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Growth performance, ruminal fermentation profiles, and carcass characteristics of beef steers grazing tall fescue without or with nitrogen fertilization[1]

C. T. Noviandi,* B. L. Waldron,† J.-S. Eun,*[2] D. R. ZoBell,* R. D. Stott,* and M. D. Peel†
*Department of Animal, Dairy, and Veterinary Sciences, Utah State University, Logan 84322-4815; and †Forage and Range Research Laboratory, USDA-ARS, Logan, UT 84322

ABSTRACT

A 2-yr study was conducted to evaluate the effects of finishing beef cattle grazed on tall fescue (TF) pastures without or with N fertilization on growth performance, ruminal fermentation, and carcass characteristics. In each grazing season, 18 Angus crossbred steers were arranged in a completely randomized design with repeated measures on the following 2 treatments: TF without N fertilizer (TF–NF) and TF with N fertilizer (TF+NF). Three replicated pastures with 3 steers per replicate were assigned to each treatment. A total of 168 kg/ha N fertilizer was applied in 3 split applications at 56 kg/ha each to the TF+NF in each grazing season. Steers rotationally grazed on 0.47-ha pasture for 7 d with a 28-d rotation interval for a total of 16 wk. Body weight data and pasture forage samples were collected every 4 wk, whereas ruminal fluid was collected at wk 4, 10, and 16. After the completion of 16-wk grazing, ultrasound measurement was performed to assess carcass characteristics. In response to N fertilization, greater CP concentration was detected on TF+NF compared with TF–NF in 2011 (11.9 vs. 10.6% DM, respectively; $P < 0.01$). Overall ADG was greater in steers that grazed TF+NF pastures ($P < 0.05$) in the 2-yr grazing seasons, and tended to increase ($P = 0.07$) overall DMI and G:F in 2010. Regardless of N fertilization, ADG peaked between wk 4 and 8 (1.05 kg/d; $P < 0.01$), and then declined until wk 16. A gradual decline of G:F was noticed with progression in grazing seasons ($P < 0.05$). Greater total VFA concentrations were detected in ruminal fluid of steers that grazed TF+NF ($P < 0.01$), but a minor effect was shown on individual VFA (acetate, propionate, and butyrate) concentrations and acetate-to-propionate ratio. Ruminal ammonia-N (NH_3-N) concentration increased ($P < 0.01$) with N fertilization, whereas NH_3-N:total VFA increased ($P < 0.01$) with the progression of grazing seasons. Backfat thickness, ribeye area, and intramuscular fat concentration did not differ between treatments. Overall results of this study indicate that N fertilization on TF affected ruminal fermentation which positively influenced growth performances, but did not affect carcass characteristics of grazing beef steers. In addition, readily fermentable carbohydrate supplementation is needed to improve utilization of increased dietary CP due to N fertilization and consequently enhance growth performances of grazing steers.

Key words: grazing beef steer, growth performance, nitrogen fertilization, ruminal fermentation, tall fescue

INTRODUCTION

Tall fescue (**TF**; *Festuca arundinacea Schreb.*) is a coarse-textured grass, and it is considered a moderately

[1] Approved as Journal Paper Number 8428 of the Utah Agricultural Experiment Station, Utah State University, Logan.
[2] Corresponding author: jseun@usu.edu

drought-tolerant turfgrass because of its deep root system (Christians, 2004). This forage has a broad range of adaptation due to its tolerance to periodic drought, low soil fertility, and fluctuating seasonal temperatures, and thus it is a popular pasture grass in the Intermountain West (i.e., Utah, Idaho, Wyoming, Montana, and parts of Arizona and Nevada). Although TF tolerates low soil fertility, N fertilization increases biomass production and N concentration of TF (Berg and Sims, 2000; Teuton et al., 2007) and positively affects beef cattle performance (Berg and Sims, 1995). Wolf and von Boberfeld (2003) reported that application of N fertilizer in 2 split applications resulted in greater CP concentration of TF, and its effect was cumulative, causing a greater rate of CP increase at later N application.

