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Conjugated linoleic acid content of beef differs by feeding regime and muscle

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Abstract

The project objective was to determine the CLA content of three muscles (*Longissimus lumborum*, LD; *Semimembranosus*, SM; *Triceps brachii*, TB), in both raw and cooked states, in cattle finished on pasture or with grain supplements. Cattle were randomly assigned to one of four finishing regimens; pasture ($n = 11$), pasture with grain supplement ($n = 11$), pasture with grain supplement containing soyoil ($n = 12$), and feedlot ($n = 12$). In the raw state, TB had higher ($P < 0.05$) CLA than LD or SM on a mg/g sample basis. Total CLA was higher ($P < 0.05$) in the soyoil diet when compared to the other three feeding regimes on a mg/g sample basis and when expressed as mg/g fat in both raw and cooked analyses. Pasture inclusion produced higher levels ($P < 0.05$) of total CLA than the feedlot diet on a mg/g fat basis for cooked samples while maintaining acceptable eating quality.

Keywords: Beef; Conjugated linoleic acid; Muscle

1. Introduction

Conjugated linoleic acid (CLA) is a naturally occurring fatty acid found in ruminant animal fats. CLA is a product of ruminal biohydrogenation of polyunsaturated fatty acids (Kelly et al., 1998), and there is strong evidence that CLA has anticarcinogenic properties in laboratory animals (Ip, Scimeca, & Thompson, 1994) as well as being protective against heart disease, diabetes, and obesity (Sumeca & Miller, 2000; Weiss, Martz, & Lorenzen, 2004). The CLA content of beef has been characterized by previous researchers (Ma, Wierzbicki, Field, & Clandinin, 1999; Shantha, Crum, & Decker, 1994); however, these studies used small sample sizes and the tested beef was purchased from retail stores implying that the cattle producing the beef had been fed in a normal production scheme including a high-concentrate finishing diet. CLA content in grass fed cattle was greater in the *Semimembranosus* muscle compared to cattle on pasture and supplemented with grain (Shantha, Moody, & Tabeidi, 1997). French et al. (2000) reported a linear increase in CLA content with increased percentage of grass in the diet. While these studies indicate the likelihood that beef from pasture-fed or pasture-finished cattle will contain higher concentrations of CLA than feedlot cattle, small sample sizes and the limited selection of muscles for analysis prevent a firm conclusion.

Since beef is not consumed raw, cooking and other processing methods that may alter the original CLA content of the meat also deserve investigation. CLA content in cooked meat patties has been shown to increase on a mg/g of fat basis and mg/100 g of cooked meat basis (Shantha et al., 1994). In order for consumers to receive the health benefits of CLA from meat, there will need to be a maintained and/

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or elevated amount in the cooked product. In addition, muscles differ in fat concentration based on function and location within the body making it important to investigate more than one muscle. Therefore, the objective of this project was to compare the CLA content of different muscles in the raw and cooked states from different grain supplementation and pasture finishing regimes.

2. Materials and methods

2.1. Cattle selection and feeding

Forty-eight steers were obtained from Grassland Beef Inc., a Missouri producer owned operation, and used in a Management-intensive Grazing (MiG) system at the University of Missouri Forage Systems Research Center (FSRC; Linneus, MO). Cattle were the same age and biological type, British × Continental crosses, appropriate for pasture-based finishing. Steers were background grazed on pasture on a producer-cooperator farm to a weight of 363–385 kg and then moved to finishing pastures at the FSRC. Target harvest weights were uniform for all treatments, 500 kg live weight with 0.76 cm carcass backfat.

Cattle were weighed two consecutive days at the beginning and end of the trial and each month while on feed. Prior to the start of the trial, all cattle received only pasture. Grazing commenced on July 23 and continued until each group had reached target weights and backfat thickness or until adequate pasture was no longer available. Less than average rainfall resulted in pastures becoming limited in their ability to support extended grazing, and thus, the target weight and backfat thickness was not attained for some feeding regimen groups. Four feeding treatments (Table 1) were employed: (1) pasture only, (2) grain supplement (soyhulls) offered to 1.2% of body weight, (3) soyoil supplement (dried distillers grains and soyhulls plus soyoil premix) offered to 1.2% of body weight, and (4) feedlot ration (cracked corn and soyhulls) offered free choice in dry lot with a self feeder. There were two replications of six steers per replication for each feeding treatment. Two animals were removed from the study due to animal management issues.

