SE=0.06.

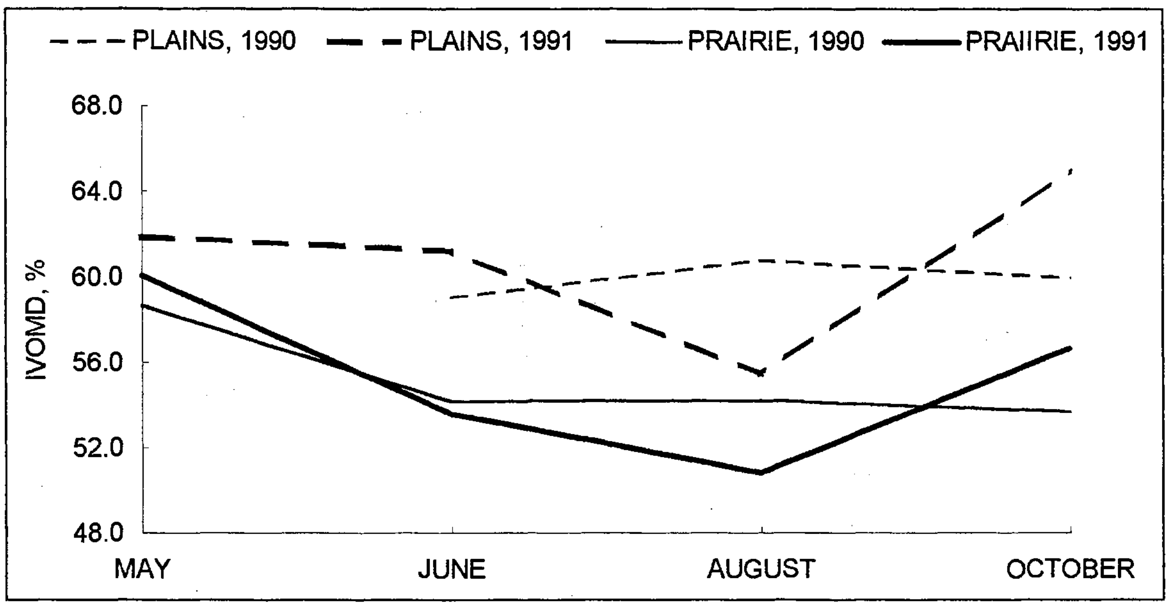

Figure 3-3. In vitro OM disappearance (IVOMD) from masticate samples collected from midgrass prairie rangeland (PRAIRIE) and Plains bluestem pasture (PLAINS). Pooled SE=0.65.

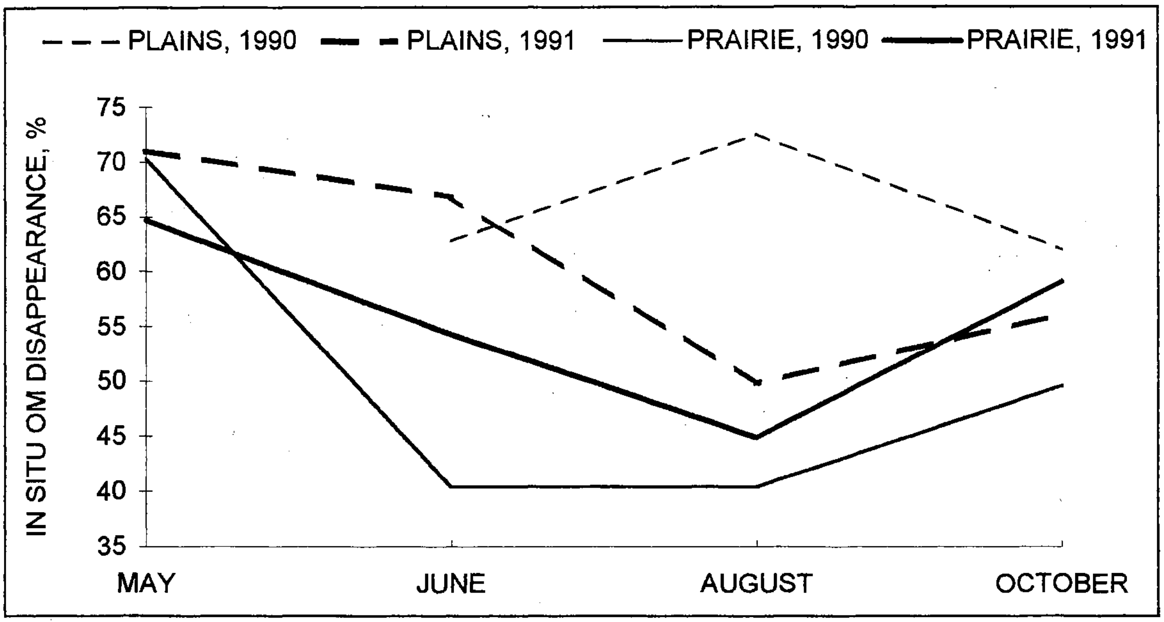

Figure 3-4. In situ OM disappearance from masticate samples collected from midgrass prairie rangeland (PRAIRIE) and Plains bluestem pasture (PLAINS) after 24 h of incubation. Pooled SE=2.4.

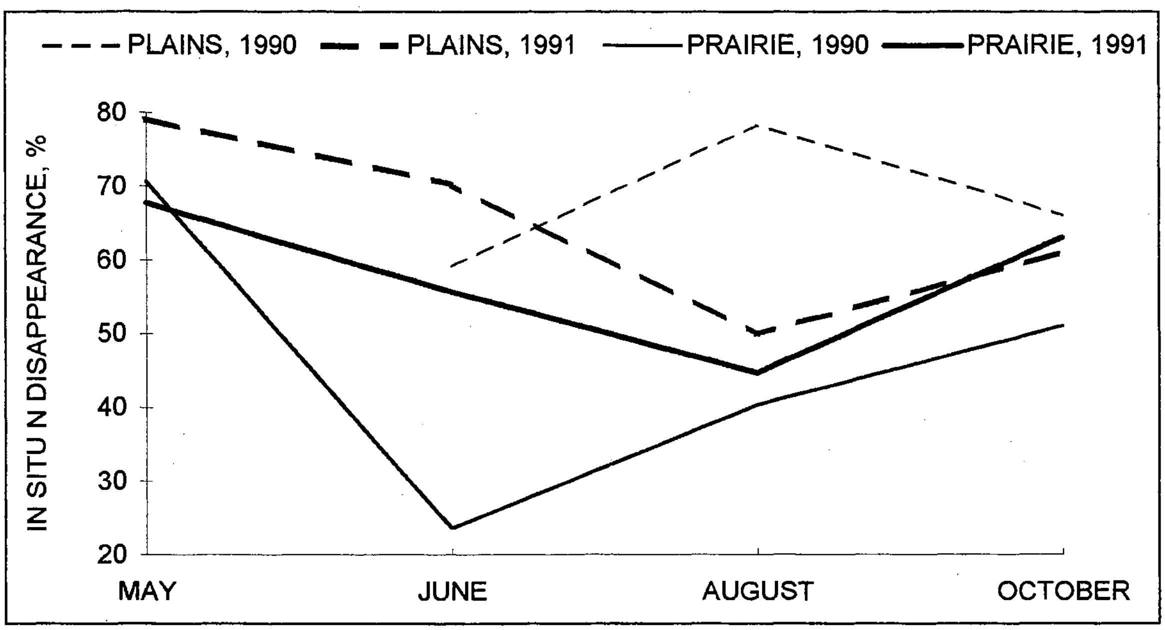

Figure 3-5. In situ nitrogen (N) disappearance from masticate samples collected from midgrass prairie rangeland (PRAIRIE) and Plains bluestem pasture (PLAINS) after 24 h of incubation. Pooled SE=2.7.

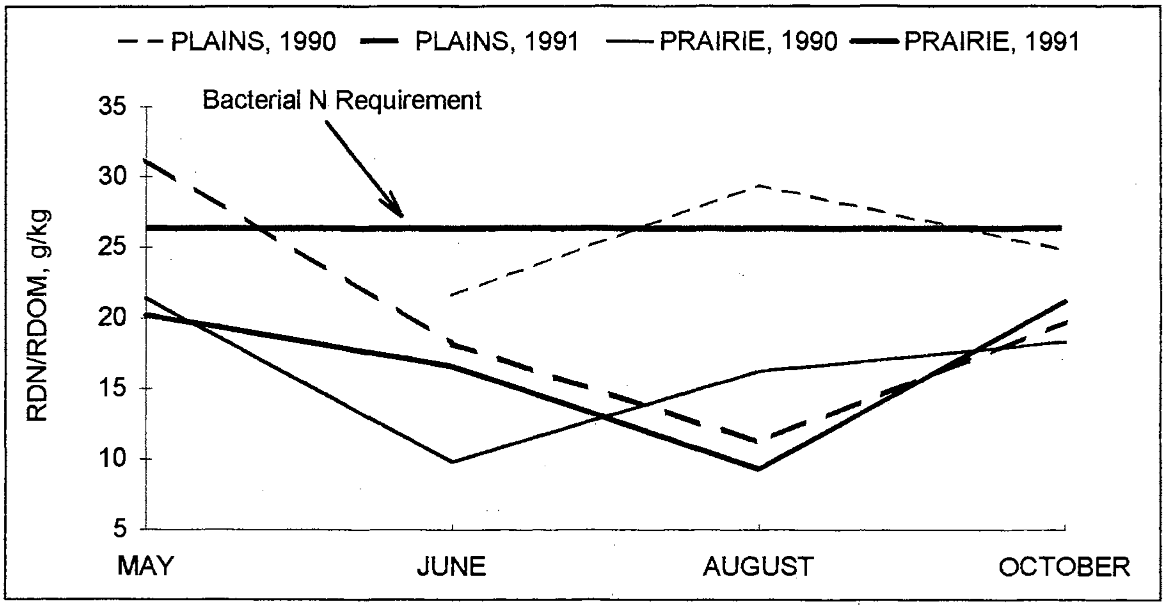

Figure 3-6. Balance of rumen degradable nitrogen and rumen digestible OM (RDN/RDOM) in masticate samples collected from midgrass prairie rangeland (PRAIRIE) and Plains bluestem pasture (PLAINS) after 24 h of incubation. Pooled SE=0.05.

CHAPTER IV

SITE AND EXTENT OF NUTRIENT DIGESTION AND MICROBIAL PROTEIN SYNTHESIS IN BEEF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND AND PLAINS BLUESTEM THROUGHOUT THE SUMMER[1]

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ABSTRACT: Beef cattle fitted with esophageal (4 hd/pasture) or ruminal and duodenal cannulae (6 hd/pasture; avg beginning BW=274) grazed midgrass prairie range (PRAIRIE) or plains bluestem (*Bothriochloa ischaemum* var. Plains) pasture (PLAINS) during mid-May, late June, mid-August, and mid-October of 1990 and 1991. The range site was in excellent range condition. The PLAINS contained approximately 10% Russian thistle during 1990; however, during 1991 the thistle content of the pasture was negligible. Forage OM intake (OMI) by cattle grazing PRAIRIE or PLAINS was similar ($P>.05$) in June and August. In May and October cattle grazing PRAIRIE consumed more ($P<.05$) forage OM. However, digestible OMI for cattle grazing PLAINS tended to be higher in June and August and lower in May and October. Duodenal non-microbial OM flow in cattle grazing PRAIRIE increased ($P<.05$) and the extent of true ruminal OM digestion declined ($P<.05$) later in the grazing season. True ruminal OM digestion was similar ($P>.05$) between forage types except in October of 1991 when digestion of PLAINS was greater ($P<.05$). Fecal OM output increased ($P<.05$) as the forage became less

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[2] Animal Science Department.
[3] We thank Maria Mottola for assistance with the laboratory analysis and Matt Cravey, Jackie Hogue, Mike Lohman, Twig Marston, Juan Mieres, Mike Van Koevering, and Gary Zeihe for assistance with the collection of the samples.
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digestible ($P<.05$) and as the cattle grew from May through August; however, during October of 1990 fecal output from cattle decreased ($P<.06$) on both sites. Nitrogen intake by cattle grazing PRAIRIE tended to be lower in June and August than in May and October. Nitrogen intake by cattle grazing PLAINS peaked ($P<.05$) in August during 1990; however, N intake was lowest ($P<.05$) in August of 1991. Non-ammonia N flow at the duodenum was higher ($P<.05$) in cattle grazing PLAINS than in cattle grazing PRAIRIE from May through August. However, in October of 1991, cattle grazing PLAINS had the lowest ($P<.05$) duodenal non-ammonia N flow. Microbial N flow at the duodenum responded ($P<.05$) quadratically as more OM was digested in the rumen. Extent of true ruminal N digestion decreased ($P<.05$) as forage became mature and lower in total N. Apparent N digestion indicated that up to 100% of intake N was recycled to the rumen and used by ruminal microbes. Midgrass prairie appeared superior to PLAINS in May and October due to a higher energy intakes. However, PLAINS appeared to be an excellent complement to PRAIRIE if grazed during June through August. These data suggest that non-ammonia N flow was disproportionately high in relation to energy intake in cattle grazing either forage and performance may be improved with limited energy supplementation.

(KEY WORDS: Rangelands, Grazing, Intake, Rumen Digestion, Microbial Protein, Fiber)

Introduction

Native range and old world bluestems are the two primary forage resources for beef cattle production in southwestern Oklahoma. Plains bluestem (*Bothriochloa ischaemum* var. Plains; PLAINS) was introduced to the Southern Plains in 1972 and has been promoted as a complementary forage to native ranges for integrated forage-livestock systems (Taliaferro et al., 1972; Sims and Dewald, 1987.). One unique quality of PLAINS is that it begins spring growth later than midgrass prairie (PRAIRIE) and the majority of growth occurs in the summer while PRAIRIE may be in summer dormancy (Taliaferro et al., 1972).

Many native grasses require nutrient supplementation to optimize animal performance during mid- to late-summer (Funk et al., 1987a; Campbell, 1989; Park et al., 1989: Torell et al., 1991; Brandyberry et al., 1992; Karges et al., 1992). Considering the differences in growth curves for PRAIRIE and PLAINS, grazing PLAINS during the summer may be an economical alternative to supplementation. In addition, using PLAINS as a complement to PRAIRIE would increase carrying capacity. Well-managed seedings of Old World Bluestems can produce four times as much forage as native rangeland (Coyne and Bradford, 1985).

This study was conducted to measure differences between PRAIRIE and PLAINS in nutrient intake, site and extent of digestion, and non-ammonia N yield from the rumen in cattle grazing in southwestern Oklahoma.

Materials and Methods

Sampling Procedures: Four sampling periods were conducted from May 9 to October 19 during 1990 and 1991. Site descriptions and climatic information were provided by Gunter et al. (1993). Trial dates during 1990 were mid-spring (9 May to 20 May), mid-growing season (20 June to 1 July), mid-summer dormancy (8 August to 19 August), and fall-growing season (8 October to 19 October). Because of winter kill in 1990, PLAINS was allowed to recover until mid-June before grazing was initiated. Therefore, the mid-spring trial in 1990 lacks PLAINS. Trial dates for 1991 were 10 May to 20 May, 22 June to 2 July, 12 August to 22 August, and 5 October to 15 October.

Four steers fitted with esophageal cannulae were allowed to graze 48.6 ha of PRAIRIE. Another set of esophageally cannulated steers were allowed to graze 6.5 ha of PLAINS. Six ruminally and duodenally cannulated cattle also grazed each study site. Different cattle were cannulated each year in order to represent young growing cattle (1990, heifers, British x British, beginning avg BW=274 kg; 1991, steers, British x British, beginning avg BW=259 kg). All cattle were placed on the study sites 2 wk before the first sampling and then allowed to graze the entire season. Cattle had ad libitum access to water and mineralized salt[5].

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[5] Contained (% of DM): 20.5% NaCl, 16.5% Ca, 8% P, .02% I, trace minerals, 44,000 IU vit. A/kg, and 22,000 IU vit D_3/kg.

Esophageal masticate was collected on d 1 and 2 of each trial to evaluate dietary nutrient composition. Collection and analysis of samples were described by Gunter et al. (1993).

Chromic oxide was used to determine fecal output and duodenal flow. Administration of the marker via the ruminal cannula began on d 1 of each sampling period and continued through d 10 (7.5 g A.M. and P.M.). Fecal samples were collected at sunrise and 12 h later during the last 5 d of each sampling period. Duodenal samples were collected on PLAINS at sunrise on d-6 and 9, 6 h after sunrise on d-7 and 9 and 12 h after sunrise on d-7 and 8. On PRAIRIE, duodenal samples were collected at sunrise on d-7 and 10, 6 h after sunrise on d-6 and 10 and 12 h after sunrise on d-6 and 9. This schedule was followed to minimize disruption of grazing. Approximately 250 ml of chyme were collected at each time and composited across days and times within animal and stored frozen.

On d 11, 2 liters of ruminal fluid were collected from each animal for isolation of bacteria. Ruminal contents were strained through cheese-cloth and the fluid was preserved with formaldehyde (25 ml 9% (w/v) NaCl in 37% formaldehyde/100 ml ruminal fluid).

Laboratory Analysis: Duodenal and fecal samples were lyophilized[6] and ground through a 2-mm screen in a Wiley mill. Samples were analyzed for DM and ash (AOAC, 1991), NDF and ADF (Goering and Van Soest, 1970), and Kjeldahl N (AOAC, 1991). Chromium concentration in the duodenal and fecal samples was determined by atomic absorption spectroscopy with a nitrous oxide/acetylene flame (Williams et al., 1962). Duodenal samples were analyzed for ammonia N (AOAC, 1991) and purines (Zinn and Owens, 1986). Bacteria were isolated from the formaldehyde-preserved ruminal fluid by differential centrifugation (Merchen and Satter, 1983), lyophilized, ground with a mortar and pestle, and analyzed for DM, ash, N, and purines.

Calculations: Organic matter flow at the duodenum and fecal OM output were calculated by dividing the Cr dose by the Cr concentration in the sample. Intake was estimated by dividing fecal OM output by the in vitro OM indigestibility of the masticate (Gunter et al., 1993). Individual constituent flows were calculated by multiplying sample constituent concentration by

[6] Virtis Freeze Drier. Model 10-100V, Virtis Corp., Gardiner, NY.

OM flows. The ratios of purines to N in isolated bacteria were used to calculate flow of bacteria to the small intestine.

Metabolic fecal N requirements are excluded from the N requirements in figure 4-2 so that the available non-ammonia N flows at the duodenum can be compared to the requirement of an example animal (NRC, 1985). Metabolic fecal N was assumed to be 14.4 g N•kg fecal OM output^{-1}•d^{-1} (NRC, 1984) and subtracted from the total non-ammonia N flow.

Multiple regression models were developed to estimate various response variables. For each instance, models contained forage type as an indicator variable in addition to linear and quadratic terms for the independent variables of choice and interaction terms. If an independent variable was found insignificant (P>.10) then it was excluded from the analysis. All data were analyzed in one model to minimize the SE of the predicted Y-value (Neter et al., 1989). Data were analyzed by analysis of variance with a model including the effects of year, forage type, month, year x forage type, month x forage type, and year x month within forage type (Lentner and Bishop, 1986). The effects of year and forage were tested with the interaction of year x month. Least square means were separated using the lsd procedure (Lentner and Bishop, 1986).

Results and Discussion

Animal Weight. Average animal body weights across both years are presented in Table 4-1. Nutrient intake and flows have been adjusted linearly to these average weights so that forages and years can be compared without concern for differences in body weight. The growth rate of the cannulated cattle averaged over forage types and years was reasonably good (.7 kg/d) indicating that these cattle presumably consumed normal amounts of feed and had normal grazing behavior. McCollum and Gillen (unpubl. data) reported that steers (205 kg initial BW) grazing adjacent PRAIRIE gained .9 kg/d from May 1 through September 15, 1990.

Masticate Composition. Nutrient composition of masticate was described by Gunter et al. (1993). One of the primary changes was a depression in N content in June and August, except for PLAINS during 1990 (Table 4-1). In vitro OM digestion followed a similar pattern (r =.66) to the masticate N content. Other research has recorded similar relationships between in vitro OM disappearance and diet N content (Campbell, 1989; Brandyberry et al., 1992; Park et al., 1990).

Intake. In May, OM intake (OMI) by cattle grazing PRAIRIE was similar (P>.05) between years and was about 3.1% of BW (Table 4-2). This intake level is slightly higher than that reported by Funk et al. (1987a); they reported that steers grazing blue grama rangeland in New Mexico consumed 2.5% of BW. Campbell (1989) reported that steers grazing tallgrass prairie in central Oklahoma consumed 1.9% of BW in May. Cattle grazing PLAINS in May of 1991 consumed less (P<.05) forage than cattle grazing PRAIRIE. The level of OMI by cattle grazing PLAINS probably was restricted by grazing time. The PLAINS was mowed in late-April to remove standing dead forage that remained from the previous year. But, the grazing horizon appeared to be below the level of the dead stubble, cattle probably spent considerable time searching for "preferable forage" (Minson, 1990). In June and August, OMI decreased to about 2.5% of BW, except on PLAINS in June of 1991 when OMI was 2.8% BW (P<.05). Also, OMI was greater (P<.05) in 1991 than in 1990. In October, cattle grazing PRAIRIE consistantly consumed more (P<.05) OM than cattle grazing PLAINS.

Total digestible nutrient intake was calculated by assuming that TDN is equivalent to digestible OM (NRC, 1985). Based on this assumption, cattle grazing either forage failed to consume enough TDN to meet the energy requirement for a medium-frame steer gaining .9 kg/d (Fig. 4-1). During June and August, TDN intake tended to be higher for cattle grazing PLAINS. Cattle grazing blue grama rangeland in New Mexico consumed a similar level of TDN as the cattle grazing PRAIRIE even though the blue grama rangeland diets were more digestible (Funk et al., 1987a,b).

Neutral and acid detergent fiber intake increased (P<.05) from May to June (Table 4-4). After June the fiber content of the diet fluctuated little; therefore, any change in fiber intake after this time was the result of changes in OMI. Neutral detergent fiber has been implicated as an important regulator of intake in forage-fed cattle (Balch and Campling, 1962; Conrad et al., 1964; Forbes, 1986). This conclusion cannot be drawn from the current study. In May, June, and

August, OMI declined as fiber intake increased. But in October, the relationship between fiber intake and OMI was less apparent.