When N fertilization improves biomass production and N concentration of TF, the process demands energy and leads to less concentrations of nonfibrous carbohydrates (**NFC**), leading to increased fiber concentration and decreased digestibility. For example, Peyraud et al. (1997) reported that N fertilizer treatment increased NDF and ADF concentration from 50 to 53% and 25 to 28%, respectively, whereas Probasco and Bjugstad (1980) found that IVDMD decreased from 63 to 60% due to N fertilization. On the contrary, greater NDF degradations were reported when pasture grasses were fertilized with N fertilizer (Valk et al., 1996; Galdámez-Cabrera et al., 2003; Nordheim-Viken and Volden, 2009). Forages containing high CP concentrations are often considered to supply the CP required by rapidly growing ruminants, but its utilization efficiency depends on several factors such as carbohydrate availability. Berg and Sims (1995) indicated that steer BW gain per hectare during the 4 summer grazing periods increased with N fertilization at rates up to 68 kg N/ha when animals grazed Old World Bluestem (*Bothriochloa ischemum*) pasture. Increase in BW gain as a response to N fertilization on pasture may have resulted from increases in forage production and ADG. Berg and Sims (2000) also reported that BW gain of steers responded linearly to N fertilization up to 102 kg N/ha per year with an increase of BW gain from 185 to 505 kg/ha. In the rumen, N fertilized grasses increased ruminal ammonia-N (**NH_3-N**) concentration as a result of increasing CP concentration (Peyraud et al., 1997; Valk et al., 2000). When applied on perennial ryegrass (*Lolium perenne*), N fertilizer increased total VFA concentration with greater proportion of acetate, less proportion of butyrate, and similar proportion of propionate (Peyraud et al., 1997). By increasing both NH_3-N and total VFA, an improvement of animal growth performance can be expected, as a result of greater protein-energy efficiency between NH_3-N and VFA.

Research on forage quality and animal performance often focuses on improving forage yield and N utilization efficiency in pastures. Much is known about fertilizer type, amount, and timing of application for maximizing crop yield. However, major gaps still exist in our knowledge of the relationships between application of N fertilizer to pasture grasses and its impacts on the ruminal fermentation profiles and growth performance of beef steers. The objective of this grazing study was to test the overall hypothesis that fertilizing TF with N would improve the ruminal fermentation profiles, and thus positively influence growth performance and carcass quality of beef steers.

MATERIALS AND METHODS

This study was conducted under the approval of the Institutional Animal Care and Use Committee at Utah State University, and the animals were cared for according to its guidelines.

Grazing was completed at Utah State University Pasture Research Farm (Lewiston, UT) from May through September in each year of study in 2010 and 2011. Prior to grazing, all steers were administered with brucellosis vaccination, parasite treatment (Dectomax, Pfizer Animal Health, Exton, PA), 8-way Clostridial vaccine (Pfizer Animal Health), and an intranasal respiratory product (BoviShield, Pfizer Animal Health). In addition, animals were implanted with Ralgro (36 mg of Zeranol, Schering Plough, Madison, NJ).

Animals and Experimental Design

Eighteen Angus crossbred steers (402 ± 9.9 and 379 ± 7.9 kg of BW in 2010 and 2011, respectively) were allocated to 1 of 2 treatments in a completely randomized design: TF without N fertilizer (**TF−NF**) and TF with N fertilizer (**TF+NF**), with 3 replications per treatment and 3 steers per paddock. A total of 168 kg/ha N fertilizer was applied in 3 split applications at 56 kg/ha to the TF+NF in each study year. Each 0.47-ha treatment pasture was divided evenly into 4 paddocks (approximately 0.12 ha/paddock), with a single strand of polywire electrified by a battery-powered fence charger. Three steers were allotted to each paddock with a pasture allowance of 215 kg of DM per paddock. Pasture availability was continuously monitored on a daily basis to ensure sufficient forages for 3 steers in each paddock. Grazing seasons lasted for 118 d (May 27 to September 21, 2010) and 120 d (May 25 to September 21, 2011). Pastures were managed under rotational stocking during the grazing seasons. Each paddock was grazed for 7 d, and then the same paddock was rested for 21 d until wk 12. However, starting on wk 13 in 2010 and wk 14 in 2011, each paddock was grazed for 3 to 5 d, and then it was rested for 9 to 15 d until the end of grazing study due to availability of forage. All animals were rotated to new paddocks between 0900 and 1000 h. All steers had ad libitum access to fresh water and mineral supplement (Right Now Emerald, Cargill Animal Nutrition, Minneapolis, MN), and were weighed every 4 wk to determine BW (Figure 1).

