Digestive Physiology of Steers Grazing Fertilized and Non-fertilized Blue Grama Rangeland


Abstract

Eight field trials [early August 1983 (EAUG83), late August 1983 (LAUG83), early November 1983 (ENOV83), early January 1984 (EJAN84), May 1984 (MAY84), late July 1984 (LJUL84), late August 1984 (LAUG84), late November 1984 (LNOV84)] were conducted on blue grama (Bouteloua gracilis) rangeland in southwestern rangeland in southern New Mexico to examine relationships among nitrogen (N) fertilization of forage, stage of plant growth, diet botanical and chemical composition, forage intake, digesta kinetics, and ruminal fermentation in beef steers. A fertilized pasture (45 kg N/ha) was evaluated during the year of and year after fertilizer application and compared with an adjacent unfertilized pasture. Two epophaseal- and 4 ruminally cannulated steers/pasture were used in a split-plot design. Dietary organic matter percentage was not affected by fertilization; however, fiber components increased as plants approached dormancy on both fertilized and unfertilized rangeland. Dietary crude protein levels were numerically higher in the fertilized pasture within all trials. Fertilization had no consistent effect on rate or extent of in vitro organic matter digestibility. Fertilization increased (P<0.05) ruminal ammonia (NH₃) concentrations in all but one trial and levels were adequate for maximal microbial protein synthesis; however, in the unfertilized pasture, ruminal NH₃ levels were potentially inadequate during periods of dormancy. Ruminal pH was numerically higher for steers on the fertilized pasture than for those on the unfertilized pasture each sampling trial except LNOV84. Fertilization had little effect (P>0.05) on total volatile fatty acid (VFA) concentration or molar proportion of individual acids. Total ruminal VFA concentration was highest in steers during periods of active plant growth. Voluntary organic matter intake was usually unaffected (P>0.05) by fertilization except in EJAN 84 when intake was higher (P<0.05) in the fertilized pasture and LNOV84 when intake was higher (P<0.05) for steers grazing the nonfertilized pasture. Organic matter intake by steers averaged 21.8 g/kg body weight (BW) and 21.6 g/kg BW across the 8 trials for fertilized and unfertilized pastures, respectively. Intake in both pastures declined with advancing season. Particulate passage rate (FPR) was not different between treatments (P>0.05) during ENOV83, MAY84 and LNOV84. However, FPR was faster (P<0.05) for steers grazing the fertilized than in the unfertilized pasture during the remaining 5 sampling periods. Correspondingly, retention time of digesta in the gastrointestinal tract was reduced for steers grazing the fertilized pasture during these 5 trials. Estimated gastrointestinal fill was unaffected (P>0.05) by treatment except during the EAUG83 and LAUG84 trials when steers grazing fertilized pasture had reduced (P<0.05) fill compared with steers grazing nonfertilized pasture. Fluid passage rate (FPR) did not differ (P>0.05) between treatments for any trials except in LAUG84 when steers in the fertilized pasture had a lower (P<0.05) FPR than steers in the nonfertilized pasture.

Key Words: forage quality, fertilization, digesta kinetics

Livestock production from native rangeland depends on diet quality and availability. Various improvement practices and land-use strategies have been implemented in an attempt to manipulate vegetative resources to maximize animal production.

Fertilization of rangeland has been employed to increase forage quantity and quality and consequently, animal production. Humphrey (1960) indicated range forage production was limited more by nitrogen (N) deficiency than by any other element. Nitrogen fertilization has increased herbage production on native rangeland (Rogler and Lorenz 1965, Buzlaff et al. 1968, Goetz 1969). Under proper conditions, N fertilization of blue grama (Bouteloua gracilis) dominated rangeland has resulted in a several-fold increase in annual herbage production (Banner 1969, Reed 1969, Schickedanz 1970, Kelsey et al. 1973, Pieper et al. 1974, Donart et al. 1978). Furthermore, diet quality (Kelsey et al. 1972, 1973; Havstad et al. 1979; Wallace et al. 1983) and animal production (Schickedanz 1970; Donart et al. 1978, 1983) have been enhanced by N fertilization of blue grama rangeland.