Nitrogen intake by cattle grazing either forage type consistently decreased ($P<.05$) from May to June (Table 4-5). Nitrogen intake by cattle grazing PRAIRIE was similar ($P>.05$) between months in June and August of 1990. However, N intake on PLAINS increased ($P<.05$) from June through August of 1990. This rise in N intake probably resulted from two factors. First, in June and August, cattle grazing PLAINS were readily consuming the Russian thistle. Hand clipped samples of Russian thistle contained 4.3% N. Second, on July 26, 69 kg of N/ha was applied to the PLAINS. Minson (1990) noted that the N level in plants peaks about 3 wk after N fertilizer is applied. About 20 d separated the fertilizer application in July and the August sampling period. Levels of N in the diets were similar between August of 1990 and May of 1991, the two sampling periods immediately following N application (Table 4-1). This similarity suggests that mid-summer N intake potentially can be manipulated by fertilizing Old World Bluestem pasture in mid-July. Further research is needed to compare the amount of fertilizer N captured as non-ammonia N and protein versus the amount of protein supplied by a supplement. During 1991, the N intake by cattle grazing either forage resource followed a similar decline from May through August. But in October, cattle grazing PRAIRIE tended to consume more ($P<.05$) N than cattle grazing PLAINS.

Site and Extent of Digestion. Duodenal OM flow during 1990 remained constant ($P>05$) from May through August on both forage types (Table 4-2). In October, OM flow at the duodenum was lower on PLAINS due to the ($P<.05$) decline in OMI. During 1991, duodenal OM flow in cattle grazing PRAIRIE increased ($P<.05$) as they grew, but flow remained constant as a percent of body weight (1.8%). The duodenal OM flow in cattle grazing PLAINS during 1991 remained constant ($P<.05$) throughout the grazing season and generally was lower than the flow observed on PRAIRIE. Campbell (1989) and Funk et al. (1987a) reported a similar increase in duodenal OM flow as the cattle grew throughout their experiments. The constant rather than increasing duodenal OM flow is explained partially by a tendency (P<.09) for more ruminal OM disappearance in cattle grazing PLAINS than in cattle grazing PRAIRIE (Table 4-3).

Duodenal non-microbial OM flow followed a pattern similar to total OM flow among months and between forages (Table 4-2). The extent of true ruminal OM digestion in cattle grazing either forage type decreased (P<.05) as the grazing season advanced (Table 4-3). The only exception was in cattle grazing PLAINS during October of 1991, when ruminal OM digestion increased (P<.05) above the level recorded in August. The flow of microbial OM to the small intestine appeared to be related positively to the amount of OM digested in the rumen (Table 4-2).

Fecal OM output followed a pattern similar to duodenal flow among months and between years (Table 4-2). Fecal OM output was similar within forage types from May through August (PRAIRIE=1.2; PLAINS=1.0% BW). In October, fecal OM output differed by year and forage type (PRAIRIE, 1990=0.84, 1991=1.3; PLAINS, 1990=0.6, 1991=0.9% BW). Campbell (1989) and Funk et al. (1987a) noted that cattle maintained or slightly increased fecal OM output later in the grazing season. Lower tract OM digestion was similar among most months and between forage types (Table 4-3). Estimates of lower tract OM digestion tended to be higher than values reported by some researchers (Funk et al., 1987b; Stokes et al., 1988; Campbell, 1989) but similar to values reported by Gunter et al. (1990). Digestion of OM in the small intestine is composed largely of microbial cells, while both microbial cells and undigested fiber are fermented in the hindgut (Funk et al., 1987a).

Ruminal digestion of NDF and ADF accounted for 87 and 90%, respectively, of total tract digestion (Table 4-4). These extents of ruminal NDF and ADF digestion in the rumen are similar to reports by other researchers (Funk et al., 1987a; Gunter et al., 1990; Stokes et al., 1988). Funk et al. (1987b) documented that as grazed forages matured, the extent of fiber digestion that occurred in the rumen increased. In contrast, the extent of ruminal fiber digestion in our study tended to remain constant (Table 4-4).

Non-ammonia N flow at duodenum usually was greater ($P<.05$) in cattle grazing PLAINS than in cattle grazing PRAIRIE (Table 4-5). Plains bluestem pasture consistently supplied more ($P<.05$) non-ammonia N during August. These estimates tended to be higher than estimates reported by other researchers (Funk et al., 1987b, Campbell, 1989). Non-ammonia N supply in relation to the requirement of a medium-frame steer gaining .9 kg/d is illustrated in figure 4-2 (NRC, 1985). The lowest non-ammonia N supply was recorded from cattle grazing PLAINS in October of 1991. Non-ammonia N supply in these cattle was 134% of the requirement. By comparing figures 4-1 and 4-2, it seems that energy probably was first-limiting for performance of cattle grazing these forages.

Non-microbial N flow at the duodenum decreased ($P<.05$) as the grazing season advanced (table 4-5), possibly resulting from a decreased concentration of N in the forage OM (Table 4-4) as well as more efficient conversion of forage protein to microbial protein in the rumen. Non-microbial N supply is within the range (40-60%) suggested by Owens and Zinn (1988) for diets of various N content. These non-microbial N flows are greater than those reported by Funk et al. (1987a) or Campbell (1989); the higher level of OMI may be responsible for these higher non-microbial N flows. Even though non-microbial N tended to decrease from May until August, non-microbial OM tended to increase (Tables 4-2 and 4-5). This inverse relationship probably results from a lower concentration of digestible N in forage OM (Gunter et al., 1993).

Across both years and in both forages, microbial N flow was highest in May; by June microbial N flow had decreased about 16% (Table 4-4). The production appears low compared to a review written by Minson (1990). However, other researchers have reported similar values (Funk et al., 1987a; Campbell, 1989; MacRae and Ulyatt, 1974). Multiple regression produced the equations for each forage type to predict microbial N yield (g/d; MNY) from RDOM (kg/d, Fig. 4-3). These derived equations share a $s_{y \cdot x} = 6.6$, $r^2 = .89$, and $n = 15$. Previous predictions have used a linear relationship to predict MNY from RDOM with coefficients ranging from 24.1-27.0 g N/kg RDOM (Stern and Hoover, 1979; NRC, 1985; Minson, 1990; Owens et al., 1991). In contrast, the ARC (1980) stressed that these coefficients are not biological constants and MNY is not always related linearly to RDOM. Linear equations often are used for ease of calculation (ARC, 1980) and probably are functional within a narrow range. At the average RDOM intake (3.9 kg/d), the equations developed from our data estimate MNY within 4 and 9% of actual yield for PRAIRIE and PLAINS, respectively. The prediction equations of Owens et al. (1991) over-estimated the MNY measured by 24%. The NRC (1985) equation under-estimated the MNY by 13% (Fig. 4-3).

Fecal N excretion was lower ($P<.05$) during times of low N intake (Table 4-5). The percent dietary N (PDN) was regressed on the percent fecal N (PFN) to produce the equation presented in figure 4-4. Overall, a good association between the diets and feces was observed with 80% of the variation in diet N being accounted for by fecal N. Forage type was an unimportant ($P=.51$) as a source of variation. The slope closely agrees with a slope reported by Cordova (1977; $b_1=1.22$) developed from samples collected in New Mexico. However, the slope is steeper ($P<.01$) than slopes reported by Holechek et al. (1982; $b_1=0.85$) for cattle grazing Blue Mountain rangeland in Oregon and reported by McCollum (1990; $b_1=0.74$) for cattle grazing tallgrass prairie in central Oklahoma. The difference between the coefficients is not readily explained but, may in part be due to an unbalanced protein/energy ratio in the diet or soluble phenolics contained in the diet (Holechek et al., 1982). Robbins et al. (1975) found that the coefficient for deer was extremely high ($b_1=2.78$). The higher coefficient in our equation may be due to cattle consuming more forbs than cattle grazing tallgrass prairie. However, no research has been conducted in this region on the species composition of cattle diets to support our conclusion.

Apparent ruminal N digestibility was correlated ($r=0.72$) to level of N in the diet (Table 4-4). Regression analysis indicated that apparent ruminal N digestion (ARND) was zero at a dietary N concentration of $2.8\pm3.8\%$ (ARND = 44.3 PDN-125, $s_{x \cdot y}=23.2$, $r^2=.51$). The SD for the point at which ARND equals zero is high because the predicted independent variable is at the upper limit of the data (1.0-2.8). Other researchers have estimated this point to lie somewhere between 2.1-2.4% diet N (Minson, 1990; Owens and Zinn, 1988; McCollum, 1991). Additional research is needed to refine this estimate.

The NRC (1984) and ARC (1980) assumed a ratio of intake N:post-ruminal N of 1.0 when calculating the protein requirements of beef cattle. This ratio in our study ranged from 1.2 to 2.0 on PRAIRIE and 0.9 to 2.1 on PLAINS. The NRC (1984) assumption would overestimate the dietary protein requirements of these cattle.

The high ratios of post-ruminal N flow to intake N in the present study suggest that the cattle were energy deficient at the tissue level (ARC, 1980). If energy is first-limiting for performance, protein will be catabolized for energy until energy needs are met; the remaining protein will be used to meet protein needs (Clanton and Zimmerman, 1971). Matras and Preston (1989) found that N retention was increased by the intravenous infusion of glucose into lambs consuming a high-protein diet at near maintenance levels of energy intake. Additionally, supplemental energy has increased apparent ruminal N digestibility and N retention in steers (Lake et al., 1974a; Krysl et al., 1989). The limited-supplementation (.45 kg/d) of steers grazing irrigated pasture with a pelleted corn (94%) and molasses (5%) mixture increased gain by .31 kg/d over a 122 d period (Lake et al., 1974b). It may be reasonable to conclude that N retention and growth would be improved if cattle on PRAIRIE and PLAINS were supplemented with a limited quantity of medium-protein, high-energy supplement.

True ruminal N digestion was low in comparison to some previous estimates (Table, 4-6; NRC, 1984; NRC, 1985; Owens and Zinn, 1988; NRC, 1989; Minson, 1990): but, similar to other reports (Funk et al., 1987a; Stokes et al., 1988; Campbell, 1989). Most of the forage N degradability data to date has been generated with cool-season forages. It is possible that proteins in warm-season forages are less degradable in the rumen than proteins in cool-season forages (Jones et al., 1987; Jones et al., 1988; Brake et al., 1989). In June of 1990, true ruminal N digestion was negative for PRAIRIE. Other researchers have noted this same impossibility when estimating true ruminal N digestion of low quality forages (Campbell, 1989; Gunter et al., 1990). Calculations do not account for endogenous N secretions and sloughed epithelium and these contributions should decrease digestibility estimates. MacRae et al. (1979) suggested that in addition to N recycled to the rumen via blood and salivary urea, sloughed epithelial cells, or secretions contribute significant amounts of N to duodenal flow. The magnitude of these endogenous contributions is not well defined and is still under dispute. Kreikemeier et al. (1992) failed to measure a significant contribution of abomasal secretions to duodenal N in steers fed different diets at various levels of intake. Both of these sources of endogenous N are included in the non-microbial fraction flowing into the duodenum when estimates are calculated by difference between total N flow and microbial N flow.

Microbial efficiency (MCOEFF; Table 4-6) remained relatively high in respect to some other research (Funk et al., 1987a; Stokes et al., 1988). Estimates of MCOEFF for both forage types were within expected ranges (NRC, 1985; McMeniman et al., 1986; Minson, 1990). In June and August the grams of rumen degradable N (RDN)/RDOM was as low as 9 (Gunter et al., 1993) which in well below the suggested requirement of 20 g RDN/kg RDOM (McMeniman and Armstrong, 1977; Nolan et al., 1986). It is evident that in this instance recycled N to the rumen contributed significantly to microbial protein synthesis.

Plains bluestem pasture appeared to complement PRAIRIE well during the summer grazing season and hence fits the characteristics prescribed for complementary forages (Nichols and Clanton, 1987). Plains bluestem pasture complemented PRAIRIE by supplying more non-ammonia N at the duodenum and more digestible OM in June and August. During this same time period, cattle grazing PLAINS had higher ($P<.05$) yields of microbial protein from the rumen that probably resulted from high ruminal degradation of N and OM in the rumen. This conclusion is supported by the higher ($P<.05$) extent of in situ N and OM disappearance (Gunter et al., 1993) for PLAINS.

The non-ammonia N flow at the duodenum was disproportionately high in relation to energy intake for cattle grazing either forage resource. It is reasonable to conclude that N retention and growth would be improved if cattle on PRAIRIE and PLAINS were supplemented with a limited quantity of a medium-protein, high-energy supplement. The low apparent N digestibilities in the rumen suggest that recycled N was sufficient to meet microbial demands in the rumen, but if the energy status of the animal is increased by supplementation, then the quantity of N available for recycling to rumen might be reduced. Therefore, supplement formulations should provide a source of RDN as well as energy to offset the reduced supply of recycled N.

Implications

Based on these data, a forage system incorporating PLAINS and PRAIRIE as complements should use PRAIRIE during the spring and fall and PLAINS during the summer. This grazing pattern would allow the PRAIRIE to rest during the summer when the nutritional value of PLAINS is highest. In addition, overall performance should be improved and supplementation requirements should be reduced.

Cattle grazing both forages consumed ample N to support a very high level of performance. However, digestible OMI appeared to be first-limiting if greater performance was desired. Providing small amounts (<.3% BW) of supplemental energy should improve performance (Lake et al., 1974b) by enhancing N retention without depressing forage intake (Lake et al., 1974a; Krysl et al., 1989; Pordomingo et al., 1991). Although N intake was meeting the requirements for weight gain, in situ data from both forage types suggested that the RDN supply was marginal from June through October (Gunter et al., 1993). Therefore, a supplement for cattle during this time period should focus on energy intake yet provide adequate RDN to avoid a ruminal N deficiency.

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TABLE 4-1. BODY WEIGHTS AND NITROGEN CONTENT AND IN VITRO OM DIGESTIBILITY (IVOMD) OF ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) AND PLAINS BLUESTEM PASTURE (PLAINS)

			Month				
Item	Forage	Year	May	June	August	October	SE[a]
BW, kg			267	306	337	363	
			% of OM				
Nitrogen	PRAIRIE	1990	2.1[e]	1.4[cg]	1.5[cdgi]	1.7[dgi]	.1
		1991	1.9[eg]	1.6[d]	1.0[cj]	2.0[ej]	.1
	PLAINS	1990	---	2.3[chi]	2.8[dhi]	2.3[chi]	.1
		1991	2.8[eh]	1.7[dj]	1.2[cj]	1.9[dj]	.2
		SE[b]	.1	.1	.2	.1	
IVOMD	PRAIRIE	1990	58.6[d]	54.2[cg]	54.2[cgi]	53.7[cgi]	.7
		1991	60.0[f]	53.6[dg]	50.8[cgj]	56.6[egj]	1.0
	PLAINS	1990	---	58.9[hi]	60.4[hi]	60.0[hi]	.4
		1991	61.9[d]	61.2[dhj]	55.4[chj]	64.9[ehj]	.9
		SE	.7	.9	.9	1.3	

[a] n=16, except on PLAINS during 1990, n=12.
[b] n=16, except during May, n=12.
[c-f] Row means with uncommon superscripts differ (P<.05).
[g,h] Pasture means within year with uncommon superscripts differ (P<.05).
[i,j] Year by forage type means with uncommon superscripts differ (P<.05).

TABLE 4-2. INTAKE AND DUODENAL FLOW OF OM (g/d) IN BEEF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) AND PLAINS BLUESTEM PASTURE (PLAINS)

			Month				
Item	Forage	Year	May	June	August	October	SE[a]
Intake	PRAIRIE	1990	7949[d]	7479[cd]	7863[d]	6551[cgi]	221
		1991	8701[cg]	8416[c]	8739[c]	10748[dgi]	299
	PLAINS	1990	---	7954[di]	8530[d]	5267[chi]	403
		1991	6856[ch]	8704[dej]	8052[d]	9381[ehj]	262
		SE[b]	249	206	207	513	
Passage							
Duodenal flow							
Total	PRAIRIE	1990	4764	4840	4929	4579[gi]	84
		1991	5188[cgi]	5280[c]	5925[dg]	7064[egj]	217
	PLAINS	1990	---	4791[d]	5053[d]	3968[chi]	149
		1991	4479[ch]	4859[cd]	5266[dh]	4738[cdhj]	92
		SE	122	113	124	272	
Non-microbial	PRAIRIE	1990	3976	4234	4244[i]	4003[gi]	93
		1991	4094[cg]	4521[cdg]	5021[dgj]	6004[egj]	207
	PLAINS	1990	---	3875[cd]	4113[d]	3308[ch]	124
		1991	3416[ch]	3884[cdh]	4223[dh]	3861[cdh]	96
		SE	121	124	121	240	
Microbial	PRAIRIE	1990	788[di]	607[cgi]	684[cdi]	576[cgi]	28
		1991	1094[dj]	759[cgj]	905[cej]	1061[dgi]	42
	PLAINS	1990	---	916[dh]	940[dh]	660[ci]	38
		1991	1063[d]	975[cdh]	1043[d]	877[chj]	30
		SE	42	39	37	48	
Fecal	PRAIRIE	1990	3288[cd]	3428[cd]	3601[di]	3034[cgi]	97
		1991	3478[cg]	3906[cdg]	4299[dgj]	4660[dgj]	138
	PLAINS	1990	---	3268[cd]	3381[d]	2109[chi]	162
		1991	2614[ch]	3376[dh]	3589[dh]	3289[dhj]	104
		SE	112	92	113	217	

[a] n=24, except on PLAINS during 1990, n=18.
[b] n=24, except during May, n=18.
[c-f] Row means with uncommon superscripts differ ($P<.05$).
[g,h] Pasture means within year with uncommon superscripts differ ($P<.05$).
[i,j] Year by forage type means with uncommon superscripts differ ($P<.05$).

TABLE 4-3. SITE AND EXTENT OF OM DIGESTION IN BEEF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) AND PLAINS BLUESTEM PASTURE (PLAINS)

Item	Forage	Year	May	June	August	October	SE[a]
			Month				
			% of OM intake				
Ruminal, true	PRAIRIE	1990	49.8[d]	43.3[d]	45.5[d]	35.9[c]	2.2
		1991	52.7[d]	45.7[c]	42.4[c]	43.8[cg]	1.7
	PLAINS	1990	---	51.3[d]	50.9[d]	35.3[ci]	2.8
		1991	49.4[cd]	54.8[d]	47.0[c]	58.8[dhj]	1.7
		SE[b]	1.8	1.7	1.6	2.9	
			% entering segment				
Lower tract	PRAIRIE	1990	30.6	28.5	26.8	33.5[g]	2.2
		1991	32.7	25.3	27.3	33.5	1.7
	PLAINS	1990	---	31.5[c]	32.5[c]	46.1[dhi]	2.9
		1991	41.3[d]	30.7[c]	31.5[c]	30.3[cj]	1.8
		SE	2.0	1.6	1.8	2.6	

[a] n=24, except on PLAINS during 1990, n=18.
[b] n=24, except during May, n=18.
[c-f] Row means with uncommon superscripts differ ($P<.05$).
[g,h] Pasture means within year with uncommon superscripts differ ($P<.05$).
[i,j] Year by forage type means with uncommon superscripts differ ($P<.05$).

TABLE 4-4. INTAKE AND SITE AND EXTENT OF NDF AND ADF DIGESTION IN BEEF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) AND PLAINS BLUESTEM PASTURE (PLAINS)

Item	Forage	Year	Month				
			May	June	August	October	SE^{a}
NDF			g/d				
Intake	PRAIRIE	1990	5421^{cd}	6028^{d}	6385^{dg}	5090^{cgi}	181
		1991	4991^{c}	6520^{d}	7062^{d}	8164^{egj}	293
	PLAINS	1990	---	5314^{ci}	5280^{chi}	3881^{chi}	214
		1991	4492^{c}	6667^{dj}	6272^{dj}	6950^{dhj}	240
		SE^{b}	138	177	197	389	
Digestion			% of NDF intake				
Ruminal	PRAIRIE	1990	56.6^{i}	57.9	56.0	51.9	1.5
		1991	44.1^{cgj}	58.9^{d}	52.2^{d}	52.6^{dg}	1.9
	PLAINS	1990	---	62.6^{c}	59.2^{c}	56.7^{ci}	1.7
		1991	59.1^{ch}	64.7^{d}	55.9^{c}	65.9^{dhj}	1.4
		SE	2.0	1.6	1.4	1.9	
Total	PRAIRIE	1990	60.6^{ci}	60.0^{cgi}	63.5^{di}	60.0^{cgi}	.4
		1991	54.7^{cgj}	57.8^{dgj}	60.6^{egj}	61.7^{egj}	.6
	PLAINS	1990	---	61.2^{chi}	64.2^{di}	67.3^{ehi}	.7
		1991	68.5^{ch}	68.1^{chj}	68.0^{chj}	71.5^{dhj}	.4
		SE	1.4	.8	.6	1.0	
ADF			g/d				
Intake	PRAIRIE	1990	2861^{cd}	2909^{cd}	3169^{cgi}	2542^{cgi}	87
		1991	2944^{cg}	3212^{c}	3795^{dj}	4103^{dgj}	130
	PLAINS	1990	---	2538^{di}	2542^{dhi}	1944^{chi}	97
		1991	2328^{ch}	3226^{dj}	3364^{dj}	3574^{dhj}	120
		SE^{b}	88	89	121	198	
Digestion			% of ADF intake				
Ruminal	PRAIRIE	1990	55.5	57.4	48.1	44.4	2.9
		1991	54.4^{gj}	57.4	53.3	51.8^{g}	1.4
	PLAINS	1990	---	62.6^{d}	57.5^{d}	48.0^{ci}	2.5
		1991	65.7^{h}	62.2	56.4	66.1^{hj}	1.5
		SE	2.1	1.5	2.6	2.5	
Total	PRAIRIE	1990	61.6^{c}	64.7^{d}	62.9^{cd}	61.4^{cg}	.5
		1991	60.5^{cg}	63.5^{dg}	63.0^{cdg}	63.3^{dg}	.5
	PLAINS	1990	---	62.0^{ci}	61.6^{ci}	68.2^{dhi}	1.0
		1991	65.0^{ch}	67.4^{cdhj}	69.2^{dhj}	73.1^{ehj}	.7
		SE	.5	.6	.8	1.1	

^{a} n=24, except on PLAINS during 1990, n=18.
^{b} n=24, except during May, n=18.
$^{c\text{-}f}$ Row means with uncommon superscripts differ (P<.05).
^{g,h} Pasture means within year with uncommon superscripts differ (P<.05).
^{i,j} Year by forage type means with uncommon superscripts differ (P<.05).