The pasture used in this study was an 80-acre unit consisting of 24 permanent paddocks of approximately three acres. Paddocks were arranged such that stock water was available ad libitum in each paddock. Pastures were diverse cool season plant species mainly consisting of endophyte free tall fescue (*Festuca arundinacea*), orchardgrass (*Dactylis glomerata*), timothy (*Phleum pratense*), smooth bromegrass (*Bromus inermis*) with red clover (*Trifolium pretense*) as the principle legume with some birdsfoot trefoil (*Lotus corniculatus*). Pastures were approximately 30% legumes. Each replication group of steers was rotationally grazed on four replicated three acre pastures. The three acre pastures were further subdivided into strips to facilitate moving the steers to fresh pasture every 2–3 d.

Cattle were weighed at the end of the trial and penned overnight with water available at the FSRC. The next morning cattle were loaded and transported to the University of Missouri Meat Laboratory, approximately 170 km, for further processing.

Table 1
Composition of feeding regimes on a percentage air dry basis

Component	Feedlot	Soyoil	Grain	Pasture
Cracked corn	65	0	0	0
Soyhulls	27	50	36	0
Dried distillers grains and solubles	8	0	13	0
Heavy soyoil	0	0	0.77	0
Pasture	0	50	50	100
Mineral	Free choice	Free choice	Free choice	Free choice

2.2. Steak preparation

Prior to processing the carcasses, USDA yield and quality grade factors (USDA, 1997) were collected to characterize the cattle. The following cuts were selected from each carcass: ribeye roll similar to IMPS #112A (NAMP, 1997; USDA, 1996), shoulder clod similar to IMPS #114 (NAMP, 1997; USDA, 1996), and inside round similar to IMPS #169 (NAMP, 1997; USDA, 1996) in order to test CLA content in the middle meats, chuck, and round. Subprimals were aged for 14 d and frozen until fabrication into steaks. Frozen subprimals were cut into 2.54 cm steaks in order to obtain the following muscles: *Longissimus lumborum*, *Triceps brachii*, and *Semimembranosus*. For each subprimal, one steak was analyzed raw and one steak was analyzed cooked.

2.3. Laboratory analysis

All steaks were analyzed for moisture, fat, total fatty acids, and specific CLA isomers (*cis*-9, *trans*-11; *trans*-10, *cis*-12; *cis*-9, *cis*-11; *trans*-9, *trans*-11). Crude fat and moisture were determined using a CEM SMART Trac Moisture and Fat Analysis System (CEM Corporation, Matthews, NC). The SMART System utilizes microwave technology to determine moisture content of a meat sample. The SMART Trac NMR system utilizes nuclear magnetic resonance and directly measures fat content utilizing a signal-to-mass ratio.

For fatty acid profile and CLA analysis, lipids were extracted according to Hara and Radin (1978) using a solvent mixture of hexane and isopropanol (3:2 v/v). An aliquot of 2 g sample was extracted with 30 mL extraction solvent, which was washed with 25 mL sodium sulfate solution in a separatory funnel. The hexane layer was dried with anhydrous sodium sulfate and a 2 mL aliquot was combined with 1 mL of internal standard (1 mg/mL C17:0 methyl ester). The fatty acid profile and CLA content was determined using the alkaline methylation method of Shantha et al. (1994). The lipid extract was dried under nitrogen and transesterified using tetramethyl guanidine in methanol. The methyl esters were separated by gas chromatography (Perkin Elmer 8500) on a fused silica capillary column (Supelcowax 10, 60 m × 0.32 mm × 0.25 μm film, Supelco Inc., Bellefonte, PA) with a helium flow rate of 1.8 mL/min at 30 psi head pressure. Injector and FID temperatures were 250 °C. The initial column temperature of 100 °C was kept for 5 min, then ramped at 10 °C/min to 225 °C and held at that temperature for 30 min for a total run time of 47.5 min.

Prior to sample analysis, the method was validated by determining method accuracy and precision using CLA spiked meat imitation samples. Fatty acid methyl esters standards (C16:0, C16:1, C18:0, C18:1, C18:2, C18:3, C20:4, C20:5n-3, and C22:6n-3) and four standard CLA methyl ester isomers 9c,11c; 9c,11t; 10t, 12c and 9t, 11t (98% purity) (Matreya Inc., Pleasant Gap, PA) were used to generate an internal standard curve, with C17:0 methyl ester as the internal standard, which was used for quantifying the various fatty acids and CLA isomers. Fatty acids, including CLA, were expressed as fatty acid methyl esters.

