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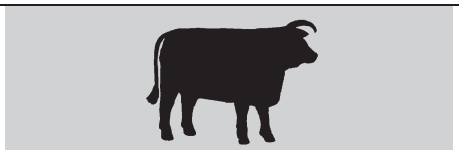

Fatty acid composition in adipose tissue of pasture- and feedlot-finished beef steers[1]

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ABSTRACT

Twenty-seven Angus crossbred steers were used to evaluate the effects of finishing beef cattle on pasture without or with N fertilization of the pasture versus feedlot finishing beef steers on fatty acid composition in subcutaneous adipose tissue. A completely randomized design with repeated measures was used to arrange steers into 3 treatments: grazing on tall fescue (TF) without N fertilizer (TF−NF), grazing on TF with N fertilizer (TF+NF), and feeding TMR on feedlot (FLT). For the pasture treatments, it was hypothesized that N fertilization would affect fatty acid composition of adipose tissue in pasture-fed beef steers because of its potential effects on nutrient and energy utilization. Three replicated pastures or group pens with 3 steers per replicate were assigned into each treatment. A total of 168 kg of N fertilizer per hectare was applied in 3 split applications at 56 kg/ha to the TF+NF. From May through September 2010 (total of 16 wk), pasture-finished steers were grazed on replicated 0.47-ha paddocks, while steers on the FLT were fed a finishing diet containing 76% barley grain. Subcutaneous adipose tissue biopsies were obtained on wk 4, 12, and 16. Total fat percentage in TF pasture did not differ due to N fertilization, and similar total fat concentrations were also measured between TF pasture and the FLT on wk 12 and 16. Nitrogen fertilization increased PUFA proportion (mg/100 mg of total fatty acid) in TF grass on wk 4 and 12, including C18:3 n-3 ($P < 0.01$). Applying N fertilizer to TF increased C18:0 on wk 12 and 16 and cis-9, trans-11 CLA proportion on wk 16 in adipose tissue of steers ($P < 0.02$). Pasture-finished steers had greater proportions of C18:0, cis-9, trans-11 CLA, and C18:3 n-3 throughout grazing compared with those on the FLT treatment ($P < 0.01$). However, C18:1 cis-9 and C18:2 n-6 proportions in adipose tissue of pasture-finishing steers decreased compared with FLT steers throughout study ($P < 0.02$). Increased SFA and decreased MUFA and n-6:n-3 ratio were observed in pasture-finished steers on wk 4, 12, and 16 compared with FLT steers ($P < 0.01$). Grazing on TF pasture increased cis-9, trans-11 CLA, C18:3 n-3, and SFA proportions in adipose tissue; however, TF pasture-finished steers had less backfat, rib fat, and rib-eye area compared with feedlot-finished steers ($P < 0.04$).

Key words: fatty acid profile, feedlot finishing diet, grazing beef steer

INTRODUCTION

The most common practice for finishing beef cattle in the United States is by feeding high-grain diets in a confinement feedlot, and this practice is very efficient in producing BW gains in a short period. However, this practice also results in a high SFA proportion of the beef, which is thought to confer negative effects on human health. Recent studies (Nuernberg et al., 2002; Realini et al., 2004; Fincham et al., 2009) demonstrated that beef of pasture-finished cattle has a lower proportion of SFA, greater n-3 and less n-6 PUFA, and higher CLA compared with high-grain-finished beef. Increased n-3 PUFA, especially C18:3 n-3, can reduce the risk of heart disease, hypertension, inflammation, and mammary cancer and lower cholesterol concentration in blood (de Deckere et al., 1998; Tapiero et al., 2002). Ha et al. (1990) and Ip et al. (1994) have suggested that CLA isomers may be valuable in the human diet because of their anticarcinogenic properties in rodent model systems. There is evidence to suggest that CLA proportion in adipose tissue

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of pasture-fed beef steers was greater compared with that of steers fed typical feedlot finishing diets (Basarab et al., 2007).

Tall fescue (**TF**; *Festuca arundinacea*) is a popular pasture grass in the Intermountain West (i.e., Utah, Idaho, Wyoming, Montana, and parts of Arizona and Nevada) due to its high adaptability to periodic drought, low fertility, and fluctuating seasonal temperatures. Although TF tolerates low 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). However, there have been no studies to evaluate whether improvement in forage quality and beef cattle performance caused by N fertilization may influence the FA composition in adipose tissue of TF-pasture-finished beef steers. Therefore, it was hypothesized that N fertilization would affect fatty acid (**FA**) composition of adipose tissue in pasture-fed beef steers because of its potential effects on nutrient and energy utilization. The objectives of this study were to determine whether N fertilization on TF pasture would influence FA profiles of fat depots in adipose tissue. In addition, we were interested in beneficial effects of grazing steers and compared the adipose tissue FA profiles between pasture- and feedlot-finished beef steers.