TABLE 4-5. INTAKE AND DUODENAL FLOW OF NITROGEN (N; g/d) IN BEEF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) AND PLAINS BLUESTEM PASTURE (PLAINS)

			Month				
Item	Forage	Year	May	June	August	October	SE^{a}
Intake	PRAIRIE	1990	166^{d}	105^{cgi}	126^{cgi}	111^{ci}	6
		1991	169^{eg}	136^{dj}	88^{cj}	213^{fgj}	10
	PLAINS	1990	---	183^{dhi}	239^{ehi}	121^{ci}	13
		1991	193^{eh}	152^{dj}	95^{cj}	175^{ehj}	8
		SE^{b}	5	7	13	10	
Passage							
Duodenal flow							
Ammonia-N	PRAIRIE	1990	6	6	6^{i}	6^{gi}	.2
		1991	7^{cg}	8^{d}	5^{cg}	13^{egj}	.7
	PLAINS	1990	---	6	7	6	.2
		1991	11^{eh}	7^{d}	9^{dh}	5^{ch}	.6
		SE	.7	.3	.4	.8	
Non-ammonia	PRAIRIE	1990	204^{e}	172^{dgi}	174^{dg}	149^{cgi}	5
		1991	214^{dg}	199^{dj}	167^{cg}	236^{egj}	7
	PLAINS	1990	---	211^{dh}	246^{chi}	170^{ch}	8
		1991	237^{eh}	203^{d}	187^{dhj}	150^{ch}	7
		SE	5	4	7	8	
Non-microbial	PRAIRIE	1990	131^{d}	118^{d}	112^{dgi}	95^{ci}	4
		1991	114^{d}	128de	86^{cj}	137^{egj}	6
	PLAINS	1990	---	126^{c}	154^{dhi}	107^{ci}	5
		1991	136^{e}	111^{d}	93^{cdj}	73^{chj}	4
		SE	5	5	5	7	
Microbial	PRAIRIE	1990	73^{di}	54^{cgi}	62^{cdgi}	54^{ci}	3
		1991	100^{dj}	71^{cgj}	81^{cgj}	98^{dgj}	4
	PLAINS	1990	---	85^{dh}	92^{dh}	63^{ci}	4
		1991	102^{d}	93^{dh}	95^{dh}	78^{chj}	3
		SE	4	4	3	4	
Fecal	PRAIRIE	1990	80^{ei}	64^{dg}	62^{dg}	53^{ci}	3
		1991	69^{dj}	69^{d}	60^{c}	79^{egj}	2
	PLAINS	1990	---	73^{dh}	83^{ehi}	47^{ci}	4
		1991	74^{e}	66de	59^{cdj}	57^{chj}	2
		SE	2	1	2	3	

[a] n=24, except on PLAINS during 1990, n=18.
[b] n=24, except during May, n=18.
[c-f] Row means with uncommon superscripts differ ($P<.05$).
[g,h] Pasture means within year with uncommon superscripts differ ($P<.05$).
[i,j] Year by forage type means with uncommon superscripts differ ($P<.05$).

TABLE 4-6. SITE AND EXTENT OF NITROGEN (N) DIGESTION IN BEEF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) AND PLAINS BLUESTEM PASTURE (PLAINS)

Item	Forage	Year	Month: May	June	August	October	SE[a]
Ruminal			% of N intake				
Apparent	PRAIRIE	1990	-26.0[d]	-70.8[cg]	-44.4[dgi]	-46.8[di]	5.6
		1991	-31.9[de]	-52.6[d]	-97.8[cj]	-18.4[egj]	7.4
	PLAINS	1990	---	-19.0[dh]	-7.8[dhi]	-49.2[ci]	6.0
		1991	-29.7[d]	-40.3[d]	-108.5[cj]	11.8[ehj]	9.7
		SE[b]	3.2	4.9	9.6	7.1	
True	PRAIRIE	1990	21.2[d]	-12.5[cg]	9.9[dg]	11.5[di]	4.5
		1991	31.9[d]	5.9[cg]	1.9[c]	34.5[dgj]	4.4
	PLAINS	1990	---	30.9[dh]	34.2[dhi]	9.4[ci]	4.2
		1991	28.6[d]	26.4[dh]	1.4[cj]	58.5[ehj]	4.9
		SE[b]	3.4	4.5	4.2	5.4	
			% entering segment				
Lower tract	PRAIRIE	1990	61.7[i]	64.0	65.5	65.8[g]	1.1
		1991	68.4[j]	66.6	65.1	67.8	.8
	PLAINS	1990	---	66.2[c]	67.0[c]	73.5[dhi]	1.3
		1991	70.3[d]	68.6[d]	69.6[d]	63.4[cj]	.9
		SE	1.2	.7	.9	1.3	
			g microbial N/100 g OM truly digested				
MCOEFF[k]	PRAIRIE	1990	18.9[c]	17.1[c]	17.7[c]	33.6[di]	2.9
		1991	22.3	19.7	22.7	21.8j	1.2
	PLAINS	1990	---	20.9[c]	22.8[c]	39.4[di]	3.2
		1991	31.6[d]	20.0[cd]	26.2[d]	14.0[ej]	1.8
		SE	1.8	1.0	1.5	3.6	

[a] n=24, except on PLAINS during 1990, n=18.
[b] n=24, except during May, n=18.
[c-f] Row means with uncommon superscripts differ (P<.05).
[g,h] Pasture means within year with uncommon superscripts differ (P<.05).
[i,j] Year by forage type means with uncommon superscripts differ (P<.05).
[k] Microbial efficiency.

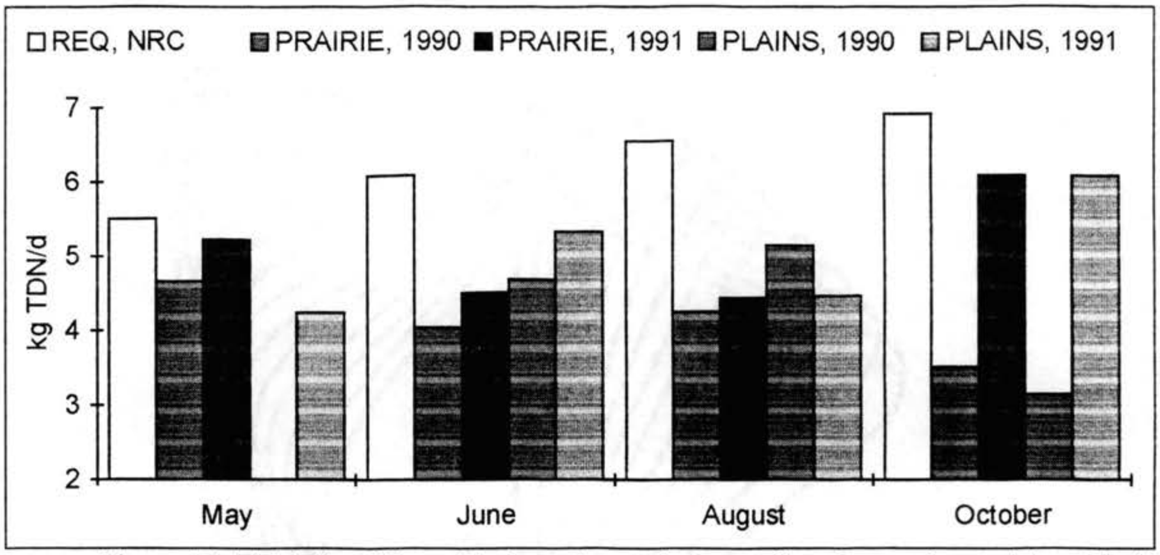

Figure 4-1. Total digestible nutrient requirement of a medium-frame steer gaining .9 kg/d (NRC, 1985) and the estimated TDN intake by cattle grazing midgrass prairie rangeland (PRAIRIE) or Plains bluestem pasture (PLAINS). Body weights for May, June, August and October were 267, 306, 337, and 363 kg, respectively.

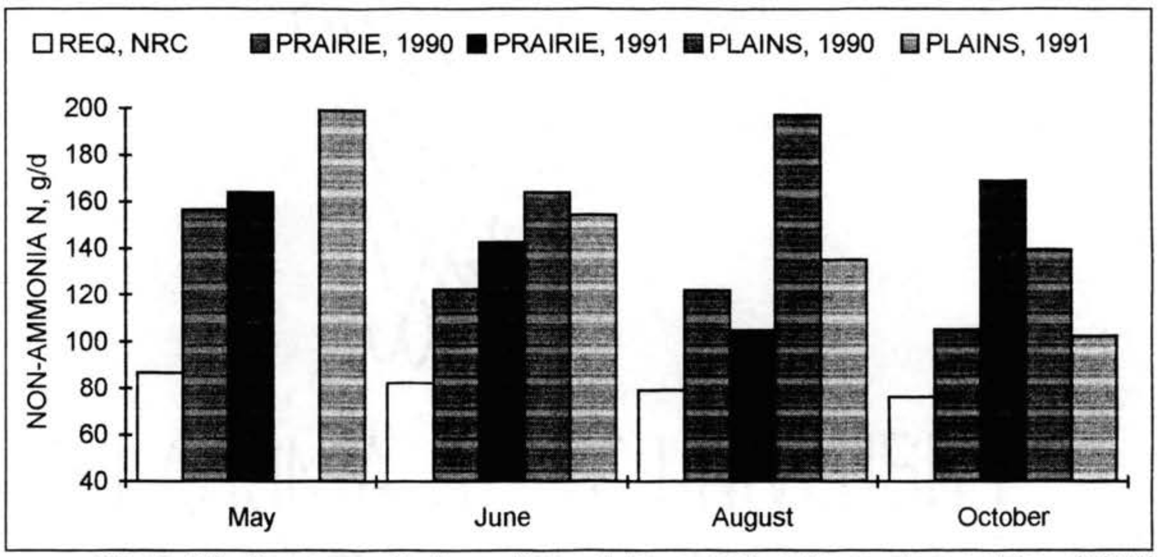

Figure 4-2. Non-ammonia N requirement for a medium-frame steer gaining .9 kg/d (NRC, 1985) and the non-ammonia N flow in cattle grazing midgrass prairie rangeland (PRAIRIE) and Plains bluestem pasture (PLAINS). All estimates exclude non-ammonia N required for metabolic fecal N. Body weights for May, June, August and October were 267, 306, 337, and 363, respectively.

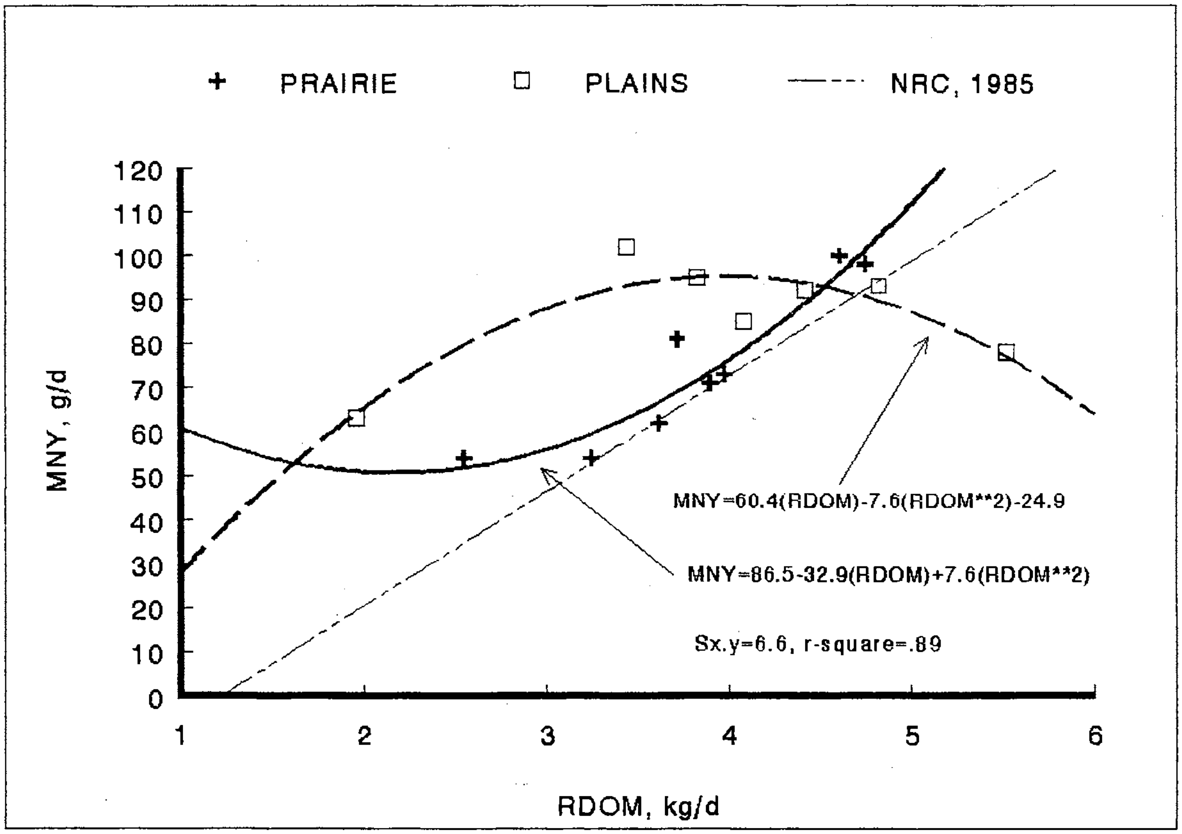

Figure 4-3. Relationship between microbial nitrogen yield (MNY) and ruminal digestible OM (RDOM) in cattle grazing midgrass prairie rangeland (PRAIRIE) and Plains bluestem pasture. The relationship between MNY and RDOM published by the NRC (1985) is MNY=26.1RDOM-31.9.

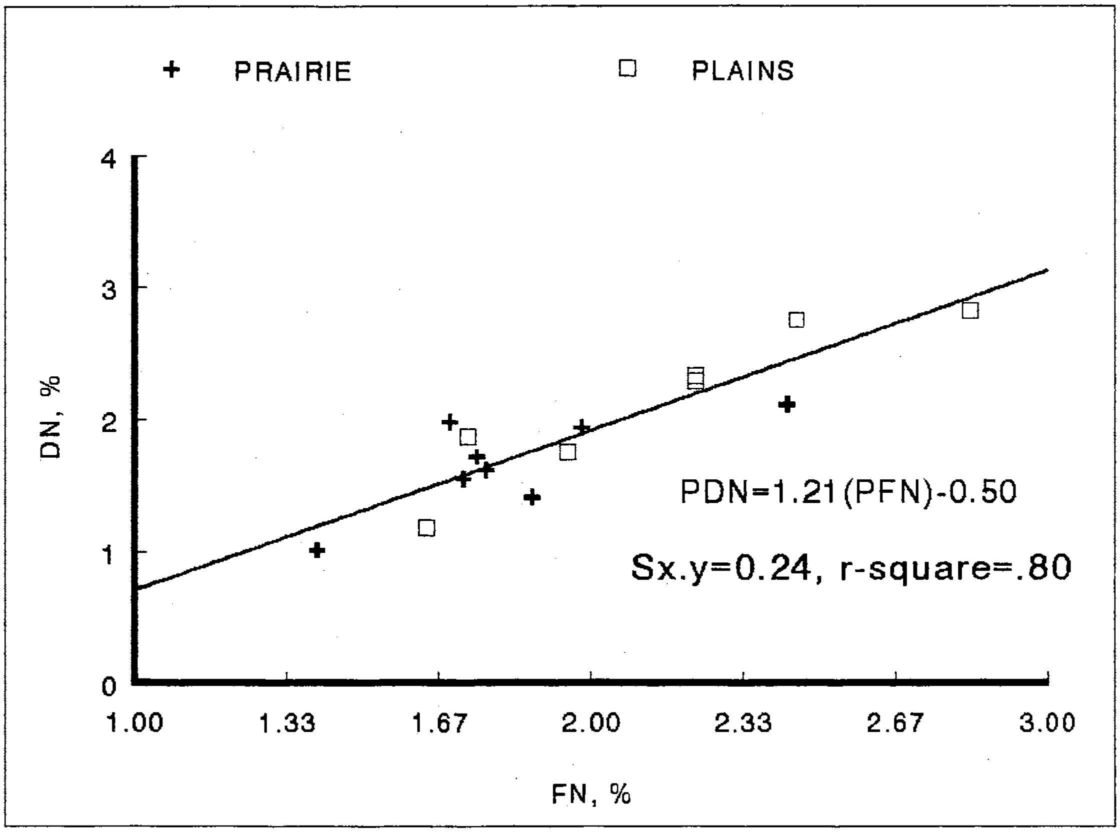

Figure 4-4. Relationship between percent dietary nitrogen (DN) and percent fecal nitrogen (FN) in cattle grazing midgrass prairie rangeland (PRAIRIE) and Plains bluestem pasture.

CHAPTER V

Forage intake and digestion by cattle grazing midgrass prairie rangeland or Sideoats grama/Sweetclover pasture

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Abstract

During mid-May, beef cattle fitted with esophageal (4 steers/pasture) or ruminal and duodenal cannulae (6 heifers/pasture; avg body weight=274) grazed midgrass prairie rangeland (PRAIRIE) or retired cropland reseeded to a mixture of Sideoats grama and Sweetclover (*Bouteloua curtipendula* (Michx.) Torr./*Melilotus officinalis* (L.) Lam.; PASTURE). The range site was in excellent range condition. The PASTURE contained 48% Sideoats grama and 6% Sweetclover. Masticate nitrogen (N), neutral detergent fiber, acid detergent fiber, and in vitro organic matter (OM) disappearance, averaged 2.1, 68.2, 36.0, and 58.6% (OM basis) for PRAIRIE, and 2.4, 64.9, 36.2, and 59.0% for PASTURE. Masticate N was the only diet variable that differed (P=.02). Extent of in situ OM and N disappearance were greater (P<.05) and rate of N disappearance was slower (P<.10) from PRAIRIE masticate than from PASTURE masticate. Based on in situ data, rumen degradable N:rumen digestible OM (g/100 g) balance differed (P<.05; PRAIRIE=2.1, PASTURE=2.5). Ruminal ammonia-N concentration (mg/dl) was lower (P=.02) in cattle grazing PRAIRIE (2.8) than in cattle grazing PASTURE (3.8). Forage OM intake and fecal OM output were similar (P>.72; avg=8207 and 3380 g/d), but duodenal OM flow tended (P=.13) to be greater (PRAIRIE=4892, PASTURE=5170 g/d) in cattle grazing PASTURE. Apparent and true ruminal OM digestion were similar (P>.18; avg=38.3 and 48.5%). Lower tract OM digestion (% entering segment) tended (P=.07) to be greater in cattle grazing PASTURE (31.2 vs 34.4). Nitrogen intake, non-ammonia N, and forage N flow at the duodenum were higher (P<.04) on PASTURE (171 vs 198, 210 vs 242, and 135 vs 162 g/d). Microbial N flow (avg=78 g/d) and microbial efficiency (avg=20 g microbial N/kg OM truly fermented) were similar (P>.25) between forage types. Apparent and true ruminal N digestion were similar (P>.65; avg=-26.6 and 19.3%) between forage resources but, N digested in the lower tract was higher (P<.02) for cattle grazing PASTURE. In this study, the non-ammonia N flow was adequate for gains in excess of 2 kg/d on either forage type but estimated digestible OM intake was only adequate for weight gains of .9 kg/d. Therefore, digestible OM intake by cattle grazing either forage type appeared to be first-limiting for performance.

(Key Words: forage quality, intake, rumen digestion, microbial protein synthesis, rangelands)

Introduction

Throughout the western United States, producers are revegetating retired croplands with introduced or native grasses. The limited species diversity of reestablished grassland places constraints diet quality and limits the nutritional value of reseeded cropland. The introduction of clovers to swards grazed by livestock often improves diet quality (Freer and Jones 1984, Ridout and Rodson 1991). Sweetclover (*Melilotus officinalis* (L.) Lam.) is a legume which grows well in western Oklahoma. This clover improves soil fertility through increased soil aeration and nitrogen fixation (Hannaway and McGuire 1982). Sweetclover is common on old-field sites as a remnant of cultivation or as a constituent of the reseeding mixture. This discussion raises two questions: first, do cattle grazing midgrass prairie rangeland (PRAIRIE) or reseeded Sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.)/Sweetclover pasture (PASTURE) consume and absorb different amounts of nitrogen (N) and digestible organic matter (DOM) in the spring? Second, what type of supplement, if any, would be required to enhance animal performance?

With these questions in mind, an experiment was constructed to determine if PRAIRIE and PASTURE are equivalent forage resources for growing cattle. This comparison was accomplished by measuring nutrient intake, ruminal fermentation, ruminal microbial protein yield, and nutrient absorption.

Materials and Methods

Research Site

This study was conducted at the Marvin Klemme Range Research Station in Washita County, OK (35° 22′ N, 99° 04′ W). The station is located in the Rolling Red Plains resource area (SCS, 1982). The 48.6 ha of PRAIRIE had never been cultivated. Soils on this site are in the Cordell Series and are mapped as Red Shale range sites. The 32.4 ha of PASTURE were established on retired cropland approximately 20 years ago. The only grazing management practice implemented on either site was continuous stocking with cattle.

Precipitation at Clinton, OK, located approximately 16.1 kilometers north of the station, was 41.9 cm (normal, 27.5 cm) from January through May in 1990. The average temperature during the experiment was 27° C with an average low of 20° C and an average high of 34° C.

Sampling Procedures

Standing crop of forage was estimated by clipping forage to ground level inside 0.1 m^2 frames (n=40) along paced transects. Herbage samples were individually weighed in the field then dried to a constant weight to determine forage dry matter (DM). Four samples from each pasture were hand-separated into live and dead fractions and processed as described above. Live:dead ratios were estimated using simultaneous equations relating total sample DM to the DM of the live and dead fractions (Gillen and Tate, 1993). The dry-weight rank method was used to estimate species composition of the pastures (Gillen and Smith 1986).

Four steers fitted with esophageal cannulae and six heifers fitted with ruminal and duodenal cannulae (British x British, avg body weight=274 kg) grazed each site for 2 weeks before sampling began. Cattle had continual access to fresh water and a commercially available mineral supplement[1]. Masticate samples were collected from each site on d 1 and 2 (May 9 and 10, 1990). The steers were fitted with screen-bottom collection bags and were allowed to graze for 30 to 45 min. Steers were herded as they grazed to obtain a more representative sample from the area. After collection, samples were composited by steer across days. A 20% aliquot of the composite was stored frozen in a plastic bag. The remaining extrusa was composited within forage type across days and steers and prepared for in situ digestion.

Chromic oxide was used to estimate fecal output and duodenal flow in the heifers. Chromic oxide was administered twice daily beginning on d 1 of the sampling period and continued through d 10 (7.5 g at sunrise and 12 h later). Fecal grab samples were collected at sunrise and 12 h later during the last 5 d of the trial. Samples were composited across days and times within heifer. Duodenal samples were collected on PASTURE at sunrise on d 6 and 9, 6 h past sunrise

[1] Contained (% of DM): 20.5% NaCl, 16.5% Ca, 8.0% P, .02% I, Trace minerals, 44,000 IU vit. A/ kg, and 22,000 IU vit D_3/kg.

on d 7 and 10, and 12 h past sunrise on d 7 and 8. On PRAIRIE, duodenal samples were collected at sunrise on d 7 and 10, 6 h past sunrise on d 6 and 10, and 12 h past sunrise on d 6 and 9. Approximately 250 ml samples of chyme were collected at each time and composited across days and times within heifer and stored frozen.