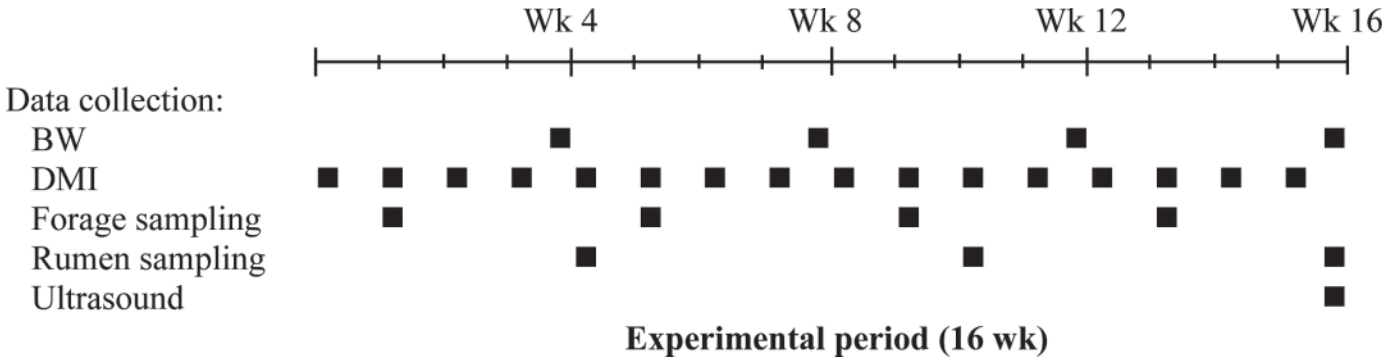

Figure 1. Experimental period and sampling schedule in 2010 and 2011.

Determination of DMI and Pasture Sampling and Analysis

Pasture yield was estimated using rising plate meter (**RPM**; 3 Research Park UMC, Columbia, MO) on a weekly basis. Seven measurements were obtained on each paddock at pre- and postgrazing to determine the total DMI per paddock. Pasture sampling for DM yield calibration was done every 4 wk on each paddock (Figure 1). Due to differences in pastures, weather, and environment, the total DM yield (DM_{yield}) per paddock was calculated by using the modified equation according to the methodology supplied by the manufacturer as follows: $DM_{yield} = RPM_{average} \times DM_{cal} \times Area_{paddock}$, where $RPM_{average}$ = average of RPM height (cm), DM_{cal} = DM yield calibration per quadrat (g/cm), and $Area_{paddock}$ = area of paddock on each week (1,165 m^2). Pasture intake was measured according to the herbage disappearance method based on the difference between pre- and postgrazing herbage mass (Lantinga et al., 2004). Intake of DM (g/kg BW) was estimated by using the equation: DMI (g/kg BW) = {(pasture intake ÷ 3 cows) ÷ BW} × 1,000.

Pasture forage samples were collected at 4-wk intervals throughout the study, beginning at approximately 0900 h. Forage samples were collected from the paddocks where the steers were grazing by clipping 6 quadrats of 0.102-m^2 each during the grazing period. Clippings were made at the same time of the day, approximately 0900 h on the first day of grazing. Pastures were clipped at 2 to 3 cm above ground level with the aid of a battery-powered portable mower (SSC 1000, Black & Decker Inc., Towson, MD), and care was taken to avoid soil contamination. Samples were placed in paper bags and immediately transported to the laboratory. Samples were weighed, dried at 60°C for 48 h, ground to pass a 1-mm screen (standard model 4; Arthur H. Thomas Co., Swedesboro, NJ), and stored for subsequent analyses. Analytical DM and OM concentration of samples was determined by oven drying at 105°C overnight and by ashing at 550°C, respectively, whereas N concentration was determined using an elemental analyzer (LECO TruSpec N, St. Joseph, MI; AOAC, 2000). The NDF and ADF concentrations were sequentially determined using an Ankom$^{200/220}$ Fiber Analyzer (Ankom Technology, Macedon, NY) according to the methodology supplied by the company, which is based on the methods described by Van Soest et al. (1991). Sodium sulfite was used in the procedure for NDF determination, and pretreatment was performed with heat stable amylase (type XI-A from *Bacillus subtilis*; Sigma-Aldrich Corporation, St. Louis, MO).

Analysis of Ruminal Fluid and Carcass Characteristics

Ruminal fluid samples were obtained using Geishauser probe at wk 4, 10, and 16 (Figure 1). The fluid was collected with a solid, tube-like probe with rows of small holes on the end (Geishauser, 1993). The pH of the ruminal fluid was measured within 5 min of collecting the samples using a portable pH meter (Oakton pH 6; Oakton Instruments, Vernon Hills, IL). Five milliliters of the ruminal fluid was mixed with 1 mL of 1% sulfuric acid and stored frozen (−40°C) for NH_3-N analysis. Concentration of NH_3-N in the ruminal contents was determined as described by Rhine et al. (1998), using a plate reader (MRX^e, Dynex Technologies, Chantilly, VA). Another 5 mL of the ruminal fluid were collected and added with 1 mL of 25% meta-phosphoric acid, and then stored at −40°C for VFA determination. Ruminal VFA were separated and quantified using a GLC (model 6890 series II, Hewlett Packard Co., Avondale, PA) with a capillary column (30 m × 0.32 mm i.d., 1 µm phase thickness, Zebron ZB-FAAP, Phenomenex, Torrance, CA) and flame-ionization detection. The oven temperature was held at 170°C for 4 min, increased to 185°C at a rate of 5°C/min, then increased by 3°C/min to 220°C and held at this temperature for 1 min. The injector and the detector temperatures were 225 and 250°C, respectively, and the carrier gas was helium (Eun and Beauchemin, 2007).