Steaks were cooked on a Farberware Open Hearth broiler (Bronx, NY). Internal temperatures were monitored with a copper constantan thermocouple inserted into the geometric center of each steak, and temperatures were monitored with a hand-held thermometer (Omega model HH21 microprocessors/thermometer; Omega Engineering Inc., Stanford, CT). Steaks were cooked to an internal temperature of 35 °C, turned, and cooked to a final internal temperature of 70 °C.

2.4. Warner-Bratzler shear force and consumer panel

Warner-Bratzler shear force was conducted according to AMSA (1995) guidelines. Briefly, steaks were cooked to a target endpoint temperature of 70 °C on a MagiKitch'n Conveyor Grill. After cooking, cuts were wrapped in Sam's Choice® oxygen-permeable clear plastic wrap to reduce evaporation and cooled overnight under refrigeration (4 °C). Six 1.27 cm cores were removed parallel to the muscle fiber and sheared perpendicular to the muscle fiber. Shear force was measured using an United STM Smart-1 Test System SSTM-500 (United Calibration Corp., Huntington Beach, CA). Settings for the United Testing System were: force units – kg, linear units – mm, cycling – 1 × 70 mm, test speed – 250 mm/min, return speed – 500 mm/min, setup scales – CAP = 226.8. The shear force value of the cores was then averaged.

Panelists ($n = 87$) were recruited from the Columbia, MO area from a list of consumers who had participated in previous meat consumer panels, posted flyers, and by word of mouth. Consumers were told that they would receive a 5-dollar gift certificate for participation in the study. Two consumer panel sessions were needed to achieve the desired number of panelists. Consumers were given verbal and written instructions on how to complete the ballot before the first sample was served. Consumers were asked to rate *Longissimus lumborum* steaks for overall liking, liking of tenderness, liking of juiciness, and liking of flavor. Samples were rated on a nine-point category scale for liking where 1 = dislike extremely and 9 = like extremely. A subset of steaks was chosen to be either Slight or Small marbling to minimize the effect of USDA quality grade (Smith et al., 1984) on consumer panel results. Duplicate treatment samples, for a total of eight samples, were served to consumers in a random order. Steaks were cooked to a target endpoint temperature of 70 °C on a MagiKitch'n Conveyor Grill. Steaks were then cut into $1 \times 1 \times 2.54\ cm^3$ cubes and each consumer received two cubes of each sample. All samples were served warmed.

2.5. Statistical analysis

Statistical analyses were performed using GLM procedures of SAS (SAS Institute Inc., Cary, NC). Carcass and consumer panel data were analyzed as a completely randomized design for treatment effects. Fat content, Warner-Bratzler shear force, and fatty acids were analyzed as a split plot design with feeding regime and animal within feeding regime as whole plots and muscle and feeding regime by muscle as sub plots. Cooked and raw samples were analyzed separately. LSMEANS were generated and separated using least significant differences.

3. Results and discussion

The entire grazing period for this study was from July 23 to December 3, 2002. Rainfall during the period was very low with less than 2.5 cm per month occurring in June, September, October, and November. About 3.8 cm of rainfall occurred in July as several small events and 7.7 cm of rain fell during a 5-day period in August. Because of this extreme drought situation, pasture condition was very poor throughout the study. Estimated forage availability was 820 kg DM/ha at the beginning of the trial. The only period when forage availability exceeded this level was a 3-week period from late August to mid-September following the mid-August rainfall when available forage reached levels near 1225 kg DM/ha.

The level of forage available was less than 800 kg DM/ha at other periods during the study which may have led to less than optimal pasture voluntary intake. The respective ADG for the trial was 1.58, 0.77, 0.91, and 0.51 kg/d for feedlot, grain, soyoil, and pasture rations. Based on experience (Martz, Gerrish, Belyea, & Tate, 1999), we estimate that the gains observed on the pasture-based treatments were at least 0.2 kg/d lower than normally observed due to drought conditions.

Cattle finished on the feedlot ration were fatter ($P < 0.05$) than cattle finished on the other feeding regimes as evidenced by heavier carcass weights, increased fat thickness, higher percentage of kidney, pelvic and heart fat, and higher USDA yield and quality grade scores (Table 2). In addition, cattle finished on the feedlot ration were more muscular ($P < 0.05$) as evidenced by larger ribeye areas. Pasture finished cattle had the lightest carcass weights and lowest percentage of kidney, pelvic and heart fat ($P < 0.05$). Mandell, Buchanan-Smith, and Campbell (1998) also reported that grain finished cattle were higher in measures of fatness and muscling than forage finished cattle. Even though feedlot finished cattle had the highest mean USDA quality grade ($P < 0.05$), mean USDA quality grades of cattle from the other feeding regimes were considered to be acceptable. Drought conditions and poor pasture conditions probably contributed to the lack of uniform finish on the pasture finished treatments. Supplementation appeared to increase the amount of finish for cattle finished on pasture but the increase was not enough to elevate these cattle into higher carcass quality grades.