On d 5 and 6, ruminal samples were obtained at sunrise, 6 h and 12 h past sunrise. One sample was collected from each heifer at each time. Ruminal pH of the rumen samples was immediately estimated using a combination electrode. All samples were strained through cheesecloth, acidified with 1 ml 7.2 N H_2SO_4/100 ml of ruminal fluid, and stored frozen.

The composite masticate samples used for in situ digestion were dried in a forced air oven at less than 30° C. During drying, samples were spread thinly and frequently mixed to minimize drying time and artifact lignin formation. Broesder et al. (1992) determined that the in situ OM disappearance of masticate dried rapidly at a low temperature was similar to estimates obtained with lyophilized masticate. Dried masticate was ground through a Wiley mill (2-mm screen). Two 5 g aliquots of esophageal masticate were placed in duplicate 10 x 20 cm polyester in situ bags (pore size = 53±10 μm, Ankom, 140 Turk Hill Park, Fairport, NY. 14450). These pairs of in situ bags were then attached to individual weighted lines. Beginning on d 8, individual lines holding bags were placed in the rumen of each heifer for 72, 48, 36, 24, 16, 12, 8, and 4 h. All the bags were removed simultaneously, rinsed with cold tap water until effluent ran clear, and then stored frozen.

After removal of the in situ bags, 2 liters of rumen fluid was collected from each heifer for isolation of bacteria. Whole rumen contents were strained through cheesecloth and the fluid was preserved with formaldehyde (25 ml 9%(w/v) NaCl in 37% formaldehyde/100 ml ruminal fluid).

Laboratory Analyses

Diet, duodenal, and fecal samples were lyophilized, ground through a Wiley mill (2-mm screen), and analyzed for DM and ash, N (AOAC 1991), neutral detergent fiber (NDF) and acid detergent fiber (ADF; Goering and Van Soest 1970). The N in the diet samples was fractioned into soluble and insoluble N by pepsin digestion (AOAC 1991). Duodenal samples were also analyzed for ammonia N (NH_3N; AOAC 1991), purines (Zinn and Owens 1987), and neutral detergent insoluble N (NDIN; Van Soest 1982). Chromium concentration in duodenal and fecal samples were determined by atomic absorption spectroscopy (Williams et al. 1962). Microhistological examination of dried and ground masticate samples followed procedures outlined by Sparks and Malecheck (1986). Twenty systematically located fields per slide and 5 slides per sample (individual steer samples) were examined at 100X magnification.

In situ bags were thawed and dried at 100° C in a forced air oven. The bags were weighed to determine DM loss and the residues were analyzed for DM, ash and N (AOAC 1991).

In vitro organic matter disappearance (IVOMD) of masticate samples was determined by inoculating the incubation tubes containing .5 g of masticate with a 50:50 ruminal fluid:McDougall's buffer containing .10% urea. Ruminal fluid was collected from rumen cannulated heifers maintained on a 50% alfalfa:50% prairie hay diet. The fluid was collected 3-4 h after the morning feeding. Laboratory standard forages were analyzed concurrently with the masticate samples.

Ruminal samples were thawed at room temperature and centrifuged at 10,000 x g for 10 min. The NH_3N concentration of the supernatant was determined using a phenol-hypochlorite procedure (Broderick and Kang 1980).

Bacteria were isolated from the preserved rumen fluid by differential centrifugation (Merchen and Satter 1983). Later, bacteria were lyophilized and ground with a mortar and pestle and analyzed for purines (Zinn and Owens 1986), DM, ash, and N (AOAC 1991).

Calculations

Fecal organic matter (OM) output and duodenal OM flow were estimated as the ratio of chromium dosed and chromium concentration in feces and duodenal samples. Forage OM intake was estimated as the ratio of fecal output and in vitro OM indigestibility. Microbial N flow at the duodenum was determined from the ratio of purine:N in bacteria and total purine flow.

The instantaneous rate of in situ OM and N disappearance were calculated for each time that extent of in situ digestion is reported. Instantaneous rates of digestion were selected over an overall rate because the initial rate of digestion of legumes is usually faster than grasses (Van Soest 1982). This method of analysis may detect differences in rate of digestion that an overall rate may confound. The percent of potentially degradable nutrient remaining after each incubation interval (rn_i) was calculated as:

$$rn_i=100*[1-(nd_i/npd)]$$

where nd_i is the percent of the nutrient (e.g., OM or N) remaining in the in situ bag after *i* h; npd is the potential degradability of the nutrient (72 h). Quadratic regression equations were then constructed by fitting rn_i to the model:

$$Y_i=\beta_0+\beta_1X_i+\beta_2X_i^2$$

for each heifer in the experiment (OM, r =.97; N, r =.96). An estimate of the instantaneous rate of digestion was determined using the first derivative of the regression equations.

Statistical Analysis

Masticate composition and rate and extent of in situ digestion data were analyzed by ANOVA. Forage type was the main model effect in the model. Models for ruminal pH and NH_3N also contained sampling time of day and were tested for a sampling time of day x forage type interaction (Lentner and Bishop 1986). In this model, forage type was tested with heifer within forage type. Models for nutrient intake and site and extent of digestion contained body weight as a covariate. Least square means were separated using the protected ($P<.05$) least significant difference procedure.

Results and Discussion

Forage availability

Total standing crop of DM was similar (Table 5-1) on both sites but species composition of the two sites differed. The PASTURE contained 128% more Sideoats grama and 6% Sweetclover. The PRAIRIE was devoid of Sweetclover but contained a greater complement of indigenous forbs and shortgrass species.

Diet composition

The level of Sideoats grama, Blue/Hairy grama (*Bouteloua gracilis* (H.K.B.) Lag. ex Steud./*B. hirsuta* Lag.), and Buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.) in the steers (Table 5-2) diets was similar to the availability in the standing crop (Table 5-1). However, the preference ratio of selected Purple locoweed (*Astragalus mollissimus* Torr.) to available locoweed was in excess of 20 for steers grazing both sites. Steers grazing PRAIRIE consumed 20% of the diet as locoweed. Research in New Mexico has reported that cattle were reluctant to start grazing Purple locoweed but, once they began to consume Purple locoweed, it comprised approximately 23% of the diet (preference ratio=1.3, Ralphs et al. 1992). Bachman et al. (1992) reported that when White locoweed (*Oxytropis sericea* Nutt.) composed 20% of the diet, beef heifers showed signs of locoism after 28 d. Purple locoweed contains .5 to 9 times more swainsonine than White locoweed (Ralphs et al. 1992). Sweetclover was 27% of the diet of steers grazing PASTURE, the preference ratio (4.5) shows that the steers selected for Sweetclover. In New Mexico, cattle grazing a pasture seeded to Blue grama, Sideoats grama, and Sweetclover consumed diets that contained about 36% Sweetclover (preference ratio=9.0; Ralphs et al. 1992).

Steers grazing the PASTURE consumed masticate that contained 12.5% more (P=.02) N than diets from the PRAIRIE (Table 5-2). Because the cattle on PASTURE preferentially grazed Sweetclover, the higher N content of the PASTURE masticate probably was due to consumption of the Sweetclover. Hand-clipped samples of Sweetclover contained 4.3% N. Masticate IVOMD was similar (P=.72) between sites. Diets containing a higher proportion of forbs typically have a lower extent of digestion than all grass diets (Bowman and Asplund 1988, Hunt et al. 1985) due to higher lignin content (Van Soest 1982). The PASTURE masticate tended (P=.11) to contain less NDF and the ratio of NDF/ADF was lower (P=.07) than masticate from PRAIRIE (Table 5-2). These characteristics further reflect consumption of the Sweetclover by the cattle because legumes have lower cell wall contents and lower NDF/ADF ratios than grasses (Van Soest 1982).

Ruminal fermentation

At sunrise and 6 h past sunrise no differences ($P>.05$) were noted in ruminal pH (avg=6.4, SE=.1). However, ruminal pH in the heifers grazing PRAIRIE decreased ($P<.05$, 6.1) at 12 h past sunrise. At this same time, the ruminal pH in the heifers grazing PASTURE remained constant ($P>.05$, 6.3). The pH remained well above levels where researchers have noted reductions in fiber digestion at all times (Van Soest 1982).

The ruminal NH_3N concentration (mg/dl) was greater ($P=.02$) in heifers grazing the PASTURE (3.8) than in heifers grazing PRAIRIE (2.8, SE=0.27). This difference was consistent across the days and may suggest reduced NH_3N utilization by ruminal microbes digesting the PASTURE diet. In cattle grazing blue grama rangeland in New Mexico, there was a strong correlation between diet N and ruminal NH_3N (r =.75, McCollum and Horn 1990). The ruminal NH_3N concentration in heifers in our study supports this relationship.

In situ OM disappearance from PASTURE masticate was less ($P<.05$) at most times (Table 5-3). Similarly, Bowman and Asplund (1988) noted a linear decrease in the extent of DM digestion as alfalfa (*Medicago sativa* L.) was increased in the diets of sheep consuming Caucasian bluestem hay (*Bothriochloa caucasia* (Trin.) C.E. Hubb). The disagreement between in vitro and in situ digestion estimates was not explained by the data; however, other researchers have also reported similar disagreements between these two digestion estimates (Campbell 1989, Barton et al. 1992, Broesder et al. 1992).

In situ N disappearance followed a pattern similar to OM disappearance (Table 5-4). Although percent of total N disappearance was greater from PRAIRIE masticate, the total amount of N released was similar ($P=.31$) because PASTURE masticate contained more N. Therefore, any differences in microbial protein production probably resulted from differences in rumen available energy (NRC 1985).

Ratios of rumen degradable N (RDN):rumen digestible OM (RDOM) were calculated from the in situ data (Gunter and McCollum 1991). The RDN:RDOM ratios were similar ($P>.05$) within a forage among all incubation times except ($P<.05$) 4, 8, and 12 h. During the early growing season, cattle grazing New Mexico blue grama rangeland have average rumen retention time of 28.6 h (Krysl et al. 1987). Therefore, ratios averaged across 16-48 h should provide good estimates of protein/energy balance in rumen. The average ratios were 21 and 25 g RDN/kg RDOM for PRAIRIE and PASTURE, respectively. The PASTURE diets provided the most ($P<.05$) RDN per gram of RDOM. This higher ratio was not the result of the higher ($P<.05$) diet N, but instead, the lower ($P<.05$) RDOM in the diet. If urea recycling is considered (NRC, 1985), a total of 25 and 29 g N/kg of RDOM were available for microbial protein synthesis from PRAIRIE and PASTURE diets, respectively. Based on NRC (1985) equations, ruminal microbes require 26 g RDN/kg RDOM to optimize protein synthesis. It is doubtful that the supplementation of RDN (e.g., soybean meal) to cattle grazing either forage type would have increased microbial protein synthesis.

In situ rate of OM digestion between 4 and 24 h of incubation was similar ($P>.20$) between forage types (Table 5-3). However, the rate of digestion at 36 and 48 h tended ($P<.09$) to be more rapid from PASTURE masticate. Legumes characteristically have faster rates of digestion (Van Soest 1982). However, the failure of the PASTURE masticate to have a significantly higher rate of digestion than PRAIRIE masticate may be due to differences in the composition of the grasses consumed. Cattle on PRAIRIE consumed less Sideoats grama and more Blue/Hairy grama and Buffalograss than cattle on the PASTURE.

In situ rate of N disappearance between 4 and 16 h tended ($P<.13$) to be faster from PASTURE (Table 5-4). At 24 h, the rate of N digestion was greater ($P=.04$) from PASTURE masticate than from PRAIRIE masticate. But, by 48 h the rate of N digestion was similar ($P=.39$) between forage types. This tendency for an initially faster release of N from PASTURE masticate may explain the higher accumulation of NH_3N in the rumen of cattle grazing PASTURE.

Intake

Total OM intake was similar ($P=.72$, Table 5-5) with the heifers consuming 3.0% of their BW/d on either forage type. This level of intake exceeds the value (2.3% BW) predicted by NRC

(1984) equations. Due to the high level of intake, cattle may perform superior to NRC (1984) estimates if judgments are based solely on the chemical composition of diets.

Intake of DOM was 4826 g/d on both forage types. Assuming DOM is equal to TDN (NRC, 1985), the energy intake by the cattle was sufficient for .9 kg/d of weight gain (NRC, 1984). Cattle grazing rangeland adjacent to the PRAIRIE gained an average of .7 kg/d (McCollum and Gillen unpubl. data) over a 76 d period (May 1 to July 15).

Total N intake was 16% greater (P=.01) for heifers grazing PASTURE (Table 5-6). Nitrogen intake from both forage types provided enough crude protein for a 274 kg medium frame-heifer to gain in excess of 2 kg/d (NRC 1985). Weight gains this high are unrealistic, but this estimate of potential gain based on N intake establishes that TDN intake probably was first-limiting for performance.

Intakes of NDF and ADF were similar (P>.38; Table 5-7). Related research has shown that as the percentage of alfalfa is increased in the diet, NDF intake decreased and ADF intake remained constant (Bowman and Asplund 1988). This reduction in cell wall intake was suggested as being responsible for the animal's ability to maintain a high level of intake and digestion because the fiber content of legumes is lower and less digestible than in grasses.

Site and extent of digestion

Total OM flow and forage OM flow at the duodenum tended (P=.13) to be greater in heifers grazing PASTURE (Table 5-5). This tendency for greater OM flow reflects the lower in situ OM disappearance estimates observed on PASTURE (Table 5-3). The flow of microbial OM at the duodenum was similar (P=.62) between forage types.

Apparent and true ruminal OM digestion were similar (P>.25) between forage types (Table 5-5) while lower tract OM digestion (% entering segment) tended (P=.07) to be higher in heifers grazing PASTURE (Table 5-5). Non-microbial neutral detergent soluble OM flowing into the duodenum was greater on PASTURE (PRAIRIE=1675 vs PASTURE=2080 g/d, SE=79.7) which may explain the tendency for higher lower tract OM digestion in heifers grazing PASTURE.

Total N flow at the duodenum was 14% greater (P=.04) in cattle grazing PASTURE (Table 5-6). This increased N flow can be accounted for by non-microbial, non-ammonia N (i.e., forage N) escaping the rumen. Neutral detergent insoluble N flow was similar (P=.68) between forage types. However, non-microbial neutral detergent soluble N flow was greater (P=.02) in cattle grazing PASTURE. Assuming that ruminal degradation of protein in the cell contents of forage is in excess of 95% and that N in the NDF fraction is of forage origin (Van Soest 1982), it is reasonable to conclude that the N in duodenal NDF was forage protein that escaped ruminal degradation and N that was neutral detergent soluble in duodenal samples was associated with bacteria or transitional compounds.

The discrepancy between the estimated forage N flow based on RNA analysis (Table 5-6) and estimated forage N flow calculated from NDIN flow (PRAIRIE=41.8, PASTURE=40.3 g/d) may be due to (1) N containing substrates not associated with cell wall or microbial OM or (2) endogenous protein unaccounted for by either method of N fractioning. Steinhour and Clark (1980) stated that up to 20% of the total N reaching the duodenum may be from endogenous sources.

Microbial N flow and efficiency of microbial protein synthesis were similar (P>.25) between forage types (Table 5-6). Based on true ruminal OM digestion (4.0 kg/d), NRC (1985) equations predict that microbial N flow at the duodenum would be 72.0 g/d. This estimate assumes that RDN is not limiting and closely approximates the measured microbial protein synthesis in our study.

Apparent N digestion in the rumen was similar (P=.94) between forage resources (Table 5-6). The negative estimate suggests that N intake was excessive in relation to energy intake (ARC 1980). Both the ARC (1980) and NRC (1984) assume that the ratio of post-ruminal N flow to intake N is equal to one when calculating the nutrient requirements of cattle. Supplementation of cattle grazing *Bouteloua* spp. with energy has increased apparent N digestion in the rumen (Krysl et al. 1989). The cattle in our study may have benefited from an improved balance between rumen available N and energy and increased N retention with low level energy supplementation (Lake et al. 1974a).

Based on pruine flow, true N digestion in the rumen was similar (P=.94) for both forage types (Table 5-6). Nitrogen truly digested in the rumen is low in contrast to the in situ data, which suggested that true ruminal N digestion was much higher. Funk et al. (1987) reported true ruminal N digestion values ranging from 25-29% during June and August on rangeland inhabited by *Bouteloua* spp. MacRae et al. (1979) suggested that a significant portion of the N recycled to the stomach is not derived from blood or salivary urea. Nitrogen also originates from sloughed epithelial cells or secretions in the abomasum. The magnitude of these endogenous contributions is not well defined. Kreikemeier et al. (1992) failed to measure a significant contribution of N to duodenal chyme from abomasal secretions in steers fed at different diets at varied levels of intake. But, either of these sources of endogenous N will be included in the forage N fraction flowing into the duodenum when estimates are calculated by difference between total N flow and microbial N flow. True N digestion in the rumen based on NDIN flow at the duodenum was 75% in cattle grazing PRAIRIE and 80% in cattle grazing PASTURE. These estimates of digestibility are in closer agreement with the in situ digestion estimates.

Total tract digestion of NDF tended to be less (P=.09) in heifers grazing PASTURE, but the total tract ADF digestion was greater (P=.004) in heifers grazing PASTURE (Table 5-5). Levels of fiber digestion were similar to values reported by Beever et al. (1972), Hume and Purser (1974), and Funk et al. (1987). Over 91% of the fiber was digested in the rumen of cattle grazing either forage type, which is similar to finding by Funk et al. (1987; >90%) and Beever et al. (1972; >91%). No differences (P>.19) were noted in the extent of hindgut fiber digestion. The level of hindgut fiber digestion was similar to values reported by Beever et al. (1972) and Funk et al. (1987).

Differences in fiber digestion between forage types could be related to differences in retention time or digestibility of fiber contained in the Sweetclover and grasses consumed. Several researchers have reported reduced NDF digestion when alfalfa is added to grass diets

(Hunt et al. 1985, Bowman and Asplund 1988). This reduction in fiber digestion may be associated with the increase in passage rate of grass particles when alfalfa is added to grass diets (Hunt et al. 1988a). Other researchers have reported that the addition of alfalfa to low quality forage diets increased NDF digestion (Soofi et al. 1982, Hunt et al. 1988a,b). In two of these reports (Hunt et al. 1988a,b), the titration of alfalfa into the basal diets suggested that the NDF in alfalfa was more digestible than the NDF in the forage because NDF digestibility of the total diet increased linearly.

In this study, the N status of cattle grazing PASTURE was superior to cattle grazing PRAIRIE. However, non-ammonia protein flow was adequate for gains in excess of 2 kg/d on either forage type and estimated DOM intake was only adequate for weight gains of .9 kg/d. Therefore, DOM intake appeared to be first-limiting for performance on both forages.

Management Implications

The nutritional management of cattle grazing either forage type should be similar. This implication is supported by the conclusion that DOM intake was first-limiting for performance on either forage type. The supplementation of cattle grazing these forage types in May with low levels of a high energy, medium protein supplement might improve weight gain (Lake et al., 1974b). Supplements designed for cattle grazing these forage types during the early spring should be balanced for RDN:RDOM to prevent the disruption of the protein/energy balance in the rumen. A supplement with an extremely low RDN:RDOM ratio may induce a ruminal N deficiency and potentially reduce metabolizable nutrient yields to the grazing animal.

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Table 5-1. Standing crop and species composition of midgrass prairie rangeland (PRAIRIE) or Sideoats grama/Sweetclover pasture (PASTURE).

Species	PRAIRIE	PASTURE
Standing crop, kg DM/ha	1686±243[a]	1837±214
Live:dead ratio	2.5	2.0
	%	
Sideoats grama	21	48
Blue/Hairy grama	17	4
Buffalograss	14	1
Little bluestem	T[b]	T
Other perennial grasses[c]	13	19
Annual grasses (*Bromus* spp.)	6	5
Forbs	27	16
Locoweed	1	T
Sweetclover	0	6
Half shrubs	2	3

a Standard error, n=40.

b Denote trace amounts (<.5%)

c Includes: *Andropogon gerardii* Vitman, *Bothriochloa saccharoides, Sorghastum nutans* (L.) Nash, *Aristida* spp.

Table 5-2. Composition of masticate collected from cattle grazing midgrass prairie rangeland (PRAIRIE) or Sideoats grama/Sweetclover pasture (PASTURE).

Item	PRAIRIE	PASTURE	SE[a]	P-value
Species composition, %				
Sideoats grama	27	42	2.39	.005
Blue/Hairy grama	15	1	1.85	.002
Buffalograss	9	1	1.21	.003
Little bluestem	5	7	.77	.20
Other grasses	22	10	1.37	.001
Sweetclover	0	27	1.47	.0001
Locoweed	20	6	1.79	.002
Other forbs	2	6	.72	.01
Nutrient composition				
N, % of OM	2.1	2.4	.05	.02
Insoluble N, % of total N	37.6	34.4	1.85	.26
NDF, % of OM	68.2	64.9	1.21	.11
ADF, % of OM	36.0	36.2	.69	.79
NDF/ADF	1.9	1.8	.03	.07
IVOMD[b], % of OM	58.6	59.0	.68	.72

[a] Standard error, n=8.

[b] In vitro OM disappearance.

Table 5-3. In situ extent and rate of organic matter disappearance from masticate samples collected from cattle grazing midgrass prairie rangeland (PRAIRIE) or Sideoats grama/Sweetclover pasture (PASTURE).

	Extent				Rate			
Incubation time, h	PRAIRIE	PASTURE	SE[a]	P-value	PRAIRIE	PASTURE	SE[a]	P-value
	%				%/h			
4	35.6	28.4	2.2	.04	2.3	2.3	.07	.68
8	41.1	35.6	1.5	.03	2.1	2.2	.06	.60
12	51.7	45.7	2.1	.07	1.9	2.0	.05	.51
16	64.2	52.5	2.2	.001	1.8	1.8	.05	.41
24	70.3	61.2	2.1	.01	1.4	1.5	.04	.21
36	75.3	68.8	1.2	.003	.8	.9	.03	.07
48	80.2	72.1	.9	.0001	.3	.4	.04	.09

[a] Standard error, n=12.

Table 5-4. In situ extent and rate of nitrogen disappearance from masticate samples collected from cattle grazing midgrass prairie rangeland (PRAIRIE) or Sideoats grama/Sweetclover pasture (PASTURE).

	Extent				Rate			
Incubation time, h	PRAIRIE	PASTURE	SE[a]	P-value	PRAIRIE	PASTURE	SE[a]	P-value
	%				%/h			
4	38.3	28.0	2.6	.02	2.0	2.2	.07	.13
8	44.6	39.2	1.5	.03	1.9	2.0	.07	.11
12	56.0	53.1	1.9	.31	1.7	1.9	.06	.09
16	64.4	52.8	2.6	.01	1.6	1.7	.05	.07
24	70.7	63.6	2.2	.05	1.3	1.4	.04	.04
36	78.0	71.5	1.1	.002	.8	.9	.03	.06
48	80.0	72.5	1.5	.005	.3	.4	.04	.39

[a] Standard error, n=12.