At the end of the grazing season, all steers were scanned using ultrasound (Aloka SSD-500V, Wallingford, CT) to determine the carcass characteristics (backfat thickness, ribeye area, and intramuscular fat concentration) using proprietary analysis software (Brethour 1991, 1992).

Statistical Analysis

Data were analyzed using the GLIMMIX procedure of SAS (SAS Institute Inc., Cary, NC). All data were assessed using a one-way ANOVA in a completely randomized design. Paddocks were considered as the experimental units. The model included the fixed effects of treatment, sampling week, and treatment × week interaction. The replication within treatment was considered as random effect. Data collected in 2-yr grazing seasons were analyzed separately by each year, because the weather and environmental conditions were different between the years. In addition, due to variations in nutritive composition of pastures during the 16-wk study, data of animal growth performance and ruminal fermentation profiles from each year were also compared within week. All means reported are least squares means. Pair-wise comparisons and contrasts were used to compare effects of treatment, sampling week, and interaction effects. In all cases, significant effects were declared at $P < 0.05$, and trends were discussed at $P < 0.10$.

RESULTS AND DISCUSSION

Nutrient Composition of TF Pastures

In both 2010 and 2011 grazing seasons, N fertilization did not show any effect on the DM of TF pasture, but increasing DM of TF pasture ($P < 0.01$) from wk 4 to wk 16 (averaged 18.6 and 25.4%, respectively) was noticed in both grazing years (Table 1). A year effect was detected ($P < 0.01$) on pasture DM, with less DM in 2011 compared with that in 2010 (20.0 vs. 24.5%) due to greater precipitation during the grazing season (May to September) in 2011 (3.0 vs. 1.5 cm, data not presented). However, there was no interaction effect between treatment and week in 2010 and 2011.

Numerically, N fertilization always resulted in greater CP, but did not significantly affect the CP concentration of TF pasture in 2010. In contrast, greater CP concentration was detected on TF+NF compared with TF−NF in 2011 (averaged 11.9 vs. 10.6% DM, respectively; $P < 0.01$; Table 1). No significant effect on CP in response to N fertilization on TF pasture in 2010 is likely to be caused by residual N in the soil, which would be often the case for the seedling year. This condition may dilute the overall effects of applying N fertilizer on TF pasture (Noviandi et al., 2011). Peyraud and Astigarraga (1998) stated that a greater dilution of grass CP contents may occur on highly fertilized pastures, which was related to the enhancement of sward mass production. In contrast, an accumulative effect of N fertilization in 2011 increased the CP concentration of TF+NF. There is a body of evidence to indicate changes in forage composition due to N fertilization and its accumulative effect from multiple applications (Wolf and Boberfeld, 2003; Teuton et al., 2007; Pecetti et al., 2008). The accumula-

Table 1. Nutrient concentration (% of DM) of tall fescue grass (n = 3)

Week and treatment[1]	2010						2011					
	DM, %	CP	EE[2]	NDF	ADF	NFC[3]	DM, %	CP	EE	NDF	ADF	NFC
Wk 4												
TF−NF	20.5	12.5	1.60	57.3[b]	30.1	14.4[a]	18.4	11.5[b]	3.69	54.3	30.3	17.5
TF+NF	19.1	13.0	1.65	59.3[a]	31.3	11.6[b]	16.4	12.7[a]	4.19	54.3	30.4	15.6
Average	19.8[f]	12.7[c]	1.63[d]	58.3[e]	30.7[e]	13.0[c]	17.4[e]	12.1[c]	3.94[d]	54.3[d]	30.3[d]	16.6[c]
Wk 8												
TF−NF	22.4	9.1	2.87	62.2	33.4	10.8	20.7	11.9[b]	4.23	56.0	32.3	11.8
TF+NF	22.8	10.2	2.95	63.2	34.1	10.1	19.3	13.3[a]	4.31	56.1	32.3	11.0
Average	22.6[e]	9.6[d]	2.91[c]	62.7[d]	33.7[d]	10.4[d]	20.0[d]	12.6[c]	4.27[d]	56.0[d]	32.3[c]	11.4[d]
Wk 12												
TF−NF	26.3	10.9	2.89	65.3[b]	35.6	6.4[a]	23.0	11.4[b]	5.41	59.2	32.5	8.6
TF+NF	24.0	12.1	3.14	67.0[a]	36.7	4.6[b]	22.0	12.5[a]	5.21	59.8	32.7	7.7
Average	25.1[d]	11.5[c]	3.02[c]	66.1[c]	36.1[c]	5.5[e]	22.5[c]	11.9[c]	5.31[c]	59.5[c]	32.6[c]	8.2[e]
Wk 16												
TF−NF	30.3	7.3	2.86	63.9	33.4	11.4[a]	20.6	7.6[b]	5.25	54.3	30.3	17.9
TF+NF	30.8	9.8	3.01	64.1	33.7	9.8[b]	19.9	9.1[a]	5.47	54.3	30.4	17.0
Average	30.6[c]	8.6[d]	2.94	64.0[d]	33.5[d]	10.6[d]	20.3[d]	8.4[d]	5.36[c]	54.3[d]	30.3[d]	17.5[c]
Pooled SEM	0.70	0.68	0.157[c]	0.51	0.41	0.40	0.69	0.31	0.167	0.82	0.50	0.72