MATERIALS AND METHODS

Animals, Treatments, and Experimental Design

All procedures related to the animals used in the current study were accepted by the Institutional Animal Care and Use Committee at Utah State University, and the animals were cared for according to its guidelines. Twenty-seven Angus crossbred steers (initial BW = 394 ± 5.5 kg) were used in this study. The experiment was conducted at the Pasture Research Farm (Lewiston, UT) and the Utah State University Beef Research Farm (Wellsville, UT) from May through September 2010. All steers had been processed similarly before trial initiation by receiving a 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).

The 18 steers on pasture were assigned to 1 of 2 treatments in a completely randomized design: TF without N fertilizer (**TF−NF**) and TF with N fertilizer (**TF+NF**). On each treatment, there were 3 replicated pastures (n = 3) with 3 steers per pasture. A total of 168 kg of N fertilizer per hectare was applied in 3 split applications at 56 kg/ha to the TF+NF. Each pasture was divided into 4 equal-size paddocks (51 × 23 m) with a single strand of polywire electrified by a battery-powered fence charger. During the experiment, grazing animals were assigned a pasture allowance of 215 kg of DM per group. Each paddock was grazed for 7 d, and then the same paddock was rested for 21 d until wk 12. Because of limitations in forage production starting on wk 13, each paddock was grazed for 3 to 5 d, and then it was rested for 9 to 15 d until the end of the study. All animals were rotated to new paddocks between 0900 and 1000 h on a weekly basis. All steers had ad libitum access to fresh water and mineral supplement (Right Now Emerald, Cargill Animal Nutrition, Minneapolis, MN).

For feedlot TMR treatment (**FLT**), 9 steers were housed in 3 pens with 3 animals per pen (n = 3) and had ad libitum access to a finishing diet containing 5.0% alfalfa hay, 15.0% corn silage, 76.0% barley grain, and 4.0% feedlot vitamin and mineral supplement (DM basis). The FLT diet contained 11.0% CP, 28.1% NDF, 11.8% ADF, 1.40% crude fat, and 54.9% nonfibrous carbohydrate on DM basis.

Pasture or pen was considered as an experimental unit. The experiment was initiated at the same time at pasture and feedlot, and overall sampling procedures were exactly the same between the treatments.

Sample Collection

Adipose tissue samples were obtained at the end of wk 4, 12, and 16, beginning at approximately 0800 h. Biopsies of subcutaneous adipose tissue were obtained from the loin area on the left side adjacent the last rib ±10 cm down from the midline. The biopsy site was clipped and surgically prepared with 3 alternate scrubs of 70% isopropyl alcohol and 1% povidone-iodine solution (Betadine Surgical Scrub, The Purdue Frederick Co., Stamford, CT). Lidocaine (2% solution; total of 8 mL/animal; Vedco, St. Joseph, MO) was injected subcutaneously cranial to the site. A linear incision (approximately 5 cm) was made with a sterile scalpel through the skin. Approximately 1 g of adipose tissue was obtained. The incision was closed in a Ford interlocking pattern using #1 polyamid suture. Ceftiofur sodium (2 mL) was administered in the surgical site before closure to prevent infection.

Pasture forage and TMR 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 on 14-d intervals by clipping six 0.102-m^2 quadrats in each plot 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 to a height of 8 cm 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 sealed plastic bags, placed in a cooler with dry ice, and immediately transported to the laboratory to be frozen at −40°C to prevent oxidation and structural changes in FA. Pasture forage samples for FA analysis were freeze-dried (FreeZone 12 L Freeze Dry Systems, Labconco Corp., Kansas City, MO) and then ground to pass a 1-mm screen (standard model 4,

Arthur H. Thomas Co., Philadelphia, PA). Ground forage samples were composited within replication for the 28-d periods. Samples of TMR and refusals were obtained on a weekly basis. Samples were immediately dried in a forced-air oven at 60°C for 48 h, ground to pass a 1-mm screen (standard model 4), and composited within replication over 28-d periods. Samples of TMR were freeze-dried for FA analysis using the same procedure used for pasture samples.

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

Laboratory Analyses

Fatty acid extraction and methylation of feed samples were carried out according to the procedures of Palmquist and Jenkins (2003). Approximately 0.4 g of samples was placed into a 15-mL screw-cap culture tube in which 1 mL of internal standard (C19:0 in benzene) and 3 mL of 10% 3 *N* methanolic HCl were added. The tubes were vortex-mixed for 30 s and then incubated in a 70°C water bath for 2 h. Then, the tubes were shaken vigorously for 5 s every 30 min, during which the reaction content in the tubes was monitored. After the tubes were removed from the water bath and cooled for 15 min, 7.5 mL of 6% K_2CO_3 and 1.5 mL of hexane were added and mixed using vortex for 10 s, and then the tubes were centrifuged at 600 × *g* for 5 min at room temperature. The hexane layers were transferred into GLC vials, capped, and then stored at −20°C until analysis.