Table 5-5. Intake and site and extent of organic matter digestion in heifers grazing midgrass prairie rangeland (PRAIRIE) or Sideoats grama/Sweetclover pasture (PASTURE).

Item	PRAIRIE	PASTURE	SE[a]	P-value
	g/d			
Intake	8150	8265	224	.72
Passage				
Duodenal flow				
Total	4892	5170	120	.13
Forage	4080	4328	116	.17
Microbial	812	842	41	.62
Fecal	3371	3389	92	.89
Digestion, % of intake	%			
Ruminal, apparent	39.3	37.3	1.1	.25
Ruminal, true	49.3	47.6	1.3	.37
Digestion, % entering segment				
Lower tract	31.2	34.4	1.1	.07

[a] Standard error, n=12.

Table 5-6. Intake and site and extent of digestion of nitrogen (N) in heifers grazing midgrass prairie rangeland (PRAIRIE) or Sideoats grama/Sweetclover pasture (PASTURE).

Item	PRAIRIE	PASTURE	SE[a]	P-value
		g/d		
Intake	171	198	5	.01
Passage				
Duodenal				
Total	215	249	10	.04
Ammonia-N	6	7	1	.13
Forage	135	162	8	.04
NDIN[b]	42	40	2	.68
NDSN[c]	93	122	7	.02
Microbial	74	81	4	.38
Fecal	83	84	3	.59
Digestion, % of intake		%		
Ruminal, apparent	-26.9	-26.3	5.1	.94
Ruminal, true	20.7	17.9	4.3	.65
Digestion, % entering segment				
Lower tract	61.8	66.0	1.0	.02
Microbial efficiency, g microbial N/kg OM truly fermented	19.3	20.5	.7	.25

[a] Standard error, n=12.
[b] Neutral detergent insoluble N.
[c] Non-microbial neutral detergent soluble N=(Forage N-NDIN).

Table 5-7. Intake and site and extent of digestion of neutral (NDF) and acid detergent fiber (ADF) in heifers grazing midgrass prairie rangeland (PRAIRIE) or Sideoats grama/Sweetclover pasture (PASTURE).

Item	PRAIRIE	PASTURE	SE[a]	P-value
NDF		g/d		
Intake	5559	5367	148	.38
Passage				
Duodenal flow	2406	2248	107	.33
Fecal	2192	2183	73	.93
Digestion		%		
Ruminal	56.2	58.2	1.9	.46
Lower tract	4.3	1.1	.5	.19
Total Tract	60.5	59.3	.4	.09
ADF		g/d		
Intake	2934	2992	81	.62
Passage				
Duodenal flow	1295	1204	76	.42
Fecal	1126	1061	37	.25
Digestion		%		
Ruminal	54.7	60.1	2.7	.20
Lower tract	6.9	4.5	2.6	.53
Total Tract	61.6	64.6	.4	.004

[a] Standard error, n=12.

CHAPTER VI

SUGGESTED RESEARCH TO IMPROVE THE NUTRITIONAL MANAGEMENT OF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND AND PLAINS BLUESTEM PASTURE

On the basis of my data, I would suggest four areas to focus on in future research at the Marvin Klemme Range Research Station: 1) Plains bluestem (PLAINS) and midgrass prairie rangeland (PRAIRIE) as complements, 2) the effect of stocking rate on nutrient intake and digestion, 3) nutrient supplementation, 4) and the use of fertilizer application to replace protein supplements. Each of these topics could have an impact on the efficiency of beef cattle production in the Southern Plains.

Midgrass prairie rangeland and PLAINS possess characteristics of complementary forages. This potential could be evaluated on a small scale with the resources at the Klemme station. If the 6.5 ha of PLAINS was complemented with 42.5 ha of PRAIRIE, compared to 49 ha of PRAIRIE, and years were used as replicates, a researcher may get reliable estimates of the value of PLAINS as a complementary forage. The PRAIRIE system would need to be stocked at 3.7 ha/AU, which was determined by Gillen and McCollum (personal comm.) to give the highest net return/ha over three years. The PLAINS/PRAIRIE grazing system would need to be stocked at 2.6 ha/AU. This higher stocking rate on PLAINS/PRAIRIE is justified by the higher production of PLAINS (McCollum, personal comm.). The grazing schedule would be PRAIRIE from 1 May to 10 July, PLAINS from the 11 July to 30 August, and PRAIRIE from 1 September to 31 September. This grazing schedule would utilize about 50% of the standing crop from both forage types. Important variables to evaluate would be increased production/unit of land, individual animal performance, and total production cost.

One remaining question is "how does stocking rate effect the intake and digestion of these forage types?" It is possible that cattle stocked at heavier rates consume less rumen digestible OM. Reduced rumen digestible OM intake would decrease VFA absorption and reduce metabolizable nitrogen yield from the rumen. If protein supply to and absorption from the small intestine is reduced, efficiency of ME utilization may be reduced. This reduced efficiency would put cattle stocked at the heavier rate in double jeopardy, besides intake of digestible OM being limited, efficiency of ME utilization would be reduced.

The supplement requirements for cattle grazing either of these forage resources differs markedly from supplement requirements for cattle grazing tallgrass prairie. Cattle grazing PLAINS and PRAIRIE during the spring-fall period appear to be energy deficient and intake of energy does not appear to be limited by protein intake. The effects of supplement type and amount on intake and digestion by cattle grazing these forage types during the summer has not been defined. To start, testing the effects of low, medium, and high protein supplements at a limited supplemental energy intake may yield an estimate of the proper protein:energy ratio needed in supplements. Stratification of protein level within a constant supplemental energy intake will allow the determination of which nutrient is deficient in the diet and at what level (protein vs. carbohydrates). Measuring intake and digestion would help determine if increases in performance of supplemented cattle originate from increased forage intake or from increased efficiency of nutrient utilization.

Fertilizer application traditionally is viewed as a means to increase forage production. These data indicate that the potential exists to use fertilizer to reduce supplementation requirements. The nitrogen content of masticate and the non-ammonia nitrogen flow in cattle grazing PLAINS in August of 1990 and May of 1991 were similar. Both of these sampling periods occurred about 20 d after nitrogen fertilizer was applied. Perhaps it is possible to capture fertilizer nitrogen as metabolizable nitrogen more economically than providing protein as a supplement. This would reduce the labor and expense of providing protein supplement to cattle.

APPENDIX 1. IN SITU OM DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Incubation time, h	Forage type	Year	Month: May	June	August	October	SE[a]
6	PRAIRIE	1990	38.4[f]	10.3[cgi]	15.6[dgi]	19.7[ei]	2.3
		1991	38.7[e]	25.0[cdj]	22.1[cj]	27.7[dj]	2.0
	PLAINS	1990	---	28.9[dhi]	40.4[ehi]	20.9[ci]	1.4
		1991	40.0[d]	24.0[cj]	24.5[cj]	26.2[cj]	1.5
		SE[b]	.9	1.5	2.0	.8	
48	PRAIRIE	1990	80.2[ei]	57.2[cgi]	65.2[dg]	65.3[dgi]	1.9
		1991	73.0[egj]	67.0[dgj]	62.3[c]	70.2[degj]	1.1
	PLAINS	1990	---	69.4[chi]	78.8[ehi]	75.0[dh]	.9
		1991	78.5[dh]	76.1[dhj]	63.6[cj]	75.1[dh]	1.4
		SE[b]	.9	1.6	1.5	1.0	
72	PRAIRIE	1990	80.3[ei]	64.6[cgi]	69.8[dg]	69.4[dgi]	1.3
		1991	75.5[dgj]	69.9[cgj]	67.4[c]	74.5[dgj]	1.1
	PLAINS	1990	---	72.0[chi]	81.4[ehi]	77.8[dh]	.8
		1991	81.0[d]	79.6[dhj]	70.2[cj]	80.3[dh]	1.1
		SE[b]	.6	1.3	1.3	.9	

[a] n=24, except on PLAINS during 1990, n=18.
[b] n=24, except during May, n=18.
[c-f] Row means with uncommon superscripts differ (P<.05).
[g,h] Forage type means within year with uncommon superscripts differ (P<.05).
[i,j] Years by forage type means with uncommon superscripts differ (P<.05).

APPENDIX 2. IN SITU NITROGEN DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Incubation time, h	Forage type	Year	Month: May	June	August	October	SE[a]
6	PRAIRIE	1990	41.5^{f}	-5.5^{cgi}	18.6^{dgi}	29.3^{egi}	3.8
		1991	43.4^{eg}	22.5^{cdj}	36.8^{dgj}	35.2^{dgj}	1.5
	PLAINS	1990	---	22.4^{ch}	36.6^{ehi}	22.5^{chi}	1.9
		1991	38.7^{fh}	18.5^{c}	25.1^{dhj}	29.4^{ehj}	1.7
		SE[b]	1.2	2.5	1.9	1.1	
48	PRAIRIE	1990	80.9^{e}	40.2^{cgi}	67.3^{dg}	69.1^{dg}	3.4
		1991	76.1^{eg}	68.5^{dgj}	53.8^{c}	75.3^{de}	2.1
	PLAINS	1990	---	65.5^{chi}	82.8^{ehi}	78.7^{dh}	2.0
		1991	86.0^{ch}	79.6^{dhj}	57.7^{cj}	77.6^{d}	2.3
		SE[b]	1.2	3.4	2.4	1.0	
72	PRAIRIE	1990	83.8^{ei}	59.9^{cgi}	76.2^{dg}	77.4^{dgi}	2.2
		1991	84.8^{egj}	70.8^{dgj}	58.8^{c}	80.8^{egj}	1.8
	PLAINS	1990	---	71.2^{chi}	87.5^{dhi}	82.9^{dh}	2.1
		1991	88.0^{e}	81.8^{dhj}	64.2^{cj}	81.8^{dh}	2.0
		SE[b]	.6	2.0	2.4	.7	

[a] n=24, except on PLAINS during 1990, n=18.
[b] n=24, except during May, n=18.
[c-f] Row means with uncommon superscripts differ (P<.05).
[g,h] Forage type means within year with uncommon superscripts differ (P<.05).
[i,j] Years by forage type means with uncommon superscripts differ (P<.05).

APPENDIX 3a. CHEMICAL COMPOSITION OF ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Dry matter, %	Ash, % of DM	Nitrogen, % of OM	Pepsin insoluble nitrogen, % of N	Neutral detergent fiber, % of OM	Acid detergent fiber, % of OM	In vitro organic matter disappearance, % of OM
1990	PRAIRIE	May	1	93.19	12.70	2.26	34.55	66.53	36.09	58.60
1990	PRAIRIE	May	2	92.13	13.29	2.08	37.97	67.94	34.81	56.06
1990	PRAIRIE	May	3	92.22	14.30	2.12	39.19	66.57	36.70	60.50
1990	PRAIRIE	May	4	93.29	12.69	1.97	38.84	71.60	36.32	59.38
1990	PRAIRIE	June	1	93.29	11.62	1.51	51.93	78.48	38.12	55.66
1990	PRAIRIE	June	2	93.77	11.95	1.34	63.49	80.35	40.19	51.81
1990	PRAIRIE	June	3	93.79	11.99	1.43	55.11	81.64	38.23	54.88
1990	PRAIRIE	June	4	95.25	11.84	1.37	56.92	81.92	38.02	54.29
1990	PRAIRIE	August	1	94.45	11.79	1.44	54.04	81.01	39.12	53.96
1990	PRAIRIE	August	2	94.16	13.03	1.83	43.41	78.75	39.72	53.25
1990	PRAIRIE	August	3	94.24	11.11	1.56	50.61	82.02	41.32	53.78
1990	PRAIRIE	August	4	94.36	10.84	1.36	52.71	82.95	40.88	55.82
1990	PRAIRIE	October	1	96.53	12.72	1.73	45.01	78.12	37.92	55.43
1990	PRAIRIE	October	2	96.31	10.58	1.60	39.17	77.92	41.57	49.50
1990	PRAIRIE	October	3	95.72	11.68	1.68	44.89	78.90	38.29	54.22
1990	PRAIRIE	October	4	95.60	11.86	1.87	48.32	75.84	37.43	55.58
1990	PLAINS	May	5	xx.xx	xx.xx	x.xx	xx.xx	xx.xx	xx.xx	xx.xx
1990	PLAINS	May	6	xx.xx	xx.xx	x.xx	xx.xx	xx.xx	xx.xx	xx.xx
1990	PLAINS	May	7	xx.xx	xx.xx	x.xx	xx.xx	xx.xx	xx.xx	xx.xx
1990	PLAINS	May	8	xx.xx	xx.xx	x.xx	xx.xx	xx.xx	xx.xx	xx.xx
1990	PLAINS	June	5	93.25	17.20	2.37	41.42	66.88	31.84	58.16
1990	PLAINS	June	6	93.45	17.20	2.42	44.73	63.53	33.21	59.59
1990	PLAINS	June	7	93.44	14.72	2.09	46.81	70.04	30.60	59.25
1990	PLAINS	June	8	93.80	14.46	2.25	45.34	66.99	31.66	58.70
1990	PLAINS	August	5	94.01	13.23	2.35	39.17	67.17	30.91	60.69
1990	PLAINS	August	6	94.00	18.48	3.25	32.69	54.82	27.79	62.41
1990	PLAINS	August	7	91.98	15.52	2.73	40.40	63.58	30.72	59.16
1990	PLAINS	August	8	94.14	13.86	2.68	33.30	62.03	29.76	59.19
1990	PLAINS	October	5	92.94	11.95	2.30	42.05	72.94	37.29	59.03
1990	PLAINS	October	6	93.23	11.32	2.29	46.68	75.47	37.40	61.62
1990	PLAINS	October	7	93.76	11.82	2.41	43.24	72.57	35.89	59.20
1990	PLAINS	October	8	xx.xx	xx.xx	x.xx	xx.xx	xx.xx	xx.xx	xx.xx

APPENDIX 3b. CHEMICAL COMPOSITION OF ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Dry matter, %	Ash, % of DM	Nitrogen, % of OM	Pepsin insoluble nitrogen, % of N	Neutral detergent fiber, % of OM	Acid detergent fiber, % of OM	In vitro organic matter disappearance, % of OM
1991	PRAIRIE	May	1	93.84	13.36	2.01	30.35	54.88	33.03	62.94
1991	PRAIRIE	May	2	94.87	12.57	1.80	31.67	63.39	34.19	60.70
1991	PRAIRIE	May	3	94.78	13.55	1.86	33.33	56.45	33.43	59.97
1991	PRAIRIE	May	4	94.89	13.06	2.09	32.06	54.76	34.69	56.52
1991	PRAIRIE	June	1	94.78	12.19	1.56	53.85	75.54	37.26	54.58
1991	PRAIRIE	June	2	94.31	12.59	1.59	55.97	80.95	38.67	53.74
1991	PRAIRIE	June	3	94.29	12.30	1.64	45.73	78.03	39.40	51.95
1991	PRAIRIE	June	4	94.81	10.84	1.70	48.82	75.37	37.33	54.10
1991	PRAIRIE	August	1	96.22	12.92	0.90	63.33	79.51	41.24	53.45
1991	PRAIRIE	August	2	96.39	13.82	1.04	53.85	83.12	46.72	50.16
1991	PRAIRIE	August	3	96.07	13.08	1.02	54.90	79.72	40.07	49.38
1991	PRAIRIE	August	4	95.10	13.34	1.08	54.63	80.90	45.70	50.25
1991	PRAIRIE	October	1	97.13	13.33	2.00	41.00	77.13	36.86	57.47
1991	PRAIRIE	October	2	92.57	13.29	1.96	45.92	77.03	40.22	55.32
1991	PRAIRIE	October	3	97.77	12.98	1.98	39.39	73.73	37.44	57.14
1991	PRAIRIE	October	4	xx.xx	xx.xx	x.xx	xx.xx	xx.xx	xx.xx	xx.xx
1991	PLAINS	May	5	94.13	15.20	2.70	38.89	66.88	33.61	62.50
1991	PLAINS	May	6	93.84	13.90	2.99	38.80	64.37	33.41	60.56
1991	PLAINS	May	7	94.77	19.28	2.73	38.46	63.80	35.09	62.26
1991	PLAINS	May	8	93.73	16.55	2.85	38.60	67.02	33.68	62.16
1991	PLAINS	June	5	94.45	9.57	1.55	44.52	75.49	38.48	59.41
1991	PLAINS	June	6	93.64	10.52	1.79	49.72	79.21	37.93	60.85
1991	PLAINS	June	7	93.34	9.88	1.74	51.72	78.77	36.86	62.99
1991	PLAINS	June	8	94.47	10.76	1.90	50.53	72.93	34.97	61.57
1991	PLAINS	August	5	98.55	9.54	1.20	50.83	78.34	41.79	54.83
1991	PLAINS	August	6	94.94	8.90	1.05	50.48	80.07	43.48	56.22
1991	PLAINS	August	7	97.58	8.98	1.19	47.06	77.07	41.23	55.88
1991	PLAINS	August	8	96.71	8.65	1.27	48.03	76.06	40.64	54.80
1991	PLAINS	October	5	97.84	12.60	1.96	36.73	73.82	37.03	64.68
1991	PLAINS	October	6	94.01	12.96	1.74	50.00	73.28	37.39	65.13
1991	PLAINS	October	7	97.79	15.82	1.85	41.62	74.97	38.22	65.41
1991	PLAINS	October	8	92.41	13.56	1.94	43.81	74.28	39.77	64.53

APPENDIX 4a. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1990	PRAIRIE	May	1	6	37.53	42.14
1990	PRAIRIE	May	1	12	41.27	48.93
1990	PRAIRIE	May	1	16	60.82	65.59
1990	PRAIRIE	May	1	24	61.22	65.94
1990	PRAIRIE	May	1	36	71.01	76.81
1990	PRAIRIE	May	1	48	81.93	83.89
1990	PRAIRIE	May	1	72	78.58	84.82
1990	PRAIRIE	May	2	6	38.76	43.53
1990	PRAIRIE	May	2	12	53.33	56.98
1990	PRAIRIE	May	2	16	61.95	65.26
1990	PRAIRIE	May	2	24	74.35	75.02
1990	PRAIRIE	May	2	36	77.43	78.90
1990	PRAIRIE	May	2	48	80.70	81.45
1990	PRAIRIE	May	2	72	80.82	83.49
1990	PRAIRIE	May	3	6	41.35	42.06
1990	PRAIRIE	May	3	12	56.74	57.49
1990	PRAIRIE	May	3	16	69.91	65.07
1990	PRAIRIE	May	3	24	74.66	71.80
1990	PRAIRIE	May	3	36	78.10	78.19
1990	PRAIRIE	May	3	48	79.27	76.20
1990	PRAIRIE	May	3	72	79.43	80.42
1990	PRAIRIE	May	4	6	45.83	49.82
1990	PRAIRIE	May	4	12	57.34	58.46
1990	PRAIRIE	May	4	16	64.76	69.82
1990	PRAIRIE	May	4	24	75.74	78.48
1990	PRAIRIE	May	4	36	77.90	81.07
1990	PRAIRIE	May	4	48	82.87	84.36
1990	PRAIRIE	May	4	72	82.55	86.80
1990	PRAIRIE	May	5	6	31.85	34.06
1990	PRAIRIE	May	5	12	51.65	60.69
1990	PRAIRIE	May	5	16	61.14	55.23
1990	PRAIRIE	May	5	24	66.08	61.22
1990	PRAIRIE	May	5	36	70.72	73.01
1990	PRAIRIE	May	5	48	75.67	73.45
1990	PRAIRIE	May	5	72	78.38	81.76
1990	PRAIRIE	May	6	6	34.77	37.10
1990	PRAIRIE	May	6	12	49.82	53.53
1990	PRAIRIE	May	6	16	66.65	65.49
1990	PRAIRIE	May	6	24	69.54	71.53
1990	PRAIRIE	May	6	36	76.91	79.72
1990	PRAIRIE	May	6	48	80.96	80.63
1990	PRAIRIE	May	6	72	81.80	85.52

APPENDIX 4b. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1990	PLAINS	May	7	6	xx.xx	xx.xx
1990	PLAINS	May	7	12	xx.xx	xx.xx
1990	PLAINS	May	7	16	xx.xx	xx.xx
1990	PLAINS	May	7	24	xx.xx	xx.xx
1990	PLAINS	May	7	36	xx.xx	xx.xx
1990	PLAINS	May	7	48	xx.xx	xx.xx
1990	PLAINS	May	7	72	xx.xx	xx.xx
1990	PLAINS	May	8	6	xx.xx	xx.xx
1990	PLAINS	May	8	12	xx.xx	xx.xx
1990	PLAINS	May	8	16	xx.xx	xx.xx
1990	PLAINS	May	8	24	xx.xx	xx.xx
1990	PLAINS	May	8	36	xx.xx	xx.xx
1990	PLAINS	May	8	48	xx.xx	xx.xx
1990	PLAINS	May	8	72	xx.xx	xx.xx
1990	PLAINS	May	9	6	xx.xx	xx.xx
1990	PLAINS	May	9	12	xx.xx	xx.xx
1990	PLAINS	May	9	16	xx.xx	xx.xx
1990	PLAINS	May	9	24	xx.xx	xx.xx
1990	PLAINS	May	9	36	xx.xx	xx.xx
1990	PLAINS	May	9	48	xx.xx	xx.xx
1990	PLAINS	May	9	72	xx.xx	xx.xx
1990	PLAINS	May	10	6	xx.xx	xx.xx
1990	PLAINS	May	10	12	xx.xx	xx.xx
1990	PLAINS	May	10	16	xx.xx	xx.xx
1990	PLAINS	May	10	24	xx.xx	xx.xx
1990	PLAINS	May	10	36	xx.xx	xx.xx
1990	PLAINS	May	10	48	xx.xx	xx.xx
1990	PLAINS	May	10	72	xx.xx	xx.xx
1990	PLAINS	May	11	6	xx.xx	xx.xx
1990	PLAINS	May	11	12	xx.xx	xx.xx
1990	PLAINS	May	11	16	xx.xx	xx.xx
1990	PLAINS	May	11	24	xx.xx	xx.xx
1990	PLAINS	May	11	36	xx.xx	xx.xx
1990	PLAINS	May	11	48	xx.xx	xx.xx
1990	PLAINS	May	11	72	xx.xx	xx.xx
1990	PLAINS	May	12	6	xx.xx	xx.xx
1990	PLAINS	May	12	12	xx.xx	xx.xx
1990	PLAINS	May	12	16	xx.xx	xx.xx
1990	PLAINS	May	12	24	xx.xx	xx.xx
1990	PLAINS	May	12	36	xx.xx	xx.xx
1990	PLAINS	May	12	48	xx.xx	xx.xx
1990	PLAINS	May	12	72	xx.xx	xx.xx