Another important consideration regarding livestock production on native rangeland is the influence of advancing season on decline of nutritive value and diet selection of grazing ruminants. Such information is paramount to development and implementation of grazing schemes and supplementation programs. Several authors (Cook 1972, Pieper et al. 1978, Kothmann 1980, McCollum et al. 1985) have examined the influence of advancing season on nutritive value of range forages; however, few studies (McCollum et al. 1985) have related diet quality to ruminal characteristics of the grazing herbivore. Because the rumen is the primary site of forage degradation, ruminal fermentation end-products and pH of ruminal contents may have profound effects on fiber digestion (Mertens 1979), microbial protein synthesis (Satter and Slyter 1974), and ultimately energy and protein available for maintenance, growth, and reproduction of grazing animals.

To improve forage utilization and productivity from native rangelands, it is necessary to measure or at least approximate components that affect livestock production. Forage intake by the grazing ruminant may be the most important of these components. It is essential that factors regulating forage intake be understood in order for livestock managers to make responsible management decisions to enhance livestock productivity and profitability.

Cordova et al. (1983) reviewed literature on intake of grazing sheep and cattle and found values ranging from 1 to 2.8% of body weight. Other researchers have examined effects of advancing season on quality and intake of legumes forages (Van Soest 1965, Thornton and Minson 1973). Only limited information is available on chemical and botanical composition of the diets of freely grazing ruminants and associated changes in forage intake (Holechek and Vavra 1982, McCollum and Galyean 1985b).

Rate of digesta disappearance from the gastrointestinal tract of ruminants encompasses both rate of digestion and rate of passage of undigested residues (Ellis 1978, Van Soest 1982). Furthermore, Ellis (1978) concluded ruminal volume, volume occupied by undigested residues and factors influencing ruminal turnover were the major determinants of forage intake. Hence, studies examining the interrelationships of these factors in grazing ruminants should provide greater insight into possible mechanisms controlling forage intake.

Cognizant of these potential relationships, we undertook this
study to relate dietary changes in steers grazing N fertilized and nonfertilized blue grama rangeland during the year of and year after fertilization with changes in seasonal forage quality, ruminal fermentation, intake, and digesta kinetics.

Materials and Methods

Study Area
Field data for this study were collected at the Fort Stanton Experimental Ranch located in the foothill-mountain region between the Sierra Blanca and Capitan Mountains in southern Lincoln County, New Mexico. Elevation of the area is variable, ranging from 1,900 to 2,300 m, with the study pastures at 1,950 m. Mean temperature is 11°C, with a mean maximum of 18.6°C and a mean minimum of 2.2°C. The average frost-free period is 161 days, with average first frost date of 10 October and average last frost date of 2 May. Mean annual precipitation is 35 cm with an average minimum of 2.2°C.

Tannins, CE

Phenolics, (mg/g) 9.6 10.8 11.6 11.2 12.3 12.5 12.0 10.6 12.5 10.4 8.5 11.1 9.4 7.8 5.8 9.9

Tannins, CE

Digestibility (%/h) 3.9 4.0 3.2 5.7 5.1 4.2 4.1 5.1 5.9 6.5 6.9 6.1 3.5 4.8 4.1 4.5

Tannins, CE

Table 1. Botanical and nutritional composition of steer diets from fertilized (F) and nonfertilized (NF) blue grama rangeland during the year of and after fertilization.

<table>
<thead>
<tr>
<th>Item</th>
<th>Sampling periods (year after fertilization)</th>
<th>Sampling periods (year of fertilization)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>NF</td>
</tr>
<tr>
<td>Grasses</td>
<td>38.5</td>
<td>58.8</td>
</tr>
<tr>
<td>Forbs</td>
<td>61.5</td>
<td>41.2</td>
</tr>
<tr>
<td>Organic matter</td>
<td>75.3</td>
<td>75.8</td>
</tr>
<tr>
<td>Neutral detergent fiber</td>
<td>67.7</td>
<td>78.8</td>
</tr>
<tr>
<td>Acid detergent fiber</td>
<td>39.0</td>
<td>60.3</td>
</tr>
<tr>
<td>Acid detergent lignin</td>
<td>13.1</td>
<td>17.7</td>
</tr>
<tr>
<td>Crude protein</td>
<td>26.9</td>
<td>18.1</td>
</tr>
<tr>
<td>Extent of In vitro</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic matter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>digestibility</td>
<td>63.5</td>
<td>47.4</td>
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<tr>
<td>Rate of In vitro</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic matter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digestibility (%/h)</td>
<td>3.9</td>
<td>4.0</td>
</tr>
<tr>
<td>Phenolics, (mg/g)</td>
<td>9.6</td>
<td>10.8</td>
</tr>
<tr>
<td>Tannins, CE</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

1No statistical analyses were conducted on these data.