Fatty acid extraction from adipose tissue samples was performed according to the procedures of O'Fallon et al. (2007). Briefly, 100 mg of adipose tissue samples was placed into 15-mL screw-cap culture tubes in which 0.7 mL of 10 *N* KOH in water and 5.7 mL of MeOH were added. The tubes were incubated in a 55°C water bath for 1.5 h with vigorous hand shaking for 5 s every 20 min to properly permeate, dissolve, and hydrolyze the sample. After the tubes were cooled in a cold tap water bath for 15 min, 0.58 mL of 24 *N* H_2SO_4 was added. The tubes were mixed by inversion and incubated again in a 55°C water bath for 1.5 h with hand shaking for 5 s every 20 min. After the tubes were cooled in a cold tap water bath, 3 mL of hexane was added, and the tubes were vortex mixed for 1 min. The tubes were centrifuged at 252 × *g* (Sorvall RC-5B, DuPont Instrument, Wilmington, DE) for 5 min at 20°C, and the hexane layers were transferred into a GLC vial. The vial was capped and placed at −20°C until analysis.

Analysis of FA methyl esters was performed using a GLC equipped with an autoinjector, autosampler, and flame ionization detector (HP 6890N, Agilent Technologies Inc., Wilmington, DE). Samples containing methyl esters in hexane (1 μL) were injected through the split injection port (100:1) onto the column (100 m × 0.25 mm × 0.2 μm, CP-Sil 88, Varian, Lake Forest, CA). The oven temperature was set at 80°C, held for 10 min, and then increased to 190°C at 12°C/min for 39 min. The temperature was then increased again to 218°C at 20°C/min and held for 21 min. Injector and detector were set at 250°C. Total run time was 71 min. Nonadecanoic acid methyl ester (C19:0) was used as a reference standard to determine recoveries and correction factors for individual FA. Individual FA proportions were obtained by taking the specific FA area as milligrams of FA per 100 mg of total FA.

Fatty acid identification and quantification were performed using ChemStation Software 10.01 (Agilent Technologies Inc.) by comparison with known standards (Nu-Chek Prep Inc., Elysian, MN). Total SFA was calculated by summation of C12:0, C14:0, C15:0, C16:0, C17:0, C18:0, and C20:0. Total MUFA was calculated by summation of all FA with one carbon-carbon double bond, whereas total PUFA was calculated by summation of all FA with 2 or more carbon-carbon double bonds. The ratio of n-6 to n-3 FA was calculated by the sum of n-6 PUFA divided by the sum of n-3 PUFA.

Statistical Analyses

Data analyses were computed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). The effects of treatments (2 pasture treatments and FLT treatment) over time on FA compositions in pasture and FLT and adipose tissue were assessed using a one-way ANOVA in a completely randomized design with repeated measures. The model included treatment, sampling time, and the interaction between treatment and sampling time as fixed effects and the random effect of replication within treatment. Appropriate covariance structures for the repeated measures through time were selected based on information criteria. Pair-wise comparisons and contrasts were used to compare effects of pasture treatment and FLT. In all cases, significant effects were declared at $P < 0.05$, and trends were discussed at $P < 0.10$.

RESULTS AND DISCUSSION

With the recent high cost of fuel and fertilizer, it may not be profitable to apply N fertilizer to pastures at the recommended application rates of 40 to 100 kg of N per hectare (Poore et al., 2000; Lacefield et al., 2006). However, the practice may be still considered if it would beneficially shift FA composition in adipose tissue of steers, which motivated us to conduct the current study.

FA Composition in Pasture Forages and FLT

Total fat concentration did not differ between the TF−NF and TF+NF pasture treatments throughout the study (Table 1). Compared with TF pasture, a greater total fat concentration was measured in the FLT on wk 4, but no differences were observed on

Table 1. Comparison of total fat, saturated, monounsaturated, and C18 fatty acid isomers in tall fescue pasture and feedlot finishing TMR (n = 3)[1]