APPENDIX 4c. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1990	PRAIRIE	June	1	6	10.44	2.01
1990	PRAIRIE	June	1	12	21.50	18.66
1990	PRAIRIE	June	1	16	31.90	18.57
1990	PRAIRIE	June	1	24	42.63	30.99
1990	PRAIRIE	June	1	36	54.78	51.51
1990	PRAIRIE	June	1	48	61.60	57.71
1990	PRAIRIE	June	1	72	65.25	60.46
1990	PRAIRIE	June	2	6	10.96	-5.17
1990	PRAIRIE	June	2	12	26.03	15.85
1990	PRAIRIE	June	2	16	39.73	22.26
1990	PRAIRIE	June	2	24	48.87	32.56
1990	PRAIRIE	June	2	36	59.71	57.96
1990	PRAIRIE	June	2	48	61.31	41.41
1990	PRAIRIE	June	2	72	70.81	67.59
1990	PRAIRIE	June	3	6	12.83	-2.96
1990	PRAIRIE	June	3	12	19.02	10.22
1990	PRAIRIE	June	3	16	22.02	3.38
1990	PRAIRIE	June	3	24	40.24	14.69
1990	PRAIRIE	June	3	36	51.28	42.10
1990	PRAIRIE	June	3	48	50.68	24.23
1990	PRAIRIE	June	3	72	57.06	48.03
1990	PRAIRIE	June	4	6	7.92	-12.76
1990	PRAIRIE	June	4	12	18.93	8.35
1990	PRAIRIE	June	4	16	32.26	18.03
1990	PRAIRIE	June	4	24	45.18	39.22
1990	PRAIRIE	June	4	36	57.39	55.84
1990	PRAIRIE	June	4	48	62.74	57.07
1990	PRAIRIE	June	4	72	68.36	74.32
1990	PRAIRIE	June	5	6	8.77	-8.42
1990	PRAIRIE	June	5	12	19.70	3.99
1990	PRAIRIE	June	5	16	31.97	8.31
1990	PRAIRIE	June	5	24	38.68	11.13
1990	PRAIRIE	June	5	36	47.58	25.93
1990	PRAIRIE	June	5	48	54.95	24.27
1990	PRAIRIE	June	5	72	60.43	50.11
1990	PRAIRIE	June	6	6	10.70	-5.47
1990	PRAIRIE	June	6	12	24.33	12.81
1990	PRAIRIE	June	6	16	53.87	51.38
1990	PRAIRIE	June	6	24	26.80	13.54
1990	PRAIRIE	June	6	36	45.95	31.46
1990	PRAIRIE	June	6	48	51.94	36.62
1990	PRAIRIE	June	6	72	65.91	58.75

APPENDIX 4d. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1990	PLAINS	June	7	6	31.03	25.30
1990	PLAINS	June	7	12	50.43	53.71
1990	PLAINS	June	7	16	47.37	41.03
1990	PLAINS	June	7	24	62.71	61.94
1990	PLAINS	June	7	36	68.39	65.77
1990	PLAINS	June	7	48	70.38	69.03
1990	PLAINS	June	7	72	73.94	71.78
1990	PLAINS	June	8	6	29.99	28.83
1990	PLAINS	June	8	12	34.66	27.34
1990	PLAINS	June	8	16	58.75	58.06
1990	PLAINS	June	8	24	61.21	55.90
1990	PLAINS	June	8	36	59.22	49.24
1990	PLAINS	June	8	48	63.43	50.54
1990	PLAINS	June	8	72	65.30	60.70
1990	PLAINS	June	9	6	30.96	22.36
1990	PLAINS	June	9	12	43.91	45.31
1990	PLAINS	June	9	16	58.75	58.06
1990	PLAINS	June	9	24	64.81	62.92
1990	PLAINS	June	9	36	65.59	63.59
1990	PLAINS	June	9	48	70.07	66.71
1990	PLAINS	June	9	72	74.38	77.04
1990	PLAINS	June	10	6	23.71	17.38
1990	PLAINS	June	10	12	44.93	53.16
1990	PLAINS	June	10	16	58.25	59.81
1990	PLAINS	June	10	24	64.34	64.19
1990	PLAINS	June	10	36	68.28	71.57
1990	PLAINS	June	10	48	73.22	74.89
1990	PLAINS	June	10	72	75.16	80.52
1990	PLAINS	June	11	6	29.10	20.86
1990	PLAINS	June	11	12	45.55	50.75
1990	PLAINS	June	11	16	57.18	56.47
1990	PLAINS	June	11	24	64.04	60.98
1990	PLAINS	June	11	36	70.13	69.51
1990	PLAINS	June	11	48	72.18	69.76
1990	PLAINS	June	11	72	71.59	76.30
1990	PLAINS	June	12	6	28.55	19.95
1990	PLAINS	June	12	12	40.82	40.85
1990	PLAINS	June	12	16	49.16	41.77
1990	PLAINS	June	12	24	59.42	48.82
1990	PLAINS	June	12	36	65.70	62.56
1990	PLAINS	June	12	48	67.08	62.17
1990	PLAINS	June	12	72	71.43	72.73

APPENDIX 4e. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1990	PRAIRIE	August	1	6	12.50	19.28
1990	PRAIRIE	August	1	12	30.14	30.14
1990	PRAIRIE	August	1	16	44.30	32.53
1990	PRAIRIE	August	1	24	22.23	24.42
1990	PRAIRIE	August	1	36	42.68	57.61
1990	PRAIRIE	August	1	48	61.02	67.88
1990	PRAIRIE	August	1	72	65.92	69.04
1990	PRAIRIE	August	2	6	15.24	12.25
1990	PRAIRIE	August	2	12	28.72	27.74
1990	PRAIRIE	August	2	16	25.85	21.68
1990	PRAIRIE	August	2	24	47.16	44.55
1990	PRAIRIE	August	2	36	63.44	67.30
1990	PRAIRIE	August	2	48	67.21	68.36
1990	PRAIRIE	August	2	72	70.54	78.63
1990	PRAIRIE	August	3	6	16.34	15.16
1990	PRAIRIE	August	3	12	29.40	31.89
1990	PRAIRIE	August	3	16	40.79	36.62
1990	PRAIRIE	August	3	24	43.16	42.65
1990	PRAIRIE	August	3	36	56.59	59.95
1990	PRAIRIE	August	3	48	67.18	69.03
1990	PRAIRIE	August	3	72	71.73	73.92
1990	PRAIRIE	August	4	6	15.83	12.86
1990	PRAIRIE	August	4	12	30.03	30.53
1990	PRAIRIE	August	4	16	38.50	36.33
1990	PRAIRIE	August	4	24	54.84	55.11
1990	PRAIRIE	August	4	36	61.10	63.57
1990	PRAIRIE	August	4	48	64.11	63.86
1990	PRAIRIE	August	4	72	70.75	76.93
1990	PRAIRIE	August	5	6	14.51	18.12
1990	PRAIRIE	August	5	12	28.85	33.36
1990	PRAIRIE	August	5	16	32.47	20.11
1990	PRAIRIE	August	5	24	41.56	36.62
1990	PRAIRIE	August	5	36	60.80	63.83
1990	PRAIRIE	August	5	48	63.99	64.24
1990	PRAIRIE	August	5	72	70.26	76.96
1990	PRAIRIE	August	6	6	19.43	34.18
1990	PRAIRIE	August	6	12	22.70	41.75
1990	PRAIRIE	August	6	16	38.89	41.48
1990	PRAIRIE	August	6	24	33.44	38.60
1990	PRAIRIE	August	6	36	56.74	57.96
1990	PRAIRIE	August	6	48	67.57	70.31
1990	PRAIRIE	August	6	72	69.37	81.88

APPENDIX 4f. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1990	PLAINS	August	7	6	36.07	35.81
1990	PLAINS	August	7	12	58.37	63.79
1990	PLAINS	August	7	16	70.19	71.28
1990	PLAINS	August	7	24	73.72	78.21
1990	PLAINS	August	7	36	77.55	82.30
1990	PLAINS	August	7	48	77.28	79.86
1990	PLAINS	August	7	72	81.31	87.39
1990	PLAINS	August	8	6	43.23	40.69
1990	PLAINS	August	8	12	51.29	56.44
1990	PLAINS	August	8	16	66.16	76.20
1990	PLAINS	August	8	24	73.15	80.46
1990	PLAINS	August	8	36	74.79	82.27
1990	PLAINS	August	8	48	77.63	83.36
1990	PLAINS	August	8	72	82.30	89.71
1990	PLAINS	August	9	6	39.24	35.04
1990	PLAINS	August	9	12	54.93	56.22
1990	PLAINS	August	9	16	57.80	62.61
1990	PLAINS	August	9	24	74.44	82.03
1990	PLAINS	August	9	36	76.53	83.31
1990	PLAINS	August	9	48	79.81	83.42
1990	PLAINS	August	9	72	81.01	88.11
1990	PLAINS	August	10	6	39.93	33.34
1990	PLAINS	August	10	12	49.32	54.47
1990	PLAINS	August	10	16	62.32	67.23
1990	PLAINS	August	10	24	69.46	76.04
1990	PLAINS	August	10	36	76.82	83.70
1990	PLAINS	August	10	48	80.07	85.50
1990	PLAINS	August	10	72	81.41	86.24
1990	PLAINS	August	11	6	43.90	38.66
1990	PLAINS	August	11	12	63.99	65.70
1990	PLAINS	August	11	16	68.55	70.09
1990	PLAINS	August	11	24	74.84	78.01
1990	PLAINS	August	11	36	79.05	81.96
1990	PLAINS	August	11	48	80.45	80.92
1990	PLAINS	August	11	72	79.81	83.81
1990	PLAINS	August	12	6	39.84	35.93
1990	PLAINS	August	12	12	67.33	75.30
1990	PLAINS	August	12	16	63.12	68.52
1990	PLAINS	August	12	24	69.61	74.93
1990	PLAINS	August	12	36	79.50	84.82
1990	PLAINS	August	12	48	77.62	83.99
1990	PLAINS	August	12	72	82.61	89.61

APPENDIX 4g. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1990	PRAIRIE	October	1	6	19.45	26.36
1990	PRAIRIE	October	1	12	31.23	38.58
1990	PRAIRIE	October	1	16	37.34	38.01
1990	PRAIRIE	October	1	24	51.49	50.97
1990	PRAIRIE	October	1	36	61.64	68.00
1990	PRAIRIE	October	1	48	66.94	70.12
1990	PRAIRIE	October	1	72	66.56	75.86
1990	PRAIRIE	October	2	6	24.28	35.62
1990	PRAIRIE	October	2	12	29.74	36.13
1990	PRAIRIE	October	2	16	34.50	43.60
1990	PRAIRIE	October	2	24	57.35	56.21
1990	PRAIRIE	October	2	36	60.82	67.31
1990	PRAIRIE	October	2	48	64.13	67.01
1990	PRAIRIE	October	2	72	68.62	75.67
1990	PRAIRIE	October	3	6	17.08	27.28
1990	PRAIRIE	October	3	12	33.66	41.47
1990	PRAIRIE	October	3	16	48.20	43.77
1990	PRAIRIE	October	3	24	37.85	42.17
1990	PRAIRIE	October	3	36	64.33	71.20
1990	PRAIRIE	October	3	48	69.16	74.60
1990	PRAIRIE	October	3	72	72.23	80.84
1990	PRAIRIE	October	4	6	20.52	31.15
1990	PRAIRIE	October	4	12	44.26	56.78
1990	PRAIRIE	October	4	16	51.28	55.45
1990	PRAIRIE	October	4	24	62.28	65.30
1990	PRAIRIE	October	4	36	67.36	73.64
1990	PRAIRIE	October	4	48	65.83	70.58
1990	PRAIRIE	October	4	72	73.16	81.48
1990	PRAIRIE	October	5	6	21.02	27.78
1990	PRAIRIE	October	5	12	25.74	34.48
1990	PRAIRIE	October	5	16	42.30	44.15
1990	PRAIRIE	October	5	24	48.35	48.35
1990	PRAIRIE	October	5	36	63.29	67.81
1990	PRAIRIE	October	5	48	69.77	72.19
1990	PRAIRIE	October	5	72	64.75	71.72
1990	PRAIRIE	October	6	6	15.66	27.38
1990	PRAIRIE	October	6	12	25.93	36.63
1990	PRAIRIE	October	6	16	29.12	36.70
1990	PRAIRIE	October	6	24	40.57	43.11
1990	PRAIRIE	October	6	36	53.74	60.67
1990	PRAIRIE	October	6	48	56.17	60.16
1990	PRAIRIE	October	6	72	70.99	78.90

APPENDIX 4h. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1990	PLAINS	October	7	6	18.89	20.27
1990	PLAINS	October	7	12	45.24	50.83
1990	PLAINS	October	7	16	60.83	64.50
1990	PLAINS	October	7	24	56.26	60.91
1990	PLAINS	October	7	36	75.28	82.96
1990	PLAINS	October	7	48	76.77	80.57
1990	PLAINS	October	7	72	77.66	84.03
1990	PLAINS	October	8	6	21.05	22.06
1990	PLAINS	October	8	12	37.32	35.19
1990	PLAINS	October	8	16	52.99	53.19
1990	PLAINS	October	8	24	61.82	66.37
1990	PLAINS	October	8	36	71.38	75.89
1990	PLAINS	October	8	48	75.45	80.05
1990	PLAINS	October	8	72	75.45	81.19
1990	PLAINS	October	9	6	22.75	27.02
1990	PLAINS	October	9	12	32.28	36.02
1990	PLAINS	October	9	16	40.77	40.77
1990	PLAINS	October	9	24	53.99	57.12
1990	PLAINS	October	9	36	64.37	68.31
1990	PLAINS	October	9	48	72.48	76.11
1990	PLAINS	October	9	72	79.01	85.89
1990	PLAINS	October	10	6	21.36	23.37
1990	PLAINS	October	10	12	41.52	46.24
1990	PLAINS	October	10	16	60.97	65.29
1990	PLAINS	October	10	24	65.07	69.53
1990	PLAINS	October	10	36	72.95	78.94
1990	PLAINS	October	10	48	74.73	77.63
1990	PLAINS	October	10	72	77.91	77.62
1990	PLAINS	October	11	6	20.68	22.37
1990	PLAINS	October	11	12	43.53	46.42
1990	PLAINS	October	11	16	57.05	62.35
1990	PLAINS	October	11	24	67.64	70.53
1990	PLAINS	October	11	36	62.96	67.69
1990	PLAINS	October	11	48	74.61	76.23
1990	PLAINS	October	11	72	77.73	82.94
1990	PLAINS	October	12	6	20.41	19.73
1990	PLAINS	October	12	12	43.65	42.69
1990	PLAINS	October	12	16	46.51	46.28
1990	PLAINS	October	12	24	67.05	71.68
1990	PLAINS	October	12	36	65.46	72.96
1990	PLAINS	October	12	48	76.08	81.38
1990	PLAINS	October	12	72	78.91	85.82

APPENDIX 4i. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1991	PRAIRIE	May	1	6	38.85	42.39
1991	PRAIRIE	May	1	12	51.55	54.35
1991	PRAIRIE	May	1	16	55.89	57.97
1991	PRAIRIE	May	1	24	66.14	67.91
1991	PRAIRIE	May	1	36	69.69	71.28
1991	PRAIRIE	May	1	48	74.21	77.50
1991	PRAIRIE	May	1	72	76.30	85.87
1991	PRAIRIE	May	2	6	36.53	41.92
1991	PRAIRIE	May	2	12	50.07	53.77
1991	PRAIRIE	May	2	16	59.78	67.09
1991	PRAIRIE	May	2	24	66.62	71.07
1991	PRAIRIE	May	2	36	66.42	71.08
1991	PRAIRIE	May	2	48	73.11	78.14
1991	PRAIRIE	May	2	72	76.10	87.17
1991	PRAIRIE	May	3	6	38.21	44.12
1991	PRAIRIE	May	3	12	48.99	54.42
1991	PRAIRIE	May	3	16	60.07	63.24
1991	PRAIRIE	May	3	24	66.55	67.76
1991	PRAIRIE	May	3	36	66.13	70.10
1991	PRAIRIE	May	3	48	71.38	73.35
1991	PRAIRIE	May	3	72	75.20	82.65
1991	PRAIRIE	May	4	6	42.78	48.56
1991	PRAIRIE	May	4	12	57.70	62.65
1991	PRAIRIE	May	4	16	61.15	64.03
1991	PRAIRIE	May	4	24	67.73	69.60
1991	PRAIRIE	May	4	36	70.81	73.29
1991	PRAIRIE	May	4	48	73.82	77.17
1991	PRAIRIE	May	4	72	75.58	85.26
1991	PRAIRIE	May	5	6	38.09	42.34
1991	PRAIRIE	May	5	12	46.36	50.62
1991	PRAIRIE	May	5	16	47.85	55.37
1991	PRAIRIE	May	5	24	60.39	63.11
1991	PRAIRIE	May	5	36	71.59	71.86
1991	PRAIRIE	May	5	48	73.57	74.81
1991	PRAIRIE	May	5	72	74.95	82.94
1991	PRAIRIE	May	6	6	37.74	41.35
1991	PRAIRIE	May	6	12	48.52	51.22
1991	PRAIRIE	May	6	16	57.40	63.08
1991	PRAIRIE	May	6	24	60.95	66.99
1991	PRAIRIE	May	6	36	69.96	71.86
1991	PRAIRIE	May	6	48	71.76	75.53
1991	PRAIRIE	May	6	72	74.90	84.67

APPENDIX 4j. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1991	PLAINS	May	7	6	34.23	39.63
1991	PLAINS	May	7	12	44.51	47.66
1991	PLAINS	May	7	16	59.80	67.61
1991	PLAINS	May	7	24	66.71	77.75
1991	PLAINS	May	7	36	70.16	80.70
1991	PLAINS	May	7	48	75.81	85.84
1991	PLAINS	May	7	72	78.40	88.22
1991	PLAINS	May	8	6	42.90	43.05
1991	PLAINS	May	8	12	61.83	68.69
1991	PLAINS	May	8	16	54.51	57.92
1991	PLAINS	May	8	24	72.95	80.93
1991	PLAINS	May	8	36	76.53	83.12
1991	PLAINS	May	8	48	80.91	86.76
1991	PLAINS	May	8	72	83.62	88.79
1991	PLAINS	May	9	6	39.80	35.17
1991	PLAINS	May	9	12	38.01	41.98
1991	PLAINS	May	9	16	58.83	64.59
1991	PLAINS	May	9	24	70.89	78.54
1991	PLAINS	May	9	36	77.48	85.43
1991	PLAINS	May	9	48	78.87	86.11
1991	PLAINS	May	9	72	77.07	85.57
1991	PLAINS	May	10	6	37.85	33.74
1991	PLAINS	May	10	12	55.97	61.18
1991	PLAINS	May	10	16	68.52	76.00
1991	PLAINS	May	10	24	70.55	78.50
1991	PLAINS	May	10	36	79.30	87.28
1991	PLAINS	May	10	48	78.68	86.44
1991	PLAINS	May	10	72	82.73	89.95
1991	PLAINS	May	11	6	37.25	32.20
1991	PLAINS	May	11	12	52.56	58.85
1991	PLAINS	May	11	16	59.70	64.76
1991	PLAINS	May	11	24	69.75	77.48
1991	PLAINS	May	11	36	74.07	82.01
1991	PLAINS	May	11	48	76.86	84.28
1991	PLAINS	May	11	72	81.86	87.79
1991	PLAINS	May	12	6	47.86	48.18
1991	PLAINS	May	12	12	51.64	56.66
1991	PLAINS	May	12	16	58.55	64.50
1991	PLAINS	May	12	24	75.11	81.47
1991	PLAINS	May	12	36	77.38	84.23
1991	PLAINS	May	12	48	79.67	86.77
1991	PLAINS	May	12	72	82.16	87.92

APPENDIX 4k. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1991	PRAIRIE	June	1	6	26.77	25.79
1991	PRAIRIE	June	1	12	35.61	36.05
1991	PRAIRIE	June	1	16	36.56	36.13
1991	PRAIRIE	June	1	24	54.98	57.70
1991	PRAIRIE	June	1	36	63.75	66.91
1991	PRAIRIE	June	1	48	68.08	70.44
1991	PRAIRIE	June	1	72	71.13	74.23
1991	PRAIRIE	June	2	6	28.26	21.04
1991	PRAIRIE	June	2	12	40.71	41.51
1991	PRAIRIE	June	2	16	46.16	43.64
1991	PRAIRIE	June	2	24	57.22	55.78
1991	PRAIRIE	June	2	36	63.56	65.03
1991	PRAIRIE	June	2	48	68.86	70.11
1991	PRAIRIE	June	2	72	71.12	69.37
1991	PRAIRIE	June	3	6	24.55	18.98
1991	PRAIRIE	June	3	12	31.66	33.03
1991	PRAIRIE	June	3	16	34.09	35.86
1991	PRAIRIE	June	3	24	52.92	54.50
1991	PRAIRIE	June	3	36	60.29	61.62
1991	PRAIRIE	June	3	48	66.05	66.73
1991	PRAIRIE	June	3	72	70.25	70.45
1991	PRAIRIE	June	4	6	24.50	23.49
1991	PRAIRIE	June	4	12	36.08	38.65
1991	PRAIRIE	June	4	16	44.57	47.54
1991	PRAIRIE	June	4	24	56.22	56.51
1991	PRAIRIE	June	4	36	65.84	66.53
1991	PRAIRIE	June	4	48	69.27	69.06
1991	PRAIRIE	June	4	72	71.50	71.88
1991	PRAIRIE	June	5	6	22.70	23.21
1991	PRAIRIE	June	5	12	31.50	34.26
1991	PRAIRIE	June	5	16	38.71	39.54
1991	PRAIRIE	June	5	24	50.78	51.44
1991	PRAIRIE	June	5	36	64.05	65.74
1991	PRAIRIE	June	5	48	66.78	68.56
1991	PRAIRIE	June	5	72	69.42	69.42
1991	PRAIRIE	June	6	6	23.33	22.30
1991	PRAIRIE	June	6	12	37.17	39.28
1991	PRAIRIE	June	6	16	39.17	26.92
1991	PRAIRIE	June	6	24	53.59	57.95
1991	PRAIRIE	June	6	36	59.82	64.41
1991	PRAIRIE	June	6	48	63.15	65.87
1991	PRAIRIE	June	6	72	65.83	69.50