2Catechin equivalents
Table 2. Ruminal fermentation measurements in steers grazing fertilized (F) and nonfertilized (NF) blue grass pasture the year of and year after fertilization.

<table>
<thead>
<tr>
<th>Item</th>
<th>Sampling periods (year after fertilization)</th>
<th>Sampling periods (year of fertilization)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early August 1983</td>
<td>Late August 1983</td>
</tr>
<tr>
<td>Ruminal pH</td>
<td>F</td>
<td>NF</td>
</tr>
<tr>
<td></td>
<td>6.3</td>
<td>6.2</td>
</tr>
<tr>
<td>Ammonia-N (mg/100ml)</td>
<td>14.9</td>
<td>9.2</td>
</tr>
<tr>
<td>Total VFA, mM</td>
<td>102.0</td>
<td>103.7</td>
</tr>
<tr>
<td>Butyrate</td>
<td>11.5</td>
<td>12.4</td>
</tr>
<tr>
<td>Minor acids</td>
<td>4.8</td>
<td>3.6</td>
</tr>
</tbody>
</table>

*Standard error, n = 16
*Means within trials differ
*Minor acids = isobutyrate + valerate + isovalerate

land-mixing contents. Ruminal pH was measured immediately with a combination electrode, after which samples were strained through 8 layers of cheesecloth, acidified (1 ml 7.2 N H2SO4/100 ml strained fluid) and frozen. After initial sampling, each steer was dosed intraruminally with 200 ml of cobalt ethylenediaminetetraacetic acid solution (CoEDTA; Uden et al. 1980) as a fluid passage marker. Steers were allowed to return to normal grazing activities and rectal grab samples were obtained at 4, 8, 12, and 24 h postdosing. On day 4 of each trial at sunrise (0600-0800 h), each ruminally cannulated steer was dosed intraruminally with its respective portion of Yb-labeled masticate. Dose was placed in the middorsal region of the rumen. Because of variation in amount of masticate ingested by steer and collection time and frozen. Dietary similarities between pastures were calculated using Kulczynski's similarity index (Oosting 1956).

Esophageal samples were collected at sunrise (0600-0800 h) from ruminally cannulated steers grazing study pastures during each trial. Ruminal fluid from 2 steers (randomly paired within a pasture) were composited for the other replication. This compositing scheme was repeated in the adjacent pasture. Extent of in vitro organic matter disappearance (IVOMD) was estimated using the Tilley and Terry (1963) 2-stage technique (48 h rumen fluid, 48 h pepsin digestion on 0.5 g samples in triplicate). Rate of organic matter disappearance (Kd) was calculated using methodology described by Mertens and Loften (1980). Incubation times used for rate analysis were 0, 4, 8, 12, 16, 20, 24, 30, 36, 48, and 72 h.

Condensed tannins were determined on esophageal masticate samples using the vanillin-HCl procedure (Burns 1971) as modified by Price et al. (1978) in which 0.5 g samples were extracted with 1% HCl in methanol for 20 min by manual inversion. Catechin (flavonoid structurally similar to flavonoids in condensed tannins) was used as a standard in this procedure; thus, results were expressed as catechin equivalents. Total phenolic content of esophageal samples was determined by the Folin-Denis procedure (AOAC 1984). The 24-h extraction with 1% HCl in methanol was conducted with 0.5-g samples in a mechanical shaker with continuous shaking.

Ruminal fluid samples were thawed and 40 ml of fluid from each sample was centrifuged at 12,000 X g for 10 min. The supernatant fraction was decanted and an aliquot was analyzed for ammonia concentration by the phenol-hypochlorite procedure of Broderick and Kang (1980). Another aliquot was analyzed for volatile fatty acids by gas chromatography (2-ethylbutyric acid as an internal standard) as described by Goetsch and Galyean (1983). Only ruminal samples collected at 0, 4, 8, and 12 h were analyzed for pH, ammonia, and total volatile fatty acids. An additional aliquot was analyzed for cobalt concentration by atomic absorption spectroscopy using an air/acetylene flame.