	Wk 4			Wk 12			Wk 16			
Item	TF−NF	TF+NF	FLT	TF−NF	TF+NF	FLT	TF−NF	TF+NF	FLT	SEM
Total fat, % DM	1.60	1.65	3.09	2.89	3.12	3.05	2.86	3.00	2.91	0.118
Fatty acids[2]										
C14:0	2.67	2.36	1.01	2.69	2.68	1.36	3.31	3.18	1.13	0.228
C16:0	8.70	9.42	20.4	10.4	10.8	21.4	6.46	7.70	21.0	0.241
C16:1 *cis*-9	0.17	0.18	0.18	0.27	0.28	0.11	0.16	0.20	0.09	0.026
C18:0	0.76	0.75	1.99	1.08	0.98	2.11	0.74	0.78	2.03	0.057
C18:1 *cis*-9	1.44	1.63	14.7	1.93	2.02	15.2	1.21	1.31	14.2	0.130
C18:1 *cis*-11	0.27	0.31	1.52	0.41	0.42	1.45	0.28	0.35	1.44	0.045
C18:2 n-6	7.40	8.25	43.0	10.3	10.5	40.3	6.44	7.04	43.5	0.435
C18:3 n-3	40.4	44.4	6.53	38.7	42.2	8.40	37.5	39.1	8.17	0.370
	Contrast,[3] *P*-value									
	Wk 4				Wk 12				Wk 16			
	1	2	3	4	1	2	3	4	1	2	3	4
Total fat	0.74	<0.01	<0.01	<0.01	0.17	0.40	0.69	0.69	0.41	0.74	0.62	0.83
C14:0	0.28	<0.01	<0.01	<0.01	0.95	<0.01	<0.01	<0.01	0.71	<0.01	<0.01	<0.01
C16:0	0.01	<0.01	<0.01	<0.01	0.21	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C16:1 *cis*-9	0.90	0.90	0.97	0.85	0.95	<0.01	<0.01	<0.01	0.13	0.04	<0.01	<0.01
C18:0	0.95	<0.01	<0.01	<0.01	0.16	<0.01	<0.01	<0.01	0.49	<0.01	<0.01	<0.01
C18:1 *cis*-9	0.20	<0.01	<0.01	<0.01	0.53	<0.01	<0.01	<0.01	0.52	<0.01	<0.01	<0.01
C18:1 *cis*-11	0.48	<0.01	<0.01	<0.01	0.84	<0.01	<0.01	<0.01	0.23	<0.01	<0.01	<0.01
C18:2 n-6	0.08	<0.01	<0.01	<0.01	0.62	<0.01	<0.01	<0.01	0.21	<0.01	<0.01	<0.01
C18:3 n-3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[1]TF−NF = tall fescue without N fertilizer; TF+NF = tall fescue with N fertilizer; and FLT = feedlot finishing TMR.

[2]Fatty acid composition was expressed as mg/100 mg of total fatty acids.

[3]Contrast: 1 = TF−NF vs. TF+NF; 2 = TF−NF vs. FLT; 3 = TF+NF vs. FLT; and 4 = TF vs. FLT.

wk 12 and 16. As a cool-season grass, TF has reduced growth during hot and dry summer months (Roberts et al., 2009), which is similar to observations in our study on wk 12 and 16. During this stage of growth, TF stores most of the excess nutrient in carbohydrates and lipids in leaves and stems, resulting in increased total fat concentration with progression of the grazing season.

The primary FA observed in TF was C18:3 n-3 (averaged 40.4%), whereas C18:2 n-6 was the primary FA found in the FLT (averaged 42.3%). Tall fescue had a lesser proportion (mg/100 mg of total FA) of C16:0, C18:2 n-6, and SFA but a greater proportion of C18:3 n-3 compared with the FLT. Nitrogen fertilization increased C18:3 n-3 proportion in the TF+NF compared with the TF−NF in all weeks. This result is consistent with Boufaïed et al. (2003), who applied 120 kg of N per hectare on timothy grass, which resulted in increased C18:3 n-3 proportion by 40%. The relatively low increase of C18:3 n-3 proportion in TF+NF when compared with TF−NF due to N fertilization (10.0, 9.0, and 4.3% increase on wk 4, 12, and 16, respectively) observed in our study may be due to the different responses to N fertilizer between TF and timothy grass. Because of its shallow and fibrous root system, timothy grass is more responsive to top-dress application of N fertilizer compared with TF, which has an extensive and deep root system. In the current study, the C18:3 n-3 proportions in the pasture forages declined after wk 4 as compared with the first 4 wk. Fincham et al. (2009) reported similar results on the decline of the C18:3 n-3 proportion throughout grazing on triticale (*Triticosecale rimpaui*)/annual ryegrass (*Lolium multiflorum*), alfalfa (*Medicago sativa*)/orchardgrass (*Dactylis glomerata*), and a cool-season grass/legume mixture. Boufaïed et al. (2003) also reported that there was a positive relationship between total N concentration in the grass and C16:0, C18:2, and C18:3 FA percentages. Likewise, we previously reported that applying N fertilizer increased N concentration in TF (Noviandi et al., 2011). Nitrogen fertilization on plants increases the metabolic component, including chloroplast, where the lipids are often localized, causing greater synthesis and accumulation of FA in the plant (Boufaïed et al., 2003).

Due to N fertilization, PUFA proportion increased in the TF+NF on

Table 2. Comparison of fatty acid families in tall fescue pasture and feedlot finishing TMR (n = 3)[1]

	Wk 4			Wk 12			Wk 16			
Fatty acid[2]	TF−NF[2]	TF+NF	FLT	TF−NF	TF+NF	FLT	TF−NF	TF+NF	FLT	SEM
SFA	26.2	27.1	44.7	32.4	30.4	45.7	26.5	27.2	44.6	0.31
MUFA	31.7	27.6	18.5	26.9	26.5	17.6	32.3	32.1	18.1	0.33
PUFA	42.1	45.4	36.7	40.7	43.1	36.7	41.2	40.7	37.3	0.34
PUFA:SFA	1.61	1.67	0.82	1.26	1.42	0.80	1.55	1.50	0.83	0.025
	Contrast,[3] *P*-value									
	Wk 4				Wk 12				Wk 16			
	1	2	3	4	1	2	3	4	1	2	3	4
SFA	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01
MUFA	<0.01	<0.01	<0.01	<0.01	0.22	<0.01	<0.01	<0.01	0.51	<0.01	<0.01	<0.01
PUFA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.24	<0.01	<0.01	<0.01
PUFA:SFA	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01

[1]TF−NF = tall fescue without N fertilizer; TF+NF = tall fescue with N fertilizer; and FLT = feedlot finishing TMR.