APPENDIX 4I. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1991	PLAINS	June	7	6	22.56	16.86
1991	PLAINS	June	7	12	42.28	38.03
1991	PLAINS	June	7	16	49.99	49.38
1991	PLAINS	June	7	24	65.12	70.90
1991	PLAINS	June	7	36	66.70	69.56
1991	PLAINS	June	7	48	71.77	74.02
1991	PLAINS	June	7	72	79.98	82.93
1991	PLAINS	June	8	6	24.79	18.33
1991	PLAINS	June	8	12	50.49	49.88
1991	PLAINS	June	8	16	54.08	57.46
1991	PLAINS	June	8	24	68.47	70.59
1991	PLAINS	June	8	36	76.60	79.90
1991	PLAINS	June	8	48	79.01	81.20
1991	PLAINS	June	8	72	81.99	84.42
1991	PLAINS	June	9	6	23.88	18.28
1991	PLAINS	June	9	12	46.81	45.18
1991	PLAINS	June	9	16	58.39	61.20
1991	PLAINS	June	9	24	68.29	71.21
1991	PLAINS	June	9	36	75.96	79.35
1991	PLAINS	June	9	48	77.89	82.91
1991	PLAINS	June	9	72	77.84	80.70
1991	PLAINS	June	10	6	22.92	20.08
1991	PLAINS	June	10	12	49.80	48.87
1991	PLAINS	June	10	16	58.68	61.22
1991	PLAINS	June	10	24	67.06	70.52
1991	PLAINS	June	10	36	75.35	75.64
1991	PLAINS	June	10	48	77.19	80.97
1991	PLAINS	June	10	72	79.42	82.45
1991	PLAINS	June	11	6	23.02	17.35
1991	PLAINS	June	11	12	37.47	31.72
1991	PLAINS	June	11	16	50.71	49.50
1991	PLAINS	June	11	24	65.07	68.28
1991	PLAINS	June	11	36	72.20	72.03
1991	PLAINS	June	11	48	73.05	77.85
1991	PLAINS	June	11	72	78.12	79.19
1991	PLAINS	June	12	6	26.66	19.91
1991	PLAINS	June	12	12	49.16	46.04
1991	PLAINS	June	12	16	60.82	62.50
1991	PLAINS	June	12	24	66.62	69.69
1991	PLAINS	June	12	36	76.06	79.44
1991	PLAINS	June	12	48	77.66	80.40
1991	PLAINS	June	12	72	80.17	81.27

APPENDIX 4m. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1991	PRAIRIE	August	1	6	25.34	39.34
1991	PRAIRIE	August	1	12	28.52	36.71
1991	PRAIRIE	August	1	16	35.47	36.81
1991	PRAIRIE	August	1	24	45.38	41.96
1991	PRAIRIE	August	1	36	60.95	57.29
1991	PRAIRIE	August	1	48	59.72	57.63
1991	PRAIRIE	August	1	72	64.66	58.40
1991	PRAIRIE	August	2	6	23.11	39.93
1991	PRAIRIE	August	2	12	31.61	38.73
1991	PRAIRIE	August	2	16	34.42	39.88
1991	PRAIRIE	August	2	24	46.70	47.81
1991	PRAIRIE	August	2	36	58.19	51.66
1991	PRAIRIE	August	2	48	67.81	61.10
1991	PRAIRIE	August	2	72	71.07	63.84
1991	PRAIRIE	August	3	6	25.09	39.92
1991	PRAIRIE	August	3	12	30.00	37.29
1991	PRAIRIE	August	3	16	34.37	43.26
1991	PRAIRIE	August	3	24	45.90	46.46
1991	PRAIRIE	August	3	36	56.70	50.84
1991	PRAIRIE	August	3	48	63.71	55.01
1991	PRAIRIE	August	3	72	67.57	60.14
1991	PRAIRIE	August	4	6	19.66	36.40
1991	PRAIRIE	August	4	12	29.93	34.31
1991	PRAIRIE	August	4	16	47.71	50.43
1991	PRAIRIE	August	4	24	46.86	41.88
1991	PRAIRIE	August	4	36	57.66	51.93
1991	PRAIRIE	August	4	48	60.96	49.98
1991	PRAIRIE	August	4	72	68.38	58.50
1991	PRAIRIE	August	5	6	19.78	30.64
1991	PRAIRIE	August	5	12	27.55	38.87
1991	PRAIRIE	August	5	16	34.32	37.74
1991	PRAIRIE	August	5	24	43.67	47.19
1991	PRAIRIE	August	5	36	52.07	46.08
1991	PRAIRIE	August	5	48	57.78	46.34
1991	PRAIRIE	August	5	72	65.45	54.65
1991	PRAIRIE	August	6	6	19.70	34.75
1991	PRAIRIE	August	6	12	27.18	34.77
1991	PRAIRIE	August	6	16	35.12	38.50
1991	PRAIRIE	August	6	24	40.61	40.61
1991	PRAIRIE	August	6	36	50.44	47.35
1991	PRAIRIE	August	6	48	63.54	53.29
1991	PRAIRIE	August	6	72	67.34	57.13

APPENDIX 4n. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1991	PLAINS	August	7	6	22.82	24.24
1991	PLAINS	August	7	12	33.84	34.45
1991	PLAINS	August	7	16	35.63	40.94
1991	PLAINS	August	7	24	49.12	49.12
1991	PLAINS	August	7	36	61.41	61.06
1991	PLAINS	August	7	48	62.81	53.94
1991	PLAINS	August	7	72	58.70	55.28
1991	PLAINS	August	8	6	21.68	24.55
1991	PLAINS	August	8	12	31.92	33.17
1991	PLAINS	August	8	16	39.88	45.39
1991	PLAINS	August	8	24	49.19	47.33
1991	PLAINS	August	8	36	67.39	65.00
1991	PLAINS	August	8	48	64.22	62.38
1991	PLAINS	August	8	72	75.33	71.25
1991	PLAINS	August	9	6	24.95	24.95
1991	PLAINS	August	9	12	31.56	29.05
1991	PLAINS	August	9	16	39.64	50.16
1991	PLAINS	August	9	24	46.81	46.32
1991	PLAINS	August	9	36	62.24	58.09
1991	PLAINS	August	9	48	60.06	48.70
1991	PLAINS	August	9	72	71.80	59.06
1991	PLAINS	August	10	6	23.08	26.61
1991	PLAINS	August	10	12	29.28	31.88
1991	PLAINS	August	10	16	37.06	38.22
1991	PLAINS	August	10	24	48.12	48.12
1991	PLAINS	August	10	36	64.27	61.65
1991	PLAINS	August	10	48	55.74	54.93
1991	PLAINS	August	10	72	67.80	63.96
1991	PLAINS	August	11	6	31.67	28.54
1991	PLAINS	August	11	12	34.33	45.78
1991	PLAINS	August	11	16	41.77	42.31
1991	PLAINS	August	11	24	56.12	56.52
1991	PLAINS	August	11	36	66.86	61.08
1991	PLAINS	August	11	48	69.73	62.51
1991	PLAINS	August	11	72	73.66	66.65
1991	PLAINS	August	12	6	22.90	21.49
1991	PLAINS	August	12	12	38.25	36.95
1991	PLAINS	August	12	16	43.32	48.00
1991	PLAINS	August	12	24	49.36	52.15
1991	PLAINS	August	12	36	66.20	60.93
1991	PLAINS	August	12	48	68.95	63.54
1991	PLAINS	August	12	72	74.09	68.86

APPENDIX 4o. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1991	PRAIRIE	October	1	6	27.30	34.68
1991	PRAIRIE	October	1	12	40.46	52.25
1991	PRAIRIE	October	1	16	52.00	60.69
1991	PRAIRIE	October	1	24	56.72	61.11
1991	PRAIRIE	October	1	36	69.12	75.39
1991	PRAIRIE	October	1	48	69.79	74.69
1991	PRAIRIE	October	1	72	73.76	81.08
1991	PRAIRIE	October	2	6	28.30	34.49
1991	PRAIRIE	October	2	12	48.00	54.60
1991	PRAIRIE	October	2	16	55.00	62.85
1991	PRAIRIE	October	2	24	64.95	71.18
1991	PRAIRIE	October	2	36	64.22	71.31
1991	PRAIRIE	October	2	48	72.23	79.56
1991	PRAIRIE	October	2	72	75.97	82.19
1991	PRAIRIE	October	3	6	28.34	34.53
1991	PRAIRIE	October	3	12	43.29	50.49
1991	PRAIRIE	October	3	16	36.00	48.37
1991	PRAIRIE	October	3	24	58.12	61.95
1991	PRAIRIE	October	3	36	56.85	60.79
1991	PRAIRIE	October	3	48	70.02	73.98
1991	PRAIRIE	October	3	72	73.40	79.34
1991	PRAIRIE	October	4	6	28.32	39.60
1991	PRAIRIE	October	4	12	45.96	51.99
1991	PRAIRIE	October	4	16	48.00	54.64
1991	PRAIRIE	October	4	24	63.90	68.85
1991	PRAIRIE	October	4	36	68.95	75.41
1991	PRAIRIE	October	4	48	70.93	76.98
1991	PRAIRIE	October	4	72	75.85	83.20
1991	PRAIRIE	October	5	6	26.14	34.76
1991	PRAIRIE	October	5	12	42.43	50.61
1991	PRAIRIE	October	5	16	45.00	54.22
1991	PRAIRIE	October	5	24	59.00	62.12
1991	PRAIRIE	October	5	36	65.87	69.34
1991	PRAIRIE	October	5	48	70.28	73.60
1991	PRAIRIE	October	5	72	73.56	77.99
1991	PRAIRIE	October	6	6	27.87	33.00
1991	PRAIRIE	October	6	12	33.30	45.49
1991	PRAIRIE	October	6	16	42.00	51.79
1991	PRAIRIE	October	6	24	51.96	52.93
1991	PRAIRIE	October	6	36	68.56	72.55
1991	PRAIRIE	October	6	48	67.85	72.75
1991	PRAIRIE	October	6	72	74.29	81.07

APPENDIX 4p. EXTENT OF IN SITU OM AND N DISAPPEARANCE FROM ESOPHAGEAL MASTICATE COLLECTED FROM MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Incubation time, Hours	Organic matter disappearance, % of OM	Nitrogen disappearance, % of N
1991	PLAINS	October	7	6	26.45	26.04
1991	PLAINS	October	7	12	41.70	46.67
1991	PLAINS	October	7	16	45.00	53.81
1991	PLAINS	October	7	24	60.69	66.05
1991	PLAINS	October	7	36	72.94	75.71
1991	PLAINS	October	7	48	69.92	74.02
1991	PLAINS	October	7	72	80.30	80.64
1991	PLAINS	October	8	6	26.40	28.91
1991	PLAINS	October	8	12	43.63	50.04
1991	PLAINS	October	8	16	50.00	56.24
1991	PLAINS	October	8	24	59.13	56.81
1991	PLAINS	October	8	36	68.29	71.53
1991	PLAINS	October	8	48	77.44	78.47
1991	PLAINS	October	8	72	80.83	82.57
1991	PLAINS	October	9	6	28.15	33.86
1991	PLAINS	October	9	12	44.71	46.60
1991	PLAINS	October	9	16	55.00	59.84
1991	PLAINS	October	9	24	35.31	39.36
1991	PLAINS	October	9	36	76.10	77.05
1991	PLAINS	October	9	48	78.11	78.36
1991	PLAINS	October	9	72	80.28	81.96
1991	PLAINS	October	10	6	25.97	25.97
1991	PLAINS	October	10	12	35.32	43.04
1991	PLAINS	October	10	16	40.00	48.20
1991	PLAINS	October	10	24	60.76	69.68
1991	PLAINS	October	10	36	62.87	67.72
1991	PLAINS	October	10	48	71.63	75.18
1991	PLAINS	October	10	72	80.14	81.15
1991	PLAINS	October	11	6	24.53	30.53
1991	PLAINS	October	11	12	34.24	38.35
1991	PLAINS	October	11	16	46.00	53.76
1991	PLAINS	October	11	24	62.87	71.73
1991	PLAINS	October	11	36	67.69	69.90
1991	PLAINS	October	11	48	75.66	79.95
1991	PLAINS	October	11	72	81.21	83.66
1991	PLAINS	October	12	6	25.86	30.91
1991	PLAINS	October	12	12	33.51	36.91
1991	PLAINS	October	12	16	45.00	51.70
1991	PLAINS	October	12	24	57.54	62.61
1991	PLAINS	October	12	36	73.80	76.48
1991	PLAINS	October	12	48	78.13	79.50
1991	PLAINS	October	12	72	79.30	81.06

APPENDIX 5a. RUMINAL AMMONIA NITROGEN AND pH IN CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Sampling time, Hours	Ruminal ammonia-nitrogen, mg/dl	Ruminal pH
1990	PRAIRIE	May	1	0	4.56	6.45
1990	PRAIRIE	May	1	6	2.51	6.39
1990	PRAIRIE	May	1	12	2.85	6.11
1990	PRAIRIE	May	2	0	3.86	6.54
1990	PRAIRIE	May	2	6	3.66	6.46
1990	PRAIRIE	May	2	12	1.55	6.07
1990	PRAIRIE	May	3	0	2.47	6.45
1990	PRAIRIE	May	3	6	3.00	6.44
1990	PRAIRIE	May	3	12	1.89	6.17
1990	PRAIRIE	May	4	0	4.07	6.43
1990	PRAIRIE	May	4	6	5.48	6.44
1990	PRAIRIE	May	4	12	1.55	6.25
1990	PRAIRIE	May	5	0	2.73	6.25
1990	PRAIRIE	May	5	6	1.78	6.22
1990	PRAIRIE	May	5	12	2.56	5.76
1990	PRAIRIE	May	6	0	1.85	6.55
1990	PRAIRIE	May	6	6	3.18	6.34
1990	PRAIRIE	May	6	12	1.49	6.29
1990	PLAINS	May	7	0	xx.xx	xx.xx
1990	PLAINS	May	7	6	xx.xx	xx.xx
1990	PLAINS	May	7	12	xx.xx	xx.xx
1990	PLAINS	May	8	0	xx.xx	xx.xx
1990	PLAINS	May	8	6	xx.xx	xx.xx
1990	PLAINS	May	8	12	xx.xx	xx.xx
1990	PLAINS	May	9	0	xx.xx	xx.xx
1990	PLAINS	May	9	6	xx.xx	xx.xx
1990	PLAINS	May	9	12	xx.xx	xx.xx
1990	PLAINS	May	10	0	xx.xx	xx.xx
1990	PLAINS	May	10	6	xx.xx	xx.xx
1990	PLAINS	May	10	12	xx.xx	xx.xx
1990	PLAINS	May	11	0	xx.xx	xx.xx
1990	PLAINS	May	11	6	xx.xx	xx.xx
1990	PLAINS	May	11	12	xx.xx	xx.xx
1990	PLAINS	May	12	0	xx.xx	xx.xx
1990	PLAINS	May	12	6	xx.xx	xx.xx
1990	PLAINS	May	12	12	xx.xx	xx.xx

APPENDIX 5b. RUMINAL AMMONIA NITROGEN AND pH IN CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Sampling time, Hours	Ruminal ammonia-nitrogen, mg/dl	Ruminal pH
1990	PRAIRIE	June	1	0	1.56	6.50
1990	PRAIRIE	June	1	6	1.71	6.57
1990	PRAIRIE	June	1	12	3.32	6.30
1990	PRAIRIE	June	2	0	2.28	6.48
1990	PRAIRIE	June	2	6	1.78	6.50
1990	PRAIRIE	June	2	12	1.35	6.27
1990	PRAIRIE	June	3	0	3.47	6.46
1990	PRAIRIE	June	3	6	1.24	6.52
1990	PRAIRIE	June	3	12	2.84	6.12
1990	PRAIRIE	June	4	0	4.25	6.54
1990	PRAIRIE	June	4	6	1.54	6.66
1990	PRAIRIE	June	4	12	3.08	6.50
1990	PRAIRIE	June	5	0	3.23	6.60
1990	PRAIRIE	June	5	6	1.72	6.47
1990	PRAIRIE	June	5	12	2.08	6.35
1990	PRAIRIE	June	6	0	3.41	6.58
1990	PRAIRIE	June	6	6	6.64	6.55
1990	PRAIRIE	June	6	12	0.58	6.40
1990	PLAINS	June	7	0	4.00	6.41
1990	PLAINS	June	7	6	3.18	6.57
1990	PLAINS	June	7	12	2.96	6.62
1990	PLAINS	June	8	0	3.35	6.40
1990	PLAINS	June	8	6	2.80	6.57
1990	PLAINS	June	8	12	3.38	6.62
1990	PLAINS	June	9	0	5.06	6.42
1990	PLAINS	June	9	6	6.42	6.41
1990	PLAINS	June	9	12	6.08	6.38
1990	PLAINS	June	10	0	3.06	6.22
1990	PLAINS	June	10	6	3.01	6.50
1990	PLAINS	June	10	12	3.39	6.43
1990	PLAINS	June	11	0	2.52	5.98
1990	PLAINS	June	11	6	2.95	6.62
1990	PLAINS	June	11	12	1.76	6.59
1990	PLAINS	June	12	0	2.34	6.29
1990	PLAINS	June	12	6	3.71	6.20
1990	PLAINS	June	12	12	4.12	6.32

APPENDIX 5c. RUMINAL AMMONIA NITROGEN AND pH IN CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Sampling time, Hours	Ruminal ammonia-nitrogen, mg/dl	Ruminal pH
1990	PRAIRIE	August	1	0	1.90	6.18
1990	PRAIRIE	August	1	6	0.86	6.43
1990	PRAIRIE	August	1	12	5.41	6.20
1990	PRAIRIE	August	2	0	2.85	6.00
1990	PRAIRIE	August	2	6	3.70	6.14
1990	PRAIRIE	August	2	12	3.04	5.86
1990	PRAIRIE	August	3	0	4.87	6.17
1990	PRAIRIE	August	3	6	3.59	6.30
1990	PRAIRIE	August	3	12	3.43	5.98
1990	PRAIRIE	August	4	0	5.36	6.44
1990	PRAIRIE	August	4	6	4.22	6.51
1990	PRAIRIE	August	4	12	3.93	6.27
1990	PRAIRIE	August	5	0	4.79	6.13
1990	PRAIRIE	August	5	6	3.59	6.39
1990	PRAIRIE	August	5	12	3.03	6.34
1990	PRAIRIE	August	6	0	4.47	6.13
1990	PRAIRIE	August	6	6	4.05	6.35
1990	PRAIRIE	August	6	12	2.59	5.97
1990	PLAINS	August	7	0	7.87	6.62
1990	PLAINS	August	7	6	4.64	6.30
1990	PLAINS	August	7	12	7.64	6.45
1990	PLAINS	August	8	0	10.01	6.39
1990	PLAINS	August	8	6	3.49	6.21
1990	PLAINS	August	8	12	6.12	6.32
1990	PLAINS	August	9	0	25.26	6.52
1990	PLAINS	August	9	6	17.11	5.81
1990	PLAINS	August	9	12	12.95	6.32
1990	PLAINS	August	10	0	9.93	6.44
1990	PLAINS	August	10	6	7.61	5.82
1990	PLAINS	August	10	12	9.73	6.27
1990	PLAINS	August	11	0	5.75	6.41
1990	PLAINS	August	11	6	8.03	6.34
1990	PLAINS	August	11	12	4.74	6.38
1990	PLAINS	August	12	0	6.54	7.16
1990	PLAINS	August	12	6	6.16	6.22
1990	PLAINS	August	12	12	6.96	6.37

APPENDIX 5d. RUMINAL AMMONIA NITROGEN AND pH IN CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Sampling time, Hours	Ruminal ammonia-nitrogen, mg/dl	Ruminal pH
1990	PRAIRIE	October	1	0	3.16	6.27
1990	PRAIRIE	October	1	6	2.14	6.44
1990	PRAIRIE	October	1	12	3.84	6.37
1990	PRAIRIE	October	2	0	4.38	6.45
1990	PRAIRIE	October	2	6	4.87	6.30
1990	PRAIRIE	October	2	12	2.52	6.41
1990	PRAIRIE	October	3	0	2.85	6.23
1990	PRAIRIE	October	3	6	2.77	6.12
1990	PRAIRIE	October	3	12	2.62	6.32
1990	PRAIRIE	October	4	0	3.61	6.55
1990	PRAIRIE	October	4	6	3.16	6.62
1990	PRAIRIE	October	4	12	2.02	6.43
1990	PRAIRIE	October	5	0	5.10	6.00
1990	PRAIRIE	October	5	6	4.01	6.23
1990	PRAIRIE	October	5	12	4.05	6.24
1990	PRAIRIE	October	6	0	1.56	6.33
1990	PRAIRIE	October	6	6	3.38`	6.41
1990	PRAIRIE	October	6	12	2.64	6.22
1990	PLAINS	October	7	0	5.67	6.51
1990	PLAINS	October	7	6	3.26	6.41
1990	PLAINS	October	7	12	5.37	6.12
1990	PLAINS	October	8	0	7.76	6.43
1990	PLAINS	October	8	6	4.65	6.43
1990	PLAINS	October	8	12	4.37	6.02
1990	PLAINS	October	9	0	8.21	6.20
1990	PLAINS	October	9	6	7.95	6.10
1990	PLAINS	October	9	12	8.60	6.09
1990	PLAINS	October	10	0	8.43	6.21
1990	PLAINS	October	10	6	4.82	6.34
1990	PLAINS	October	10	12	7.10	6.00
1990	PLAINS	October	11	0	6.43	6.39
1990	PLAINS	October	11	6	7.58	6.31
1990	PLAINS	October	11	12	4.09	6.03
1990	PLAINS	October	12	0	2.18	6.45
1990	PLAINS	October	12	6	5.62	6.30
1990	PLAINS	October	12	12	3.27	6.22

APPENDIX 5e. RUMINAL AMMONIA NITROGEN AND pH IN CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Sampling time, Hours	Ruminal ammonia-nitrogen, mg/dl	Ruminal pH
1991	PRAIRIE	May	1	0	1.85	6.16
1991	PRAIRIE	May	1	6	1.47	6.83
1991	PRAIRIE	May	1	12	3.22	5.98
1991	PRAIRIE	May	2	0	0.83	6.22
1991	PRAIRIE	May	2	6	1.97	6.69
1991	PRAIRIE	May	2	12	3.06	6.21
1991	PRAIRIE	May	3	0	1.32	6.50
1991	PRAIRIE	May	3	6	1.71	6.50
1991	PRAIRIE	May	3	12	2.01	6.01
1991	PRAIRIE	May	4	0	2.60	6.37
1991	PRAIRIE	May	4	6	2.10	6.50
1991	PRAIRIE	May	4	12	3.37	6.31
1991	PRAIRIE	May	5	0	0.58	6.11
1991	PRAIRIE	May	5	6	0.50	6.26
1991	PRAIRIE	May	5	12	2.49	5.89
1991	PRAIRIE	May	6	0	2.93	6.34
1991	PRAIRIE	May	6	6	1.83	6.48
1991	PRAIRIE	May	6	12	3.98	6.10
1991	PLAINS	May	7	0	6.01	6.51
1991	PLAINS	May	7	6	3.23	6.31
1991	PLAINS	May	7	12	5.92	6.50
1991	PLAINS	May	8	0	4.47	6.23
1991	PLAINS	May	8	6	4.71	6.33
1991	PLAINS	May	8	12	6.84	6.33
1991	PLAINS	May	9	0	10.54	6.28
1991	PLAINS	May	9	6	5.03	6.38
1991	PLAINS	May	9	12	8.28	6.17
1991	PLAINS	May	10	0	8.09	6.20
1991	PLAINS	May	10	6	4.38	6.32
1991	PLAINS	May	10	12	10.92	6.05
1991	PLAINS	May	11	0	6.87	6.30
1991	PLAINS	May	11	6	7.93	6.05
1991	PLAINS	May	11	12	10.51	6.39
1991	PLAINS	May	12	0	9.59	6.16
1991	PLAINS	May	12	6	6.81	6.21
1991	PLAINS	May	12	12	7.65	6.02