Fecal samples were prepared for analysis by boiling ash residues in 3.1 N HCl for 30 minutes. After filtration (Whatman 541) and dilution, the solution was analyzed for Yb content by atomic absorption spectroscopy with a nitrous oxide/acetylene flame. Standards were made in solubilized ash from 0 h collections, and all samples and standards contained 2,000 μg/ml of potassium as an ionization buffer.

Calculations and Statistical Analysis

Fluid passage rate was calculated by regressing the natural logarithm of Co concentration on time postdosing. Fluid volume was collected at sunrise (0600-0800 h) from ruminally cannulated steers grazing study pastures during each trial. Ruminal fluid from 2 steers (randomly paired within a pasture) were composited for the other replication. This compositing scheme was repeated in the adjacent pasture. Extent of in vitro organic matter disappearance (IVOMD) was estimated using the Tilley and Terry (1963) 2-stage technique (48 h rumen fluid, 48 h pepsin digestion on 0.5 g samples in triplicate). Rate of organic matter disappearance (Kd) was calculated using methodology described by Mertens and Loften (1980). Incubation times used for rate analysis were 0, 4, 8, 12, 16, 20, 24, 30, 36, 48, and 72 h.
### Results and Discussion

#### Botanical and Nutrient Composition of Diets

During active growing periods for warm-season grasses (June--September), grass consumption averaged 67% (Table 1). As grasses approached dormancy (October--May), grass consumption decreased to 53%, while dietary forb intake increased from 33 to 47%. Blue grama, sand dropseed, and muhlenbergia species were the primary grasses consumed during the study by steers in both treatment groups. Major forbs consumed were carragh sagewort, scarlet globemallow, and kochia. Kochia consumption was restricted to the growing season, while carragh sagewort utilization occurred primarily during winter dormancy.

Dietary similarities of steers grazing fertilized and nonfertilized pastures were 61% (EJAN83), 73% (LAUG83), 61% (ENOV83), 67% (EJAN84), 90% (MAYM), 81% (LJUL84), 80% (LAUG84), and 87% (LNOVM). The low dietary similarities observed during this study indicate fertilization resulted in dietary shifts in animal selectivity or species availability. These dietary differences between pastures subsequently influenced ruminal fermentation, intake, and digesta kinetic data.

#### Organic Matter Intake (OMI) and Neutral Detergent Fiber (NDF)

Table 3. Organic matter and neutral detergent fiber intake, dry matter fill and fecal output in steers grazing fertilized (F) and nonfertilized (NF) blue grama rangeland during the year of and year after fertilization.

<table>
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</thead>
<tbody>
<tr>
<td>Item</td>
<td>F</td>
<td>NF</td>
<td>SE</td>
<td>F</td>
<td>NF</td>
</tr>
<tr>
<td>Steer weight, kg</td>
<td>374.0</td>
<td>385.0</td>
<td>392.0</td>
<td>413.0</td>
<td>396.0</td>
</tr>
<tr>
<td>Organic matter intake, g/kg BW</td>
<td>23.0</td>
<td>23.6</td>
<td>22.9</td>
<td>25.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Neutral detergent fiber intake, g/kg BW</td>
<td>15.6</td>
<td>18.6</td>
<td>1.1</td>
<td>16.6</td>
<td>20.6</td>
</tr>
<tr>
<td>Estimated dry matter fill, g/kg BW</td>
<td>11.6</td>
<td>23.6</td>
<td>1.8</td>
<td>14.2</td>
<td>18.6</td>
</tr>
<tr>
<td>Fecal output, g/kg BW</td>
<td>8.4</td>
<td>12.4</td>
<td>0.7</td>
<td>10.2</td>
<td>0.6</td>
</tr>
</tbody>
</table>

*Standard error, N = 4*  
*bMeans within trials differ (P<0.05)*

Results and Discussion

During active growing periods for warm-season grasses (June--September), grass consumption averaged 67% (Table 1). As grasses approached dormancy (October--May), grass consumption decreased to 53%, while dietary forb intake increased from 33 to 47%. Blue grama, sand dropseed, and muhlenbergia species were the primary grasses consumed during the study by steers in both treatment groups. Major forbs consumed were carragh sagewort, scarlet globemallow, and kochia. Kochia consumption was restricted to the growing season, while carragh sagewort utilization occurred primarily during winter dormancy.