[2]Fatty acid composition was expressed as mg/100 mg of total fatty acids.

[3]Contrast: 1 = TF−NF vs. TF+NF; 2 = TF−NF vs. FLT; 3 = TF+NF vs. FLT; and 4 = TF vs. FLT.

wk 4 and 12 compared with the TF−NF, but no differences were observed on wk 16 (Table 2). Greater proportion of C18:3 n-3 in the TF+NF pasture resulted in increased PUFA proportion. Similarly, Boufaïed et al. (2003) reported that N fertilization increased PUFA proportion of timothy grass. Increased proportion of PUFA in the TF+NF also resulted in greater PUFA:SFA ratio in the TF+NF compared with the TF−NF throughout grazing.

FA Composition in Adipose Tissue of Beef Steers

A major limitation in the current study is that we analyzed FA composition in adipose tissue of beef steers but not in muscle, and the latter is the most commonly consumed beef product. Therefore, data reported in this study must be carefully extrapolated.

In general, consumption of TF+NF did not affect FA proportion (mg/100 mg of total FA) in adipose tissue of steers on wk 4 and 12 (Table 3). However, proportions of C18:0 and *cis*-9, *trans*-11 CLA in steers grazed in the TF+NF were greater compared with those in the TF−NF on wk 16. Increased *cis*-9, *trans*-11 CLA proportion in response to N fertilization of the TF pastures on wk 16 is worthy of discussion, as C18:3 n-3 proportion in pasture was greater in the TF+NF than the TF−NF starting on wk 4. Therefore, duration of N application to TF may affect *cis*-9 and *trans*-11 CLA deposition in adipose tissue of beef steers. It is likely that the increased *cis*-9, *trans*-11 CLA proportion on wk 16 may have resulted from gradual increase of C18:1 *trans*-11 FA during ruminal biohydrogenation in response to accumulative N fertilization, which in turn could provide increased C18:1 *trans*-11 in adipose tissue for the action of Δ^9-desaturase. Although not significant, C18:1 *trans*-11 in adipose tissue was numerically greater in animals grazed in the TF+NF compared with those in the TF−NF only on wk 16.

Proportion of C18:0 in adipose tissue of steers fed the FLT was lower than that of those that grazed TF throughout the sampling weeks, whereas steers that grazed TF pasture had less C18:1 *cis*-9 compared with those fed the FLT (Table 3). This has important implications. Because C18:0 is a primary determinant of fat hardness (Wood et al., 2004; Chung et al., 2006), any dietary or production factor that enhances the conversion of C18:2 n-6 and C18:3 n-3 to C18:0 will increase fat hardness and then decrease palatability of beef. Kucuk et al. (2001) demonstrated that increasing dietary forage increased duodenal flow of C18:0 and C18:3 n-3 but decreased the duodenal flow of C18:1 *cis*-9 and C18:2 n-6. Feeding a high-grain diet typically decreases ruminal pH, and a prolonged reduction in ruminal pH also could cause reduction in the population of bacteria responsible for ruminal biohydrogenation (van de Vossenberg and Joblin, 2003; Fukuda et al., 2006; Wallace et al., 2006). Therefore, the decreased C18:0 proportion in adipose tissue of feedlot steers was likely due to the direct effect of the acidic fermentative environment by feeding finishing TMR, resulting in less completion of ruminal biohydrogenation. Another possibility is that rate of digesta passage in the rumen of feedlot cattle was likely greater than that in grazing animals, resulting in less completion of ruminal biohydrogenation by the FLT. Decreased ruminal retention times on high-concentrate diets would shorten the exposure time of dietary fats to ruminal microbes (Merchen,

Table 3. Effect of pasture or feedlot finishing treatments on saturated, monounsaturated, and C18 fatty acid isomers in adipose tissue of beef steers (n = 3)[1]