[a,b]Within a column and week, means with different superscripts are different ($P < 0.05$).

[c–f]Within a column, averages with different superscripts are different ($P < 0.01$).

[1]TF−NF = tall fescue without N fertilizer; TF+NF = tall fescue with N fertilizer.

[2]Ether extract.

[3]Nonfibrous carbohydrate = 100 – (CP + NDF + EE + ash).

tive effect of N fertilization in this study was apparent in the differences of CP concentration between TF−NF and TF+NF from wk 4 to 16 that gradually increased in 2010 as grazing progressed (0.5, 1.1, 1.3, and 2.5 percentage units at wk 4, 8, 12, and 16, respectively). However, the differences of CP concentration between the treatments were relatively stable during 2011 grazing season (1.2, 1.4, 1.2, and 1.5 percentage units at wk 4, 8, 12, and 16, respectively). The gradual increase in CP concentration differences between treatments in 2010 indicates that by applying 168 kg N/ha in 3 different times on TF contributed to increasing CP concentration of TF in a cumulative manner. Similarly, Wolf and von Boberfeld (2003) observed the accumulative effect of N fertilization on CP concentration of TF when 50 kg N/ha were applied at 2 different times, but the authors reported no cumulative effects of CP concentration on TF when more than 100 kg N/ha were applied. In addition to the rate of N fertilization, its application frequency may affect the accumulative effect of N fertilization. For instance, Wolf and von Boberfeld (2003) applied 100 kg N/ha in 2 applications, whereas we applied 168 kg N/ha at 3 times.

Nitrogen fertilization resulted in greater NDF concentration in 2010, but it did not influence NDF concentration in 2011 (Table 1). Concentration of ADF between treatments was similar in both grazing seasons. However, greater NDF and ADF concentrations of TF pasture in 2010 were detected ($P < 0.01$) compared with those in 2011. The difference in NDF concentration caused by N fertilization in 2010 is likely due to differences in growth rates of TF pastures. Nitrogen fertilization increases the DM yield of TF through accelerating growth rate (Read and Hipp, 1998). Rapid growth of plants demands high energy input, which typically leads to less NFC retention in the plant tissue. In our study, fiber concentrations peaked on wk 12 ($P < 0.01$), whereas NFC concentrations were the lowest on wk 12 (6.4 and 4.6% to TF−NF and TF+NF, respectively; $P < 0.01$). This decrease in NFC concentration is attributable to an increase in the utilization of carbon chains for protein synthesis and for production of the energy required for the nitrate reduction step before protein synthesis (Peyraud and Astigarraga, 1998).

Growth Performance of Steers

Intake of DM (g/kg BW) of the grazing steers did not differ between fertilized and unfertilized TF pastures in either year except wk 8 of 2010 when steers grazing TF+NF showed increased DMI compared with the nonfertilized (Table 2). In addition, overall DMI in 2010 tended to increase ($P = 0.07$) on TF+NF compared with TF−NF (19.4 vs. 18.1 g/kg BW). The tendency of increasing overall DMI on TF+NF may be related to greater NDF degradation rate due to N fertilization. In in situ studies using pastures, N fertilizer application increased NDF degradation on bromegrass (*Bromus inermis*; Messman et al., 1991), perennial ryegrass (Valk et al., 1996), bermudagrass (*Cynodon dactylon*; Galdámez-Cabrera et al., 2003), and timothy grass (*Phleum pratense*; Nordheim-Viken and Volden, 2009). Greater DMI of TF+NF at wk 8 in 2010 compared with TF−NF may be associated with the time of N fertilization. Messman et al. (1991) reported that greater NDF degradation occurred when N fertilizer was applied in the early stage of growth, which would increase DMI of grazing steers. In contrast, N fertilization did not affect overall DMI in 2011. With progression of the grazing season, DMI gradually decreased from 21.7 to 14.7 g/kg BW and from 23.1 to 19.0 g/kg BW in 2010 and 2011, respectively ($P < 0.01$). The decreasing trend of DMI is likely induced by the decreasing NFC concentration of TF during the grazing seasons. Peyraud et al. (1997) reported that DMI decreased as soluble carbohydrates decreased. This result may be related to a shortage of soluble carbohydrate in the rumen, which may limit microbial activities, thus increasing rumen fill and consequently limiting pasture intake. High concentration of cell wall contents can suppress microbial activity by reducing the availability of rapidly fermentable carbohydrates (Wilson and Hatfield, 1997). Similarly, lignification limits microbial access to structural polysaccharides in the cell wall, resulting in slower digestion and decrease in DMI (Waghorn and McNabb, 2003).