APPENDIX 5f. RUMINAL AMMONIA NITROGEN AND pH IN CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Sampling time, Hours	Ruminal ammonia-nitrogen, mg/dl	Ruminal pH
1991	PRAIRIE	June	1	0	2.91	6.15
1991	PRAIRIE	June	1	6	3.50	6.53
1991	PRAIRIE	June	1	12	1.51	6.27
1991	PRAIRIE	June	2	0	2.93	6.40
1991	PRAIRIE	June	2	6	4.48	6.45
1991	PRAIRIE	June	2	12	3.09	6.27
1991	PRAIRIE	June	3	0	3.36	6.33
1991	PRAIRIE	June	3	6	3.33	6.30
1991	PRAIRIE	June	3	12	3.22	6.20
1991	PRAIRIE	June	4	0	3.09	6.37
1991	PRAIRIE	June	4	6	6.20	4.15
1991	PRAIRIE	June	4	12	2.53	6.29
1991	PRAIRIE	June	5	0	1.88	6.12
1991	PRAIRIE	June	5	6	3.42	6.40
1991	PRAIRIE	June	5	12	0.28	6.22
1991	PRAIRIE	June	6	0	0.62	6.49
1991	PRAIRIE	June	6	6	0.25	6.64
1991	PRAIRIE	June	6	12	0.07	6.54
1991	PLAINS	June	7	0	2.01	6.53
1991	PLAINS	June	7	6	2.54	6.60
1991	PLAINS	June	7	12	4.15	6.53
1991	PLAINS	June	8	0	2.70	6.59
1991	PLAINS	June	8	6	1.39	6.56
1991	PLAINS	June	8	12	2.31	6.53
1991	PLAINS	June	9	0	4.79	6.27
1991	PLAINS	June	9	6	3.06	6.37
1991	PLAINS	June	9	12	4.40	6.46
1991	PLAINS	June	10	0	3.34	6.19
1991	PLAINS	June	10	6	1.97	6.60
1991	PLAINS	June	10	12	3.33	6.60
1991	PLAINS	June	11	0	1.27	6.53
1991	PLAINS	June	11	6	0.46	6.54
1991	PLAINS	June	11	12	0.97	6.50
1991	PLAINS	June	12	0	0.56	6.49
1991	PLAINS	June	12	6	0.17	6.45
1991	PLAINS	June	12	12	1.06	6.53

APPENDIX 5g. RUMINAL AMMONIA NITROGEN AND pH IN CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Sampling time, Hours	Ruminal ammonia-nitrogen, mg/dl	Ruminal pH
1991	PRAIRIE	August	1	0	1.23	6.57
1991	PRAIRIE	August	1	6	1.95	5.79
1991	PRAIRIE	August	1	12	1.94	6.51
991	PRAIRIE	August	2	0	1.14	6.66
1991	PRAIRIE	August	2	6	1.54	6.43
1991	PRAIRIE	August	2	12	1.69	6.55
1991	PRAIRIE	August	3	0	2.32	6.41
1991	PRAIRIE	August	3	6	1.32	6.32
1991	PRAIRIE	August	3	12	2.42	6.57
1991	PRAIRIE	August	4	0	0.68	6.51
1991	PRAIRIE	August	4	6	0.82	6.48
1991	PRAIRIE	August	4	12	1.03	6.35
1991	PRAIRIE	August	5	0	0.30	6.51
1991	PRAIRIE	August	5	6	0.45	6.31
1991	PRAIRIE	August	5	12	0.43	6.52
1991	PRAIRIE	August	6	0	0.67	6.41
1991	PRAIRIE	August	6	6	0.39	6.46
1991	PRAIRIE	August	6	12	0.44	6.42
1991	PLAINS	August	7	0	2.69	6.92
1991	PLAINS	August	7	6	1.77	6.61
1991	PLAINS	August	7	12	3.30	6.46
1991	PLAINS	August	8	0	3.22	6.46
1991	PLAINS	August	8	6	2.21	6.51
1991	PLAINS	August	8	12	3.09	6.52
1991	PLAINS	August	9	0	2.40	6.32
1991	PLAINS	August	9	6	1.51	6.49
1991	PLAINS	August	9	12	2.21	6.29
1991	PLAINS	August	10	0	2.71	6.79
1991	PLAINS	August	10	6	1.54	6.55
1991	PLAINS	August	10	12	2.03	6.58
1991	PLAINS	August	11	0	1.27	6.40
1991	PLAINS	August	11	6	2.08	6.50
1991	PLAINS	August	11	12	1.62	6.34
1991	PLAINS	August	12	0	6.43	6.41
1991	PLAINS	August	12	6	2.07	6.48
1991	PLAINS	August	12	12	2.85	6.48

APPENDIX 5h. RUMINAL AMMONIA NITROGEN AND pH IN CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Sampling time, Hours	Ruminal ammonia-nitrogen, mg/dl	Ruminal pH
1991	PRAIRIE	October	1	0	20.77	6.69
1991	PRAIRIE	October	1	6	7.32	5.97
1991	PRAIRIE	October	1	12	6.24	6.15
1991	PRAIRIE	October	2	0	6.45	6.38
1991	PRAIRIE	October	2	6	5.63	6.21
1991	PRAIRIE	October	2	12	5.67	6.55
1991	PRAIRIE	October	3	0	7.15	6.63
1991	PRAIRIE	October	3	6	8.12	6.03
1991	PRAIRIE	October	3	12	8.90	6.30
1991	PRAIRIE	October	4	0	7.15	6.63
1991	PRAIRIE	October	4	6	6.79	6.31
1991	PRAIRIE	October	4	12	10.33	6.38
1991	PRAIRIE	October	5	0	7.74	6.44
1991	PRAIRIE	October	5	6	8.71	6.15
1991	PRAIRIE	October	5	12	6.50	6.41
1991	PRAIRIE	October	6	0	12.74	6.69
1991	PRAIRIE	October	6	6	6.10	6.34
1991	PRAIRIE	October	6	12	6.54	6.53
1991	PLAINS	October	7	0	8.04	6.59
1991	PLAINS	October	7	6	0.32	6.56
1991	PLAINS	October	7	12	5.06	6.62
1991	PLAINS	October	8	0	0.88	6.68
1991	PLAINS	October	8	6	0.44	6.61
1991	PLAINS	October	8	12	0.57	6.46
1991	PLAINS	October	9	0	0.52	6.53
1991	PLAINS	October	9	6	0.77	6.52
1991	PLAINS	October	9	12	0.82	6.42
1991	PLAINS	October	10	0	0.60	6.66
1991	PLAINS	October	10	6	1.65	6.50
1991	PLAINS	October	10	12	0.60	6.59
1991	PLAINS	October	11	0	1.11	6.62
1991	PLAINS	October	11	6	0.65	6.53
1991	PLAINS	October	11	12	0.78	6.53
1991	PLAINS	October	12	0	0.22	6.72
1991	PLAINS	October	12	6	0.35	6.47
1991	PLAINS	October	12	12	0.36	6.49

APPENDIX 6a. INTAKE AND FLOW OF NUTRIENTS IN THE DIGESTIVE TRACT OF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Body weight, kg	Organic matter intake, g/d	Duodenal OM flow, g/d	Duodenal microbial OM flow, g/d	Fecal OM output, g/d	Nitrogen intake, g/d	Duodenal N flow, g/d	Duodenal ammonia-N flow, g/d	Duodenal microbial-N flow, g/d	Fecal N output, g/d	NDF intake, g/d	Duodenal NDF flow, g/d	Fecal NDF output, g/d	ADF intake, g/d	Duodenal ADF flow, g/d	Fecal ADF output, g/d
1990	PRAIRIE	May	1	268	8541	5044	949	3533	179	206	5	88	85	5825	2652.	2333	3075	1412	1211
1990	PRAIRIE	May	2	294	8011	4687	825	3314	168	213	6	75	85	5464	2234	2050	2883	1228	1084
1990	PRAIRIE	May	3	293	8890	5195	843	3677	187	250	8	78	96	6063	2441	2359	3200	1245	1204
1990	PRAIRIE	May	4	281	8231	4678	760	3405	173	215	7	71	78	5614	2335	2248	2963	1168	1131
1990	PRAIRIE	May	5	229	6469	4734	697	2676	136	189	5	64	67	4412	2364	1780	2329	1515	907
1990	PRAIRIE	May	6	298	9427	5141	814	3900	198	231	6	78	91	6429	2489	2550	3394	1186	1298
1990	PLAINS	May	7	277	xxxx	xxxx	xxxx	xxxx	xxx	xxx	x	xx	xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
1990	PLAINS	May	8	279	xxxx	xxxx	xxxx	xxxx	xxx	xxx	x	xx	xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
1990	PLAINS	May	9	273	xxxx	xxxx	xxxx	xxxx	xxx	xxx	x	xx	xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
1990	PLAINS	May	10	257	xxxx	xxxx	xxxx	xxxx	xxx	xxx	x	xx	xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
1990	PLAINS	May	11	287	xxxx	xxxx	xxxx	xxxx	xxx	xxx	x	xx	xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
1990	PLAINS	May	12	253	xxxx	xxxx	xxxx	xxxx	xxx	xxx	x	xx	xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
1990	PRAIRIE	June	1	313	6866	4373	773	3147	96	194	7	69	61	5534	2027	2138	2671	1007	942
1990	PRAIRIE	June	2	336	8877	5151	594	4089	124	191	6	55	79	7155	2674	2895	3453	1363	1227
1990	PRAIRIE	June	3	329	8413	4792	558	3856	118	184	5	50	76	6781	2412	2599	3273	1209	1014
1990	PRAIRIE	June	4	344	8397	5806	537	3849	118	210	8	51	66	6768	3252	2760	3266	1586	1210
1990	PRAIRIE	June	5	281	6879	5332	440	3154	96	171	6	38	56	5546	2876	2265	2676	1423	994
1990	PRAIRIE	June	6	348	8290	5288	988	3800	116	183	6	85	70	6682	2877	2752	3225	1287	1163
1990	PLAINS	June	7	322	7815	4504	823	3210	180	209	6	79	74	5220	1917	1975	2493	929	871
1990	PLAINS	June	8	329	9101	4867	1085	3738	209	242	6	99	82	6079	1913	2278	2903	882	1131
1990	PLAINS	June	9	314	8004	4853	789	3287	184	210	7	73	78	5346	1913	2160	2553	940	1155
1990	PLAINS	June	10	303	7435	4510	860	3054	171	221	7	78	71	4967	1797	1847	2372	799	838
1990	PLAINS	June	11	333	8015	5128	1086	3292	184	231	7	102	72	5354	2164	2066	2557	1009	915
1990	PLAINS	June	12	301	9016	5847	1054	3703	207	236	6	96	78	6023	2655	2472	2876	1344	1077

APPENDIX 6b INTAKE AND FLOW OF NUTRIENTS IN THE DIGESTIVE TRACT OF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Body weight, kg	Organic matter intake, g/d	Duodenal OM flow, g/d	Duodenal microbial OM flow, g/d	Fecal OM output, g/d	Nitrogen intake, g/d	Duodenal N flow, g/d	Duodenal ammonia-N flow, g/d	Duodenal microbial-N flow, g/d	Fecal N output, g/d	NDF intake, g/d	Duodenal NDF flow, g/d	Fecal NDF output, g/d	ADF intake, g/d	Duodenal ADF flow, g/d	Fecal ADF output, g/d
1990	PRAIRIE	August	1	338	8017	4814	846	3672	128	172	4	79	62	6510	2706	2430	3231	1363	1331
1990	PRAIRIE	August	2	336	9282	5034	710	4251	149	171	6	65	72	7537	2983	2817	3741	1451	1391
1990	PRAIRIE	August	3	355	8031	4644	773	3678	128	189	7	68	67	6521	2484	2328	3236	1245	1274
1990	PRAIRIE	August	4	358	7643	5347	564	3500	122	199	7	53	58	6206	3051	2355	3080	1475	1105
1990	PRAIRIE	August	5	301	6271	4564	514	2872	100	161	5	47	51	5092	2647	1760	2527	1246	656
1990	PRAIRIE	August	6	367	8750	5631	767	4007	140	205	6	69	66	7105	3104	2556	3526	3334	1237
1990	PLAINS	August	7	362	9487	5266	1110	3761	266	277	7	106	90	5873	2265	2080	2827	1179	1117
1990	PLAINS	August	8	353	10715	5113	805	4247	300	241	7	80	103	6633	2382	2402	3193	1144	1288
1990	PLAINS	August	9	338	7243	5784	900	2871	203	294	7	88	74	4483	2337	1557	2158	1236	847
1990	PLAINS	August	10	329	8387	4814	966	3325	235	248	9	94	80	5192	1762	1893	2499	849	993
1990	PLAINS	August	11	365	9500	5215	1048	3766	266	273	5	106	95	5881	2160	2059	2831	1065	1003
1990	PLAINS	August	12	337	7538	5020	982	2988	211	230	8	94	72	4666	2206	1717	2246	1083	812
1990	PRAIRIE	October	1	351	8007	4455	515	3709	136	149	6	49	66	6221	2288	2464	3107	1237	1138
1990	PRAIRIE	October	2	388	7184	4824	618	3328	122	158	6	58	55	5582	2471	2198	2787	1471	1215
1990	PRAIRIE	October	3	397	6265	5202	552	2902	107	183	7	52	52	4868	2605	1977	2431	1532	923
1990	PRAIRIE	October	4	398	9537	4891	548	4431	163	167	5	52	74	7434	2596	2977	3712	1483	1384
1990	PRAIRIE	October	5	323	4619	4475	523	2139	79	153	5	50	39	3589	2314	1448	1792	1312	693
1990	PRAIRIE	October	6	395	5070	4466	820	2348	86	150	8	76	43	3940	2162	1567	1967	1276	738
1990	PLAINS	October	7	401	5346	5028	788	2348	123	216	8	74	48	3940	2072	1232	1973	1291	645
1990	PLAINS	October	8	398	7967	3937	716	3191	183	185	7	72	71	5872	1534	1891	2940	938	974
1990	PLAINS	October	9	371	4899	3855	718	1962	113	176	7	69	44	3611	1456	1157	1808	884	519
1990	PLAINS	October	10	376	5323	4209	546	2132	122	184	7	54	47	3923	1741	1350	1964	1025	605
1990	PLAINS	October	11	407	5242	4520	737	2099	121	193	7	67	45	3862	1978	1293	1934	1201	647
1990	PLAINS	October	12	374	5036	3913	725	2017	116	175	5	68	44	3711	1684	1224	1858	952	591

APPENDIX 6c INTAKE AND FLOW OF NUTRIENTS IN THE DIGESTIVE TRACT OF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Body weight, kg	Organic matter intake, g/d	Duodenal OM flow, g/d	Duodenal microbial OM flow, g/d	Fecal OM output, g/d	Nitrogen intake, g/d	Duodenal N flow, g/d	Duodenal ammonia-N flow, g/d	Duodenal microbial-N flow, g/d	Fecal N output, g/d	NDF intake, g/d	Duodenal NDF flow, g/d	Fecal NDF output, g/d	ADF intake, g/d	Duodenal ADF flow, g/d	Fecal ADF output, g/d
1991	PRAIRIE	May	1	270	8251	4976	1105	3298	160	222	7	108	67	4734	2502	2173	2792	1160	1101
1991	PRAIRIE	May	2	249	8581	4975	1155	3429	166	206	7	104	67	4923	2664	2258	2904	1228	1106
1991	PRAIRIE	May	3	262	7366	4739	937	2944	143	217	6	89	66	4226	2389	1889	2493	1240	1016
1991	PRAIRIE	May	4	283	8855	4794	1077	3539	172	195	5	98	69	5080	2819	2348	2996	1306	1185
1991	PRAIRIE	May	5	247	9553	5078	1099	3817	185	216	7	95	75	5480	2720	2456	3233	1275	1304
1991	PRAIRIE	May	6	261	8465	5898	1051	3383	164	241	7	95	65	4857	3234	2145	2865	1637	1108
1991	PLAINS	May	7	276	7017	4168	1165	2676	198	224	8	109	77	4598	1745	1456	2382	776	819
1991	PLAINS	May	8	251	7071	4039	1036	2696	199	241	13	102	81	4633	1656	1464	2401	689	841
1991	PLAINS	May	9	272	6658	4326	1018	2539	188	237	10	96	73	4363	1874	1323	2261	802	754
1991	PLAINS	May	10	255	5408	4660	755	2062	153	245	10	72	59	3543	1681	1114	1836	708	659
1991	PLAINS	May	11	237	6188	4198	1059	2359	175	230	11	100	61	4045	1935	1328	2101	801	789
1991	PLAINS	May	12	247	7083	4338	1076	2701	200	251	13	106	73	4641	1599	1458	5405	760	810
1991	PRAIRIE	June	1	305	8029	4439	986	3726	130	189	10	97	63	6220	1896	2598	3065	1056	1104
1991	PRAIRIE	June	2	283	8101	4631	642	3760	131	190	9	59	65	6276	1978	2634	3092	1101	1120
1991	PRAIRIE	June	3	293	8692	4849	638	4034	141	192	8	59	73	6734	2659	2928	3318	1151	1231
1991	PRAIRIE	June	4	310	8212	5127	704	3811	133	199	8	65	71	6362	2513	2621	3135	1358	1150
1991	PRAIRIE	June	5	278	8908	5945	758	4134	144	234	8	66	65	6901	3051	3004	3400	1679	1309
1991	PRAIRIE	June	6	267	5840	4843	591	2710	95	169	4	55	53	4524	2774	1861	2229	1301	762
1991	PLAINS	June	7	323	7940	4874	918	3080	140	194	7	82	57	6082	2748	1995	2942	1432	1030
1991	PLAINS	June	8	294	7363	4570	921	2856	129	195	9	84	60	5640	2242	1744	2729	1182	875
1991	PLAINS	June	9	320	7899	5078	1079	3064	138	231	9	103	66	6050	2302	1890	2927	1202	989
1991	PLAINS	June	10	301	8731	4498	1075	3387	153	213	5	107	64	6688	1924	2109	3236	1044	1046
1991	PLAINS	June	11	259	8671	4307	917	3364	152	189	6	88	63	6642	1896	2145	3214	877	1057
1991	PLAINS	June	12	267	9043	4592	710	3508	158	189	7	69	68	6927	2169	2267	3351	1143	989

APPENDIX 6d. INTAKE AND FLOW OF NUTRIENTS IN THE DIGESTIVE TRACT OF CATTLE GRAZING MIDGRASS PRAIRIE RANGELAND (PRAIRIE) OR PLAINS BLUESTEM PASTURE (PLAINS)

Year	Forage type	Month	Animal	Body weight, kg	Organic matter intake, g/d	Duodenal OM flow, g/d	Duodenal microbial OM flow, g/d	Fecal OM output, g/d	Nitrogen intake, g/d	Duodenal N flow, g/d	Duodenal ammonia-N flow, g/d	Duodenal microbial-N flow, g/d	Fecal N output, g/d	NDF intake, g/d	Duodenal NDF flow, g/d	Fecal NDF output, g/d	ADF intake, g/d	Duodenal ADF flow, g/d	Fecal ADF output, g/d
1991	PRAIRIE	August	1	331	7427	5021	868	3653	75	162	7	78	53	6001	2307	2157	3225	1219	1085
1991	PRAIRIE	August	2	326	7290	5501	878	3586	74	171	8	78	52	5891	2883	2326	3166	1592	1158
1991	PRAIRIE	August	3	336	8770	5324	758	4314	89	166	6	69	60	7087	2935	2782	3809	1555	1342
1991	PRAIRIE	August	4	337	9176	5736	696	4514	93	162	3	58	64	7415	3365	2997	3985	1771	1589
1991	PRAIRIE	August	5	305	9796	6600	899	4819	99	159	4	76	60	7916	4161	3281	5254	2251	1716
1991	PRAIRIE	August	6	298	7552	5648	1051	3715	76	164	4	100	54	6103	3658	2422	3280	1780	1188
1991	PLAINS	August	7	366	8349	6116	1263	3721	99	226	9	113	57	6503	3383	2089	3488	1886	1061
1991	PLAINS	August	8	328	7143	5026	920	3184	84	194	9	83	55	5564	2934	1710	2984	1593	795
1991	PLAINS	August	9	358	7324	5702	1145	3284	86	207	9	104	57	5705	2526	1829	3060	1343	961
1991	PLAINS	August	10	342	8373	4600	1193	3732	99	192	8	100	61	6521	2312	2212	3498	1159	1162
1991	PLAINS	August	11	307	8411	4908	840	3749	99	178	6	80	63	6551	2359	2043	3514	1194	1092
1991	PLAINS	August	12	310	8196	5068	900	3653	97	173	11	88	58	6384	2822	2028	3424	1483	1096
1991	PRAIRIE	October	1	340	8926	5429	961	3870	177	194	11	92	65	6780	2844	2573	3407	1478	1199
1991	PRAIRIE	October	2	346	9453	6985	850	4099	187	258	15	87	74	7180	3571	2739	3608	1800	1281
1991	PRAIRIE	October	3	345	8722	5783	889	3782	173	217	13	84	65	6625	3235	3492	3329	1638	1131
1991	PRAIRIE	October	4	349	10674	8346	1088	4628	211	301	15	99	78	8108	4562	3169	4074	2281	1382
1991	PRAIRIE	October	5	320	11388	6519	1294	4938	225	209	11	108	81	8650	3574	3366	4347	1840	1675
1991	PRAIRIE	October	6	320	10443	6261	802	4528	207	210	10	76	76	7933	3693	3004	3986	1940	1727
1991	PLAINS	October	7	371	9141	4401	739	3205	171	142	6	59	49	6772	2313	1956	3483	1150	996
1991	PLAINS	October	8	342	9644	4979	940	3381	180	169	6	79	64	7145	2763	1948	3674	1381	917
1991	PLAINS	October	9	383	9308	4451	759	3263	174	142	4	69	57	6896	2118	1980	3546	1028	961
1991	PLAINS	October	10	361	9531	4428	1002	3342	178	146	4	93	52	7062	2321	2140	3631	1283	1118
1991	PLAINS	October	11	346	8620	4787	741	3022	161	151	3	68	53	6386	2273	1783	3284	1147	861
1991	PLAINS	October	12	338	8992	4788	962	3153	168	160	4	87	57	6662	2163	1858	3426	1146	820

VITA

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Candidate for the Degree of

Doctor of Philosophy

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