	Wk 4			Wk 12			Wk 16			
Fatty acid[2]	TF−NF	TF+NF	FLT	TF−NF	TF+NF	FLT	TF−NF	TF+NF	FLT	SEM
C14:0	3.82	3.86	3.37	3.50	3.67	3.35	3.69	3.56	3.26	0.201
C16:0	29.6	29.8	29.9	28.1	28.6	29.8	27.5	28.6	28.3	0.52
C16:1 *cis*-9	5.12	4.85	4.78	5.04	4.71	5.38	4.76	4.84	5.26	0.312
C18:0	14.0	13.8	10.5	13.8	15.6	9.21	13.2	14.2	9.00	0.363
C18:1 *cis*-9	35.0	35.7	39.4	36.1	35.5	40.6	37.4	36.0	43.0	0.54
C18:1 *trans*-11	1.82	1.86	1.63	2.01	2.02	1.99	2.31	2.54	1.68	0.155
C18:2 n-6	1.15	1.10	1.29	1.08	1.11	1.29	1.20	1.07	1.28	0.062
cis-9, *trans*-11 CLA	0.43	0.41	0.25	0.41	0.42	0.24	0.44	0.57	0.27	0.021
C18:3 n-3	0.42	0.41	0.22	0.38	0.40	0.17	0.41	0.44	0.18	0.038
	Contrast,[3] *P*-value									
	Wk 4				Wk 12				Wk 16			
	1	2	3	4	1	2	3	4	1	2	3	4
C14:0	0.88	0.30	0.30	0.01	0.69	0.69	0.38	0.19	0.69	0.30	0.38	0.05
C16:0	0.91	0.78	0.93	0.67	0.54	0.02	0.08	<0.01	0.12	0.26	0.78	0.58
C16:1 *cis*-9	0.66	0.55	0.89	0.47	0.55	0.55	0.42	0.08	0.89	0.55	0.55	0.11
C18:0	0.74	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
C18:1 *cis*-9	0.25	<0.01	<0.01	<0.01	0.37	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01
C18:1 *trans*-11	0.37	0.88	0.31	0.41	0.56	0.31	0.59	0.26	0.31	<0.01	<0.01	<0.01
C18:2 n-6	0.65	0.13	0.06	0.01	0.78	0.04	0.06	<0.01	0.18	0.38	0.04	0.02
cis-9, *trans*-11 CLA	0.47	<0.01	<0.01	<0.01	0.59	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C18:3 n-3	0.57	<0.01	<0.01	<0.01	0.80	<0.01	<0.01	<0.01	0.78	<0.01	<0.01	<0.01

[1]TF−NF = tall fescue without N fertilizer; TF+NF = tall fescue with N fertilizer; and FLT = feedlot finishing TMR.

[2]Fatty acid composition was expressed as mg/100 mg of total fatty acids.

[3]Contrast: 1 = TF−NF vs. TF+NF; 2 = TF−NF vs. FLT; 3 = TF+NF vs. FLT; and 4 = TF vs. FLT.

1993), which could also contribute to reduced ruminal biohydrogenation (Kucuk et al., 2001).

Proportion of C18:1 *trans*-11 (*trans*-vaccenic acid) in the adipose tissue of steers was similar between TF pasture and the FLT on wk 4 and 12, but an increased proportion was measured in adipose tissue of steers grazed on TF on wk 16 (2.43 vs. 1.68%). Proportion of *cis*-9, *trans*-11 CLA was greater in adipose tissue obtained from TF-grazed steers than in that from those fed the FLT on wk 4, 12, and 16 (0.42 vs. 0.25, 0.42 vs. 0.24, and 0.51 vs. 0.27%, respectively). There appear to be 2 routes of formation of the *cis*-9, *trans*-11 CLA: one route through the ruminal biohydrogenation process and a second route in which the precursor FA *trans*-vaccenic acid is converted to *cis*-9, *trans*-11 CLA by desaturation (removal of 2 hydrogens) at the ninth carbon of the FA by the enzyme Δ^9-desaturase. However, endogenous synthesis of *cis*-9, *trans*-11 CLA appears to be the primary mechanism of *cis*-9, *trans*-11 CLA production in ruminant products (Griinari et al., 2000; Corl et al., 2001; Kay et al., 2004). Therefore, maintaining increased proportions of *trans*-vaccenic acid in ruminal fluid of pasture-finished cattle is critical in optimizing *cis*-9, *trans*-11 CLA content in ruminant products. Ruminal fluid and serum *trans*-vaccenic acid are correlated with adipose tissue *trans*-vaccenic acid (Fincham et al., 2009). Therefore, the sizable increase in the *cis*-9, *trans*-11 CLA proportion observed in beef steers grazed on TF pasture, particularly at the end of grazing, likely resulted from elevated formation of *trans*-vaccenic acid during the ruminal biohydrogenation process. In addition, decreased ruminal retention time and its effects on ruminal biohydrogenation due to feeding the FLT would influence the lower *cis*-9, *trans*-11 CLA proportion in the FLT compared with the grazing cattle, as was previously discussed.

Although grazing steers on TF increased the *cis*-9, *trans*-11 CLA proportion in adipose, pasture-finished cattle generally have a lower total FA concentration compared with feedlot-finished cattle; therefore, when CLA content of beef is calculated, the differences are less pronounced between pasture- and feedlot-finished cattle. Thus, it is important to consider the net CLA yield to the consumer rather than merely the concentration on per unit weight of fat (Mir et al., 2004).