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Organic matter (OM) percentage of diets did not vary between fertilized and nonfertilized pasture during the year of or year after fertilization (Table 1). These values are consistent with previous studies on fertilized (Cordova 1978, Wallace et al. 1983) and nonfertilized (Thetford et al. 1971, Wallace et al. 1983, Judkins et al. 1985, McCollum et al. 1985) pastures at Fort Stanton, but are lower than those reported from other studies in the western United States (Conner et al. 1983).

Dietary ADF and NDF were not affected by treatment (Table 1) Normally, advancing maturity is associated with increasing fiber constituents (Ulyatt 1981, Van Soest 1982). However, NDF tended to decline with advancing season, during the present study, especially during the year of fertilization, which may reflect selective grazing by the steers. As previously stated, forb consumption increased with advancing season and could explain the decline in NDF. Similar declines in content of fiber constituents were observed by McCollum et al. (1985) for steers grazing comparable nonfertilized blue grama rangeland.

Dietary crude protein levels were numerically higher in the fertilized pasture than in the nonfertilized pasture for each trial (Table 1). In all trials except EJAN84 (nonfertilized pasture) and LNOVM84 (both pastures), dietary crude protein was adequate
(assuming adequate forage consumption) for growing heifers and steers (minimum wt 225 kg) gaining 0.5 kg/day (9.5–10%), lactating cows (9–10%), and heifers (9–11%; NRC 1984). Crude protein levels were, however, sufficient for pregnant cows (7–8%) and yearling heifers (8–9%) during EJAN84 and LNOV84. Crude protein levels declined appreciably with advancing forage maturity.

Generally, as season advanced extent of IVOMD declined (Table 1). Similar trends in digestibility have been reported for nonfertilized (Karn and Lorenz 1983, McCollum et al. 1985) and fertilized (Cordova 1978, Havstad et al. 1979) blue grama rangeland. In contrast, Thetford et al. (1971) did not observe a seasonal decline in IVOMD for either sheep or cattle grazing nonfertilized blue grama rangeland.

Phenolics in excess of 20 mg/g of dry matter can depress nutritious value of forages by reducing voluntary feed intake and decreasing fiber and protein digestibility (McLeod 1974, Robbins 1983, Barry and Reid 1985). Proposed causes of reduced forage intake include decreased palatability (Wilkins et al. 1953, Donnelly 1954) and decreased ruminal and intestinal permeability, which could interfere with nutrient absorption (Mitjavila et al. 1979; as cited by McLeod 1974, Barry and Forrs 1983). Decreased fiber and protein digestibility have been attributed to inhibition of microbial cellulolysis and peptolysis (McLeod 1974, Van Soest 1982, Robbins 1983, Habu et al. 1984, Barry and Reid 1985). Plants containing high amounts of tannins have often been found relatively resistant to degradation in the rumen. Tannins have strong protein-binding properties and may complex with other nutrients and metabolic intermediates (Jung and Fahey 1983). Other workers have suggested rumen microorganisms can readily adapt to phenolic and tannin exposure and alleviate negative effects of these secondary compounds (Van Soest 1982, Robbins 1983, Barry and Reid 1985).

Results of this study indicate cattle grazing blue grama rangeland did not consume phenolic or tannin compounds in quantities sufficient to markedly alter forage intake or digestibility (Table 1). However, during certain times of the year, consumption of plant species with high phenolic or tannin content could alter fermentation and digestion of protein and fiber. Further evaluation of effects of phenolic compounds on OM and digestive physiology of grazing ruminants is needed.

**Ruminal Fermentation Measurements**

Ruminal pH ranged from 5.9 to 6.5 during the study (Table 2). This range is similar to results of McCollum et al. (1985; 6.1 to 6.8) for steers grazing a nonfertilized pasture at Fort Stanton the year before the present study. Under grazing conditions, ruminal pH normally varies from 6.3 to 7.0, because of time spent grazing and digestion of protein and fiber. Further evaluation of effects of phenolic compounds on OM and digestive physiology of grazing ruminants is needed.

**Table 4.** Particulate passage rate and retention time for steers grazing fertilized (F) and nonfertilized (NF) blue grama rangeland during the year of and year after fertilization.