Although ADG did not differ between TF−NF and TF+NF at wk 4, 8, 12, and 16 in 2010, it increased on the TF+NF pastures at wk 4 in 2011 (Table 2). In both grazing years, overall ADG increased by steers grazed with TF+NF compared with those grazed with TF−NF ($P < 0.05$). The positive effect of N fertilizer on overall ADG may have resulted from increased ruminal fermentation evidenced by increased VFA concentration with N fertilization as discussed later. Regardless of N fertilization, maximum ADG of grazing steers was achieved at wk 4 and 8 in both grazing years (averaged 1.05 kg/d; $P < 0.01$), and then declined until the completion of this grazing study. The gradual decrease of ADG during later phases in the grazing season is likely due to increased energy demand of rapidly growing steers that could not be met by available energy in TF pasture. As shown in Table 1, NFC concentration in our study decreased by 8.0 percentage units on average from wk 4 to 12 in both grazing seasons. Wolf and von Boberfeld (2003) reported that the energy concentration of TF decreased throughout the grazing season.

Nitrogen fertilization did not affect G:F at any week in 2010 and 2011, whereas steers grazed with TF+NF tended to increase overall G:F ($P = 0.07$) compared with those grazed with TF−NF in 2010, but they had similar overall G:F in 2011. In 2010 and 2011, G:F gradually decreased ($P < 0.01$) with progression in grazing season. Increased overall ADG in response to N fertilization in 2010 supported increased overall G:F of steers grazed TF+NF. As discussed previously, lack of energy availability in TF

Table 2. Effect of N fertilization of tall fescue on growth performance of grazing beef steers (n = 3)

Week and treatment[1]	2010 DMI, g/kg BW	2010 ADG, kg/d	2010 G:F	2011 DMI, g/kg BW	2011 ADG, kg/d	2011 G:F
Wk 4						
TF−NF	21.1	1.06	0.148	22.5	0.87[b]	0.097
TF+NF	22.3	1.06	0.158	23.6	1.22[a]	0.125
Average	21.7[c]	1.06[cd]	0.153[c]	23.1[c]	1.04[c]	0.111[c]
Wk 8						
TF−NF	19.1[b]	1.09	0.126	22.7	0.87	0.090
TF+NF	21.6[a]	1.23	0.143	23.0	1.05	0.102
Average	20.3[c]	1.16[c]	0.135[cd]	22.8[c]	0.96[c]	0.096[c]
Wk 12						
TF−NF	17.7	0.85	0.111	21.1	0.77	0.082
TF+NF	19.0	1.06	0.133	20.7	0.83	0.085
Average	18.3[d]	0.95[de]	0.122[d]	20.9[d]	0.80[cd]	0.084[cd]
Wk 16						
TF−NF	14.5	0.79	0.121	18.8	0.58	0.066
TF+NF	14.9	0.90	0.135	19.1	0.61	0.065
Average	14.7[e]	0.85[e]	0.128[cd]	19.0[e]	0.59[d]	0.065[d]
Wk 4 to 16[2]						
TF−NF	18.1	0.95[h]	0.126	21.3	0.77[h]	0.084
TF+NF	19.4	1.06[g]	0.142	21.6	0.93[g]	0.094
Pooled SEM	0.66	0.059	0.0101	0.66	0.084	0.0103

[a,b]Within a column and week, means with different superscripts are different ($P < 0.05$).

[c–e]Within a column, averages with different superscripts are different ($P < 0.05$).

[g,h]Within a column, means with different superscripts are different ($P < 0.05$).

[1]TF−NF = tall fescue without N fertilizer; TF+NF = tall fescue with N fertilizer.

[2]Comparison between TF−NF and TF+NF in overall 16 wk of study.

pastures led to decreased G:F with the progression of grazing seasons.