Applying N fertilizer did not influence C18:2 n-6 proportion in adipose tissue of pasture-finished steers, but a greater proportion of C18:2 n-6 was

found in the FLT steers compared with those on the TF pasture across all sampling weeks (averaged 1.29 vs. 1.12%, respectively). Basarab et al. (2007) and Duckett et al. (2009) reported higher proportion of C18:2 n-6 in subcutaneous fat from grain-finished cattle compared with those finished in pasture. In this study, proportion of C18:2 n-6 in the FLT diet increased compared with those on TF pasture (averaged 43.3 vs. 8.32%), which caused greater proportion of C18:2 n-6 in adipose tissue of FLT steers. Although the FA in ruminants are at greater levels in muscle than in adipose tissue (Pavan and Duckett, 2007; Wood et al., 2008), the proportion of FA in those locations is positively correlated (Basarab et al., 2007).

Adipose tissue proportion of C18:3 n-3 was similar between the TF−NF and TF+NF treatments, but a higher C18:3 n-3 proportion was observed in adipose tissue of steers fed TF pasture compared with those in the FLT on wk 4, 12, and 16. Similar to C18:2 n-6, the high proportion of C18:3 n-3 in adipose tissue of grazing steers reflects the unique FA composition in TF pasture and resultant greater intake of C18:3 n-3. French et al. (2000) reported that steers offered grass increased intakes of n-3 PUFA because of the greater proportion of C18:3 in grass than in the concentrate.

Although de novo FA biosynthesis appears to be the primary mechanism of SFA and MUFA production in cattle, grazing TF+NF pasture resulted in greater SFA and lower MUFA in adipose tissue of steers compared with those grazing TF−NF pasture on wk 12 and 16 (Table 4). Greater SFA and lesser MUFA proportions in adipose tissue were also observed in pasture-finishing steers compared with FLT steers on wk 4, 12, and 16. In this study, the dominant SFA in both TF and FLT treatments were C16:0 and C18:0, whereas the dominant MUFA was C18:1 *cis*-9. Pasture diets have been reported to cause more favorable ruminal pH, which may enhance microbial activity of *Butyrivibrio fibrisolvens* for isomerization and hydrogenation of PUFA into C18:0 (French et al., 2000; Jenkins et al., 2008). Increased forage intake also increases duodenal flow of C18:0 and SFA, whereas duodenal flow of C18:1 *cis*-9 and unsaturated FA is decreased (Kucuk et al., 2001). These FA are absorbed via the intestine into the blood stream, resulting in higher SFA and lesser MUFA proportions in adipose tissue.

Proportion of PUFA in adipose tissue from steers in the TF pasture increased on all sampling weeks compared with those in the FLT treatment by 11.8, 12.3, and 22.5%, respectively. French et al. (2000) and Realini et al. (2004) observed increased PUFA in intramuscular fat as a result of pasture finishing compared with grain finishing by 8 and 40%, respectively. In our study, increased C18:3 n-3 and *cis*-9, *trans*-11 CLA proportions caused the rise of PUFA proportion in adipose tissue. However, because the *cis*-9, *trans*-11 CLA in adipose tissue comes mostly from endogenous synthesis involving the Δ^9-desaturase enzyme (Bauman et al., 2003), the effect of feed on the increasing proportion of this FA could be a minor.

Throughout all sampling weeks, no effects on the ratio of total PUFA:SFA were detected due to N fertilization or between TF pas-

Table 4. Effect of pasture or feedlot finishing treatments on fatty acid families in adipose tissue of beef steers (n = 3)[1]

	Wk 4			Wk 12			Wk 16			
Fatty acid[2]	TF−NF	TF+NF	FLT	TF−NF	TF+NF	FLT	TF−NF	TF+NF	FLT	SEM
SFA	50.8	50.7	47.2	49.2	50.5	45.2	48.0	48.9	43.0	0.33
MUFA	47.2	47.3	51.0	48.8	47.5	53.0	49.9	49.0	55.2	0.35
PUFA	2.09	1.99	1.83	1.98	2.00	1.77	2.15	2.16	1.76	0.098
PUFA:SFA	0.041	0.039	0.039	0.040	0.040	0.039	0.045	0.044	0.041	0.0020
n-6:n-3	2.72	2.71	5.91	2.84	2.81	7.39	2.89	2.46	7.14	0.273
	Contrast,[3] *P*-value									
	Wk 4				Wk 12				Wk 16			
	1	2	3	4	1	2	3	4	1	2	3	4
SFA	0.79	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
MUFA	0.61	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
PUFA	0.46	0.08	0.22	0.03	0.97	0.13	0.12	0.03	0.97	0.03	0.30	<0.01
PUFA:SFA	0.72	0.52	0.85	0.42	0.85	0.85	0.93	0.72	0.85	0.20	0.32	0.06
n-6:n-3	0.98	<0.01	<0.01	<0.01	0.98	<0.01	<0.01	<0.01	0.30	<0.01	<0.01	<0.01

[1]TF−NF = tall fescue without N fertilizer; TF+NF = tall fescue with N fertilizer; and FLT = feedlot finishing TMR.