<table>
<thead>
<tr>
<th>Sampling periods (year after fertilization)</th>
<th>Early August 1983</th>
<th>Late August 1983</th>
<th>Early November 1983</th>
<th>Early January 1984</th>
<th>May 1984</th>
<th>Late July 1984</th>
<th>Late August 1984</th>
<th>Late November 1984</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
<td>F</td>
<td>NF</td>
<td>SE</td>
<td>F</td>
<td>NF</td>
<td>SE</td>
<td>F</td>
<td>NF</td>
</tr>
<tr>
<td>Particulate passage rate, %/h</td>
<td>5.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.4</td>
<td>5.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.4</td>
<td>3.7</td>
<td>3.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ruminal retention time, h</td>
<td>23.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>32.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.1</td>
<td>23.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>34.0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.1</td>
<td>32.5</td>
<td>30.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Intestinal transit time, h</td>
<td>12.0</td>
<td>18.0</td>
<td>1.9</td>
<td>13.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.1</td>
<td>15.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21.4&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Standard error, N = 4
<sup>b</sup>Means within trials with different superscripts differ (P<0.05).

**Table 2.** Variation in pH was low across trials. Declining diet quality with advancing season did not result in an increase in ruminal pH, which would be expected if a smaller quantity of VFA were buffered by more saliva associated with increased chewing time and rumination of dormant forages. Results of this study differ from previous work of McCollum et al. (1985) in which ruminal pH increased with advancing season for steers grazing nonfertilized blue grama rangeland.

Molar proportions of individual acids varied with plant maturity with acetate increasing with advancing season (Table 2). This would be expected, because acetate is reflective of cell wall fermentation (Van Soest 1982). Butyrate tended to decline with advancing season (Table 2). Similar shifts in molar proportions of VFA between wet versus dry and growing versus dormant seasons have been observed in grazing ruminants (Topps et al. 1965, Langlands and Sanson 1976, Playne and Kennedy 1976, McCollum et al. 1985). Minor acids (isobutyrate, valerate, isovalerate) varied seasonally, with highest proportions occurring during the growing season and lowest proportions with forage dormancy (Table 2). These minor acids are required by many cellulolytic species in the rumen (Orskov 1982) and may partially explain the concurrent decline in extent of IVOMD noted in the present study.

Fertilization decreased (P<0.05) acetate proportions only during LAUG83 (Table 2). However, fertilization increased (P<0.05) minor acid proportions during all trials except ENOV83 and MAY84 when no difference (P>0.05) was observed and LNOV84 when ruminal fluid from steers grazing nonfertilized pasture contained a higher (P<0.05) proportion of minor acids. Propionate and butyrate levels did not differ (P>0.05) between fertilized and nonfertilized pasture (Table 2).
during EJAN84 and LNOV84 were marginally sufficient for microbial protein synthesis (Table 2). On the other hand, cattle grazing nonfertilized pasture had potentially deficient NH3 levels during ENOV83 (2.2 mg/100 ml), EJAN84 (3.2 mg/100 ml), and LNOV84 (3.0 mg/100 ml) when forage was dormant. Similar ruminal NH3 levels have been reported for cattle grazing nonfertilized blue grama rangeland (McCollum et al. 1985, Funk 1986). These results indicate nonfertilized winter pasture may not contain sufficient N to supply adequate ruminal ammonia levels for optimal microbial growth and metabolism. Biological consequences include decreased rate of ruminal fermentation (Mehrez and Órskov 1976), increased microbial requirements for growth and maintenance as a result of limited substrates for biosynthesis of cellular constituents (Hespell 1979) and a loss of endogenous N from the body resulting in negative N balance. Fermentation of resistant feedstuffs can be adversely affected by insufficient NH3 levels (Tammenga 1979). In addition, Órskov (1982) suggested N requirements for optimum microbial growth are less than requirements for maximum organic matter digestion. Ruminal NH3 concentrations in both pastures in all trials were below the minimum level (>20 mg/100 ml) suggested by Órskov (1982) for maximum digestion.