In agreement with Mandell et al. (1998); Laborde, Mandell, Tosh, Buchanan-Smith, and Wilton (2002) and Varela et al. (2004), Warner-Bratzler shear force values were not affected ($P > 0.05$) by feeding regime (Table 2). However, Warner-Brazler shear force values were lower ($P < 0.05$) for LD than SM or TB (Fig. 1). Similarly, Brooks et al. (2000) reported cuts containing LD to be more tender than cuts containing SM or TB. Whether comparing the Warner-Bratzler shear force values among treatments or muscles, the means are lower than the threshold of 4.6 kg for toughness established by Shackelford, Morgan, Cross, and Savell (1991) suggesting that steaks from cattle on feeding regimes that include pasture would be acceptable to consumers for tenderness.

Fatty acid composition comparisons between feeding regimes are presented in Table 3. Cattle finished on the feedlot diet had higher ($P < 0.05$) percentages of fat and lower ($P < 0.05$) percentages of moisture regardless of cooking state. This relationship was expected due to quality grade differences between the feeding regimes. In the raw state, meat from cattle finished on pasture had higher concentrations ($P < 0.05$) of polyunsaturated fatty acids than meat from cattle finished on the grain or feedlot diets. In the cooked state, meat from cattle finished on pasture had a higher ($P < 0.05$) ratio of polyunsaturated:saturated fatty acids compared to the feedlot and grain feeding regimes. Other research groups (French et al., 2000; Mir et al., 2002; O'Sullivan et al., 2004) have demonstrated

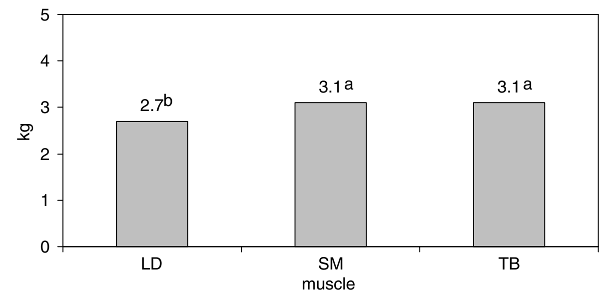

Fig. 1. Mean Warner-Bratzler shear force values (kg) for beef on different pasture feeding regimes stratified by muscle; where LD = *Longissimus lumborum*, SM = *Semimembranosus*, and TB = *Triceps brachii*. Means lacking a common superscript differ ($P < .05$).

greater effects on fatty acid composition due to diet than were seen in this study.

In the raw state, meat from cattle finished on the soyoil diet was higher ($P < 0.05$) in the *trans*-10, *cis*-12 isomer of CLA and total CLA on a mg/g fat basis than the grain or pasture feeding regimes (Table 3). On a mg/g fat basis, meat from cattle finished on the soyoil diet was the highest ($P < 0.05$) in total CLA followed by the pasture diet with meat from cattle finished in the feedlot or grain supplements on pasture having the lowest ($P < 0.05$) total CLA.

Diet has been shown to affect the CLA content in fat depots (Madron et al., 2002). Fat from pasture finished cattle have been reported to have higher total CLA contents than grain fed cattle (Poulson, Dhiman, Ure, Cornforth, & Olson, 2004; Realini, Duckett, & Windham, 2004; Steen & Porter, 2003). CLA contents of raw meat on a mg/g fat basis from the feedlot and grain supplement diets were similar to those reported by Shantha et al. (1994); these two diets most closely reflect commercial finishing procedures. However, CLA content of meat from cattle finished on the pasture and grain supplement diets were higher than the values reported by Shantha et al. (1994); the inclusion of soyhulls in the grain supplement used in the current study may explain the higher CLA content. Values reported for total CLA by Ma et al. (1999) on a mg/g fat and a mg/g sample basis were lower than the values reported in the present study. In agreement with the soyoil inclusion in the present study, Dhiman et al. (2005) feeding

Table 2
Carcass traits and Warner-Bratzler shear force means ± SE for cattle fed pasture, grain, or pasture supplemented with grain