Ruminal Fermentation Profiles

Ruminal pH ranged from 6.85 to 7.21, and it was not affected by N fertilization (Table 3). Steers that grazed TF+NF pastures had greater total VFA concentration at wk 10 and 16 in 2010 and at all weeks in 2011 ($P < 0.01$). Greater concentration of total VFA on TF+NF compared with TF−NF may have resulted from enhanced ruminal fermentation, particularly the NDF fraction. Messman et al. (1991) and Valk et al. (1996) indicated that rate of degradation of cell walls increased with N fertilization. Peyraud et al. (1997) reported that a high level of N fertilization (80 kg N/ha/cut) to perennial ryegrass increased NDF concentration in pasture and digestibility by lactating dairy cows, which resulted in increased total VFA concentration. The increase in total VFA concentration due to N fertilization on TF pasture was consistent in 2010 and 2011 in our study. The positive effect on ruminal fermentation may have contributed to the improved animal growth performance of steers grazed with TF+NF, providing more precursors toward BW gain and consequently resulting in increased overall ADG and G:F.

There were minor effects of N fertilization on molar proportions of individual VFA (acetate, propionate, and butyrate) and acetate:propionate in both grazing seasons (Table 3). However, increased propionate proportion by N fertilization ($P < 0.05$) was detected at wk 16 and 4 in 2010 and 2011, respectively. In addition, less acetate:propionate on TF+NF compared with TF−NF was noticed at wk 4 in 2011.

Steers that grazed TF+NF had greater ruminal NH_3-N concentration ($P < 0.01$) compared with steers that grazed TF−NF at wk 4 and 16 in 2010 and at all weeks in 2011 (Table 3). Regardless of N fertilization, NH_3-N concentration gradually increased ($P < 0.01$) with the progression of grazing season in 2010 and 2011. Grass under grazing conditions is usually in vegetative stage, which contains high amounts of rapidly rumen-degradable N fraction (Valk et al., 2000). Applying N fertilizer on TF further influenced dietary N utilization in the rumen as indicated by increased NH_3-N concentrations throughout grazing in our study. Greater ruminal NH_3-N concentration of TF+NF compared with TF−NF during 2-yr grazing seasons implies that dietary N utilization in the rumen was less efficient. Concentration of dietary CP can influence microbial activity, as RDP

Table 3. Effect of N fertilization of tall fescue on ruminal pH, VFA profile, and ammonia-N (NH_3-N) concentrations of grazing beef steers (n = 3)

	2010								2011							
			Individual VFA[3]								Individual VFA					
Week and treatment[1]	pH	Total VFA[2]	A	P	B	A:P	NH_3-N[4]	NH_3:VFA[5]	pH	Total VFA	A	P	B	A:P	NH_3-N	NH_3:VFA
Wk 4																
TF−NF	7.15	58.0	68.7	18.3	8.37	3.80	6.03[b]	0.061	6.99	58.4[b]	71.4	15.3[b]	9.66	4.68[a]	5.56[b]	0.056
TF+NF	7.15	60.8	67.8	18.3	8.78	3.71	8.47[a]	0.082	6.85	69.4[a]	70.7	17.2[a]	9.10	4.12[b]	7.80[a]	0.066
Average	7.15	59.4[cd]	68.3[d]	18.3[c]	8.58[d]	3.76[d]	7.25[e]	0.071[e]	6.92	63.9[cd]	71.0	16.2	9.38[c]	4.40	6.68[d]	0.061[d]
Wk 10																
TF−NF	7.21	55.0[b]	71.3	16.7	7.90	4.27	8.89	0.096	6.89	63.6[b]	70.4	16.0	8.32	4.47	10.6[b]	0.098
TF+NF	7.10	60.3[a]	70.5	17.5	7.41	4.04	10.4	0.101	6.96	68.8[a]	71.0	16.4	8.33	4.33	12.5[a]	0.107
Average	7.15	57.6[d]	70.9[c]	17.1[d]	7.66[d]	4.16[c]	9.65[d]	0.098[d]	6.92	66.2[c]	71.2	16.2	8.33[cd]	4.40	11.6[c]	0.103[c]
Wk 16																
TF−NF	7.08	59.1[b]	65.6	18.4[b]	10. 8	3.57	11.6[b]	0.115	7.16	56.3[b]	71.4	16.3	8.21	4.40	9.97[b]	0.104
TF+NF	7.11	66.3[a]	66.4	19.6[a]	9.32	3.44	13.9[a]	0.123	7.02	66.0[a]	70.4	17.3	8.01	4.06	12.1[a]	0.108
Average	7.10	62.7[c]	66.0[e]	19.0[c]	10.1[c]	3.51[d]	12.7[c]	0.119[c]	7.09	61.2[d]	70.9	16.8	8.11[d]	4.23	11.0[c]	0.106[c]
Pooled SEM	0.058	1.06	0.74	0.33	0.449	0.103	0.596	0.0061	0.062	1.05	0.54	0.29	0.475	0.099	0.323	0.0040

[a,b]Within a column and week, means with different superscripts letter are different ($P < 0.05$).

[c–e]Within a column, averages with different superscripts letter are different ($P < 0.05$).

[1]TF−NF = tall fescue without N fertilizer; TF+NF = tall fescue with N fertilizer.