**Forage Intake**

Voluntary organic matter intake (OMI) was unaffected (P>0.05) by fertilization during any sampling periods except in EJAN84 when intake was greater (P<0.05) for steers grazing fertilized than for grazersing nonfertilized pasture and LNOV84 when intake was greater (P<0.05) for steers grazing nonfertilized pasture (Table 3). These conflicting results may be caused by the larger difference in forage digestibility between pastures in LNOV84 compared with EJAN84 (Table 1). Numerous studies have shown fertilization with various levels of N did not influence forage intake by grazing sheep (Mahoney and Poulton 1962, Holmes and Lange 1963, Reid and Jung 1963, Reid et al. 1966) or cattle (Cordova 1978). However, Odhuda et al. (1965) and Kelsey et al. (1973) noted significant increases in intake for sheep consuming N fertilized forages. Minson (1973) reported a 78% increase in forage intake of sheep grazing N-fertilized tropical pasture. In the present study, organic matter intake by steers averaged 21.8 g OM/kg BW and 21.6 g OM/kg BW across the 8 trials for the fertilized and nonfertilized pastures, respectively. Cordova (1978) reported average year-long intake levels for steers grazing fertilized and nonfertilized blue grama rangeland of 16.6 g OM/kg BW and 18.0 g OM/kg BW, respectively. Similarly, McCollum (1983) reported average year-long intake levels of 18.5 g OM/kg BW for steers grazing nonfertilized blue grama rangeland. Rosiere et al. (1980) reported intake estimates for lactating and nonlactating 2-yr-old cows grazing blue grama rangeland during the summer of 21.0 g OM/kg BW and 14.0 g OM/kg BW, respectively.

In the present study, intake declined with advancing season, which is consistent with earlier studies on blue grama rangeland in New Mexico (Cordova 1978, McCollum and Galyean 1985b) and Nebraska sandhills (Powell et al. 1982). Steers grazing the fertilized pasture during the year after fertilization experienced an OMI decline of 16% from the EAUG83 and LAUG83 to ENOV83 and EJAN84 sampling periods, while a decrease of 22% was observed in the nonfertilized pasture over the same time period. In contrast, during the year of fertilization, OMI declined 33% fertilized pasture from MAY84 through LNOV84, while only a 5% decrease was observed in nonfertilized pasture for the same period.

Neutral detergent fiber intake (NDFI) estimates were variable with no consistent trends noted between fertilized and nonfertilized pastures during the year of or year after fertilization (Table 3). Neutral detergent fiber intake declined with advancing season, as would be expected with the observed decline in OMI and decrease in dietary NDF. Previous forage studies suggest cell wall content limits intake when proportion of cell wall exceeds 50-56% of the dry matter (Van Soest 1965). Diet sampled collected during this study contained in excess of 60% NDF and NDFI declined with advancing season within each pasture supporting the concept that NDF is a major factor limiting forage intake.

Fecal output (FO) varied from a low of 5.6 to a high of 12.4 g/kg BW across all sampling trials and treatments (Table 3). Kahn and Spedding (1984) and McCollum and Galyean (1985b) reported a similar range of FO estimates for cattle grazing rangeland. The variation in FO observed during this study could be the result of a combination of expanded gut capacity and botanical components consumed during these sampling periods. Freer (1981) and Kahn and Spedding (1984) postulated gut capacity would increase in response to prolonged consumption of low-quality forage in order to maintain the same intake of metabolizable energy, but only up to a point associated with critical distension of the alimentary tract during eating. Examination of data revealed that generally when gut fill was greatest (Table 3), steer diets contained predominantly grasses (Table 1). The ease and manner in which forb material fragments during comminution might enable digesta to pack more densely in the gastrointestinal tract and allow for increased fill with high-forb diets (Ingalls et al. 1966, Troelson and Campbell 1968). However, during the present study, gut fill estimates were generally lowest during sampling periods when steers consumed high-forb diets. The rate of digestion of forbs which is generally faster than other forage components may compensate for the packing density effect and result in minimal change in gut fill estimates.

### Table 5. Ruminal fluid passage rate, volume and turnover rate and time for steers grazing fertilized (F) and nonfertilized (NF) blue grama rangeland during the year of and year after fertilization.