Trait	Feedlot ($n = 12$)	Soyoil ($n = 12$)	Grain ($n = 11$)	Pasture ($n = 11$)
Hot carcass weight (kg)	$331.9^{a} \pm 8.3$	$286.5^{b} \pm 8.3$	$280.6^{b} \pm 8.7$	$254.6^{c} \pm 8.7$
Fat thickness (mm)	$111.1^{a} \pm 7.8$	$63.5^{b} \pm 7.8$	$54.3^{bc} \pm 8.2$	$34.6^{c} \pm 8.2$
Ribeye area (cm^2)	$77.5^{a} \pm 2.3$	$68.3^{b} \pm 2.3$	$70.5^{b} \pm 2.4$	$66.2^{b} \pm 2.4$
Kidney, pelvic and heart fat (%)	$3.0^{a} \pm 0.1$	$2.4^{b} \pm 0.1$	$2.3^{b} \pm 0.1$	$1.9^{c} \pm 0.1$
USDA yield grade	$3.2^{a} \pm 0.2$	$2.6^{b} \pm 0.2$	$2.4^{bc} \pm 0.2$	$2.1^{c} \pm 0.2$
Marbling score	Small $68^{a} \pm 20$	Slight $62^{b} \pm 20$	Slight $60^{b} \pm 21$	Slight $11^{b} \pm 21$
USDA quality grade	Choice-^{a} ± 1/3	Select-^{b} ± 1/3	Select-^{b} ± 1/3	Select-^{b} ± 1/3
Warner-Bratzler shear force (kg)	2.9 ± 0.1	2.9 ± 0.1	2.9 ± 0.1	3.0 ± 0.1

[a,b,c] Means within a row lacking a common superscript differ ($P < 0.05$).

Table 3
Mean fatty acid composition ± SE, expressed as fatty acid methyl esters, (mg/g fat) of beef stratified by feeding regime

Fatty acid	Feedlot ($n = 12$)	Soyoil ($n = 12$)	Grain ($n = 11$)	Pasture ($n = 11$)
Raw				
Moisture (%)	$71.4^{c} \pm .3$	$72.4^{b} \pm .3$	$73.4^{a} \pm .3$	$73.3^{a} \pm .3$
Fat (%)	$5.7^{a} \pm .3$	$4.6^{b} \pm .3$	$3.7^{c} \pm .3$	$3.7^{bc} \pm .3$
SFA[d]	378.13 ± 20.76	357.05 ± 20.76	401.44 ± 21.68	416.29 ± 21.68
MUFA[e]	407.45 ± 18.45	309.89 ± 18.45	360.30 ± 19.27	338.24 ± 19.27
PUFA[f]	$55.58^{b} \pm 3.17$	$59.50^{ab} \pm 3.17$	$53.47^{b} \pm 3.31$	$66.27^{a} \pm 3.31$
Total UFA[g]	463.03 ± 19.75	369.39 ± 19.75	413.77 ± 20.63	404.51 ± 20.63
PUFA:SFA	0.15 ± 0.01	0.17 ± 0.01	0.14 ± 0.01	0.17 ± 0.01
N6:N3	53.67 ± 5.37	22.64 ± 5.37	16.71 ± 5.61	10.42 ± 5.61
CLA				
cis-9, *trans*-11[h]	4.29 ± 0.50	11.31 ± 0.50	4.76 ± 0.52	6.47 ± 0.52
trans-10, *cis*-12[i]	$0.43^{ab} \pm 0.12$	$0.63^{a} \pm 0.12$	$0.23^{b} \pm 0.13$	$0.13^{b} \pm 0.13$
cis-9, *cis*-11[j]	0.06 ± 0.08	0.06 ± 0.08	0.20 ± 0.08	0.11 ± 0.08
trans-9, *trans*-11[k]	0.15 ± 0.01	0.17 ± 0.01	0.14 ± 0.01	0.17 ± 0.01
Total CLA	$6.10^{c} \pm 0.82$	$14.24^{a} \pm 0.82$	$6.68^{c} \pm 0.85$	$9.95^{b} \pm 0.85$
Cooked				
Moisture (%)	$60.5^{b} \pm .4$	$63.0^{a} \pm .4$	$62.9^{a} \pm .4$	$63.6^{a} \pm .4$
Fat (%)	$8.1^{a} \pm .4$	$6.2^{b} \pm .4$	$5.3^{bc} \pm .4$	$4.6^{c} \pm .4$
SFA	$282.88^{b} \pm 16.33$	$300.19^{ab} \pm 16.33$	$344.47^{a} \pm 17.05$	$310.72^{ab} \pm 17.05$
MUFA	$309.69^{a} \pm 13.12$	$261.35^{b} \pm 13.12$	$310.29^{a} \pm 13.70$	$257.93^{b} \pm 13.70$
PUFA	$52.84^{c} \pm 2.93$	$61.58^{ab} \pm 2.87$	$59.77^{bc} \pm 3.00$	$69.21^{a} \pm 3.00$
Total UFA	$365.75^{ab} \pm 14.03$	$322.94^{c} \pm 13.72$	$370.06^{a} \pm 14.33$	$327.14^{bc} \pm 14.33$
PUFA:SFA	$0.19^{b} \pm 0.02$	$0.22^{ab} \pm 0.02$	$0.18^{b} \pm 002$	$0.24^{a} \pm 0.02$
N6:N3	$40.84^{a} \pm 2.71$	$19.25^{b} \pm 2.65$	$12.29^{bc} \pm 2.77$	$9.26^{c} \pm 2.77$
CLA				
cis-9, *trans*-11	$2.85^{c} \pm 0.43$	$9.38^{a} \pm 0.43$	$4.31^{b} \pm 0.45$	$5.24^{b} \pm 0.45$
trans-10, *cis*-12	0.10 ± 0.14	0.28 ± 0.14	0.42 ± 0.14	0.20 ± 0.14
cis-9, *cis*-11	0.000 ± 0.02	0.000 ± 0.02	0.000 ± 0.02	0.050 ± 0.02
trans-9, *trans*-11	1.02 ± 0.19	1.82 ± 0.19	1.41 ± 0.20	1.92 ± 0.20
Total CLA	$3.97^{c} \pm 0.51$	$11.48^{a} \pm 0.51$	$6.15^{b} \pm 0.53$	$7.36^{b} \pm 0.53$