[2]Expressed as m*M*.

[3]Expressed as mol/100 mol. A = acetate; P = propionate; B = butyrate.

[4]Expressed as mg/100 mL.

[5]NH_3:VFA = NH_3-N (m*M*) ÷ total VFA (m*M*).

supplies peptides, amino acids, and NH_3-N derived from microbial proteolysis for use in microbial protein synthesis (Wallace et al., 1997). A minimum of 7.0% CP in diets is required for efficient microbial digestion (Hariadi and Santoso, 2010), and 5.0 mg/100 mL is considered the minimum NH_3-N concentration for bacterial growth (Satter and Slyter, 1974). The minimum levels of CP concentrations and NH_3-N productions of all pastures in this study indicate that TF pastures regardless of N fertilization supplied the minimally required N source for microbial fermentation, but they lacked energy to optimize ruminal fermentation. Increased ruminal NH_3-N concentration on TF+NF may reflect reduced ruminal capture of the NH_3-N for microbial protein synthesis. Ruminal NH_3-N concentration is a result from a balance between production (proteolysis) and assimilation (De Visser et al., 1997), and thus any efforts to maximize N utilization in the rumen should involve an optimal balance between the 2 metabolic processes. Yet, to optimize dietary N utilization, particularly pasture forages, in ruminants, protein degradation in the rumen should be decreased, whereas N use by ruminal microbes must be increased (Hoover and Stokes, 1991). It is believed that energy is the most limiting factor in microbial growth (Bach et al., 2005), and consequently decreased NFC concentration may contribute to increased difference on NH_3-N concentration between TF−NF and TF+NF. De Visser et al. (1997) reported that ryegrass (*Lolium perenne*) that was fertilized with the high amount of N (450 kg of N/ha) contained more N and less sugar than did ryegrass that was fertilized with less N (150 kg of N/ha). In ruminal fluid, the concentration of NH_3-N was less for ryegrass that was fertilized with the low amount of N (De Visser et al., 1997).

Applying N fertilizer on TF pasture did not affect NH_3-N:total VFA concentration in both years of study (Table 3). However, the ratio increased ($P < 0.01$) with the progression of grazing season (from 0.072 at

Table 4. Effect of N fertilization of tall fescue on carcass characteristics of grazing beef steers (n = 3)

	2010[2]			2011		
Treatment[1]	Backfat, cm	REA, cm^2	IM fat, %	Backfat, cm	REA, cm^2	IM fat, %
TF−NF	0.26	10.6	3.98	0.43	10.1	3.10
TF+NF	0.27	9.87	4.08	0.46	9.81	3.61
SEM	0.012	0.483	0.255	0.030	0.234	0.220
P-value	0.57	0.35	0.81	0.47	0.44	0.17

[1]TF−NF = tall fescue without N fertilizer; TF+NF = tall fescue with N fertilizer.

[2]REA = ribeye area; IM fat = intramuscular fat.

wk 4 to 0.116 at wk 16 in 2010 and from 0.061 at wk 4 to 0.108 at wk 16 in 2011). In this study, greater total VFA concentration of TF+NF was noticed, as NH_3-N concentration increased. However, the sizable increase of NH_3-N concentration was not followed by the increase in total VFA concentration at a similar level, thus resulting in greater NH_3-N:total VFA concentration with the progression of grazing seasons.

Carcass Characteristics

Nitrogen fertilization on TF pasture did not influence carcass characteristics (backfat thickness, ribeye area, and intramuscular fat concentration) of grazing beef steers (Table 4). These results agree with those of Keane and Allen (1999) who reported that levels of N fertilizer (57, 204, and 227 kg N/ha) did not affect carcass composition and meat quality traits of grazing steers. Backfat deposition of ruminants is largely dictated by acetate production in the rumen (Berger and Pyatt, 2005). In our study, N fertilization on TF pasture did not influence molar proportion of acetate (Table 3). Although N fertilization of TF increased overall ADG of steers in the current study, it appears that no impacts on the carcass characteristics were detected.

IMPLICATIONS

Nitrogen fertilization is one of the most practical approaches to increase forage production and maintain high-quality pastures for grazing animals. In this study, N fertilization improved DMI, ADG, and G:F ratio through increased ruminal fermentation of grazing steers. However, it is unclear the mechanism whereby N fertilization increases ruminal fermentation evidenced by increased VFA concentration, and thus this aspect needs to be investigated. Increased ruminal NH_3-N concentration by N fertilization on TF found in this study indicates that there is a need to supplement readily fermentable carbohydrates in TF pastures. Providing sufficient readily fermentable carbohydrates in the rumen is expected to improve dietary CP utilization by optimizing microbial protein synthesis, which may result in enhancing growth performance of grazing steers.

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