<table>
<thead>
<tr>
<th>Item</th>
<th>Sampling periods (year after fertilization)</th>
<th></th>
<th>Sampling periods (year of fertilization)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early August 1983</td>
<td>Late August 1983</td>
<td>Early November 1983</td>
<td>Early January 1984</td>
</tr>
<tr>
<td>Fluid passage rate, %/h</td>
<td>F</td>
<td>NF</td>
<td>SE</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>10.6</td>
<td>11.8</td>
<td>1.0</td>
<td>11.2</td>
</tr>
<tr>
<td>Fluid volume, liters/kg BW</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Fluid turnover rate, liters/hr</td>
<td>3.6</td>
<td>5.7</td>
<td>0.8</td>
<td>5.8</td>
</tr>
<tr>
<td>Fluid turnover time, h</td>
<td>9.4</td>
<td>8.5</td>
<td>1.4</td>
<td>8.9</td>
</tr>
</tbody>
</table>

*Standard error, n = 4.*

*Means within trials with different superscripts differ (P<.05)*
**Passage Rate Estimates**

Particulate passage rate (PPR) was faster in steers grazing fertilized pasture during LAUG83 ($P<0.05$), EJAN84 ($P<0.05$), and LAUG84 ($P<0.05$) than in steers grazing nonfertilized pasture. However, no differences ($P>0.05$) were noted in PPR during the remaining sampling periods (Table 4). In general, PPR declined in both fertilized and nonfertilized pastures with advancing season, which would be expected because there was a concurrent increase in undigested residues in the gut which was reflected in increased gut fill (Table 3) and lower organic matter digestion with advancing season (Table 1). Increased PPR was associated with decreased ruminal retention time (RRT) and intestinal transit time (ITT). Ruminal retention time was decreased ($P<0.05$) in steers grazing fertilized compared with nonfertilized pasture during the year after fertilization for the EAUG83, LAUG83, and EJAN84 trials. Similarly, during the year of fertilization, steers grazing fertilized rangeland had decreased ($P<0.05$) RRT and LAUG84 compared with steers grazing nonfertilized rangeland (Table 4). Ruminal retention time averaged 30.7 h and 35.9 h across the 8 trials for the fertilized and nonfertilized pastures, respectively. McCollum (1983) reported similar RRT (34.6 h) for cattle grazing nonfertilized blue grama rangeland. Likewise, average ITT for the present study was faster for steers grazing fertilized (14.1 h) versus nonfertilized (17.6 h) pastures. Intestinal transit time was lower ($P<0.05$) in steers grazing fertilized compared with nonfertilized rangeland during LAUG83, ENOV83 and EJAN84 (Table 4). No differences ($P>0.05$) were noted for other trials.

Organic matter intake in the fertilized pasture across both years showed a negative relationship with RRT ($r = -0.51$, $P<0.05$) and ITT ($r = -.58$, $P<0.05$). Likewise, OMI in the nonfertilized pasture across years showed a negative relationship with RRT ($r = -.50$, $P<0.05$) and ITT ($r = -.38$, $P<0.05$). In addition, dry matter intake was negatively correlated to PPR for both fertilized ($r = -.68$, $P<0.10$) and nonfertilized ($r = -.37$, $P<0.05$) pastures. These data indicate declines in OMI with advancing season are associated with dietary factors, slower PPR and increased gastrointestinal dry matter fill.

Fluid passage rate (FPR), and fluid turnover time were unaffected ($P>0.05$) by fertilization except during the LAUG84 period when FPR was faster ($P<0.05$) in steers grazing fertilized versus nonfertilized pasture (Table 5). During the year after fertilization, no differences ($P>0.05$) were noted in fluid volume and turnover rate, but some minor differences were observed during the year of fertilization (Table 5). The FPR observed in the present study were generally higher for diets consumed by steers grazing fertilized as compared with those grazing nonfertilized rangeland. Similary, fertilization increased digestibility during the growing season but digestibility was depressed by fertilization during dormancy. Results from this study indicate steers grazing N fertilized rangeland had increased ruminal pH and NH3 levels throughout the year, but fertilization had little effect on VFA proportions when compared with nonfertilized rangeland.

Nitrogen fertilization (year after application) of blue grama rangeland had a minimal effect on voluntary forage intake. However, fertilization generally increased forage digestion and PPR. Correspondingly, RRT and ITT were reduced in steers grazing fertilized blue grama rangeland. During the year of N fertilization, voluntary forage intake was increased during growing season but was depressed during dormancy. Fertilization generally increased PPR and decreased RRT and ITT.

**Literature Cited**


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35-Year Index, Journal of Range Management, edited by Elbert H. Reid. $10.00
Plants That Poison, by E.M Schmutz and L.B. Hamilton. $9.95
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