[2]Fatty acid composition was expressed as mg/100 mg of total fatty acids.

[3]Contrast: 1 = TF−NF vs. TF+NF; 2 = TF−NF vs. FLT; 3 = TF+NF vs. FLT; and 4 = TF vs. FLT.

Table 5. Effect of pasture or feedlot finishing treatments on carcass characteristics of beef steers (n = 3)

	Treatment[1]				Contrast,[2] *P*-value			
Item	TF−NF	TF+NF	FLT	SEM	1	2	3	4
Backfat, cm	0.21	0.23	0.51	0.049	0.65	<0.01	<0.01	<0.01
Rib fat, cm	0.21	0.23	0.65	0.070	0.86	<0.01	<0.01	<0.01
Rib-eye area, cm^2	10.6	9.87	13.9	0.562	0.24	<0.01	<0.01	0.04
Intramuscular fat, %	4.19	4.25	4.94	0.325	0.86	0.06	0.08	0.20

[1]TF−NF = tall fescue without N fertilizer; TF+NF = tall fescue with N fertilizer; and FLT = feedlot finishing TMR.

[2]Contrast: 1 = TF−NF vs. TF+NF; 2 = TF−NF vs. FLT; 3 = TF+NF vs. FLT; and 4 = TF vs. FLT.

ture and the FLT treatments (Table 4). The PUFA:SFA ratio is mainly influenced by genetics (De Smet et al., 2004) and de novo synthesis (Bauman et al., 2003) and much less by nutritional aspects. Thus, it is difficult in pasture-finished steers to achieve a high PUFA:SFA ratio through diet modification because of extensive biohydrogenation of dietary PUFA, leading to production of SFA in the rumen and absorption in the small intestine. However, the ratio of total PUFA:SFA tended to be greater ($P = 0.06$) in the adipose tissue from pasture- than feedlot-finished steers on wk 16 (0.045 vs. 0.041).

Adipose tissue from grazing steers had lower a n-6:n-3 ratio than that from those on the FLT treatment on all sampling weeks (averaged 2.74 and 5.11, respectively). Basarab et al. (2007) and Duckett et al. (2009) reported lower n-6:n-3 ratio in subcutaneous fat from pasture-finished compared with grain-finished cattle. The decreased n-6:n-3 ratio is a consequence of increased C18:3 n-3 proportion and relatively constant proportion of C18:2 n-6 in adipose tissue from steers on TF pasture compared with FLT steers. Steers finished on a high-grain diet showed a 2.5 times higher n-6:n-3 ratio compared with those finished on pasture (Basarab et al., 2007; Duckett et al., 2009). However, the fold of increase in the n-6:n-3 ratio can be higher (i.e., between 9.3 and 10.5) when examined in beef muscles (Lorenz et al., 2002; Nuernberg et al., 2002).

Carcass Characteristics

Nitrogen fertilization on TF pasture had no effects on carcass characteristics measured (Table 5). We previously reported that there were no noticeable effects of N fertilization on TF nutrient proportion and animal performance (Noviandi et al., 2011). Therefore, it is not surprising that there were no effects on carcass characteristics between steers grazed on the TF−NF and TF+NF pastures. Keane and Allen (1999) reported that level of N fertilizer (57 vs. 204 to 227 kg of N/ha) did not affect herbage nutritive value, animal performance, and HCW, leading to no effects on carcass composition and meat quality traits of steers.

Compared with TF-pasture-finished steers, steers on the FLT had larger backfat, rib fat, and rib-eye area (0.51 vs. 0.22 cm, 0.65 vs. 0.22 cm, and 13.9 vs. 10.2 cm^2, respectively). This is a direct result of increased body size in steers fed TMR rather than grazed on TF (611 vs. 497 kg; $P < 0.05$; data not presented). Similarly, Realini et al. (2004), Kerth et al. (2007), and Faulkner et al. (2010) reported larger backfat, rib fat, and rib-eye area of grain-finished steers compared with pasture-finished steers. In our study, intramuscular fat percentage of steers grazed on TF pasture did not differ from that of steers on the FLT, which is consistent with the result reported by French et al. (2003), who did not find any differences on intramuscular fat percentage between steers on a grass or concentrate diet.

IMPLICATIONS

Beef producers continuously seek better practices to improve nutritional values with beneficial FA composition to make their products more attractive to consumers, and management strategies have very strong effects on FA composition of beef. This study indicated that N fertilization on TF pasture increased *cis*-9, *trans*-11 CLA proportion on wk 16, whereas pasturing beef steers on TF increased *cis*-9, *trans*-11 CLA and lowered n-6:n-3 ratio in beef adipose tissue throughout grazing compared with feeding the FLT. Thus, 4 wk of grazing would be enough to observe significant differences in FA composition in the adipose tissue compared with typical feedlot finishing management. Although grazing on TF elicited positive FA composition in adipose tissue, consideration should be given to the effect on quality and grade of carcass, because TF-pasture-finished steers had less backfat, rib fat, and rib-eye area compared with those fed TMR.

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