[a,b,c] Means within a row lacking a common superscript differ ($P < 0.05$).
[d] SFA = saturated fatty acid.
[e] MUFA = monounsaturated fatty acid.
[f] PUFA = polyunsaturated fatty acid.
[g] UFS = unsaturated fatty acid.
[h] *cis*-9, *trans*-11 may also contain minor amounts of *trans*-7, *cis*-9 and *cis*-8, *trans*-10 isomers (Fritsche et al., 2000).
[i] *trans*-10, *cis*-12 may also contain minor amounts of *cis*-12, *trans*-14 (Fritsche et al., 2000).
[j] *cis*-9, *cis*-11 may also contain minor amounts of *trans*-11, *cis*-13; *cis*-7, *cis*-9; and *cis*-8, *cis*-10 isomers (Fritsche et al., 2000).
[k] *trans*-9, *trans*-11 may also contain minor amounts of *trans*-8, *trans*-10 and *trans*-10, *trans*-12 isomers (Fritsche et al., 2000).

soyoil and Mir et al. (2002) feeding sunflower oil reported higher CLA levels when a source of vegetable oil was included in the diet. Both soyoil and sunflower oil contain high amounts of linoleic acid which can be converted to CLA through ruminal biohydrogenation.

In the cooked state, the amount of saturated fatty acids was highest ($P < 0.05$) in the meat from cattle finished on the grain diet and lowest ($P < 0.05$) for those finished on the feedlot diet (Table 3). Meat from cattle finished on the feedlot and grain diets was higher ($P < 0.05$) in monounsaturated fatty acids than meat from cattle finished on the soyoil and pasture diets, whereas polyunsaturated fatty acid concentrations were higher ($P < 0.05$) in meat from cattle finished on pasture than meat from cattle finished on grain or feedlot regimes. Total unsaturated fatty acids were highest ($P < 0.05$) in meat from cattle finished on grain diets and lowest ($P < 0.05$) in meat from cattle finished on the soyoil diet. The ratio N6:N3 fatty acids were highest ($P < 0.05$) in meat from cattle finished on the feedlot diet compared to all other diets.

Meat from cattle finished on the soyoil diet was highest ($P < 0.05$) in total CLA on a mg/g fat basis, in the raw state, compared to the other feeding regimes (Table 3). Ma et al. (1999) reported similar levels for total CLA content on a mg/g sample basis as the values reported in this study, while Shantha et al. (1994) reported levels of CLA content on a mg/g sample basis that were much higher, approximately twice as high, for cooked ground beef patties than the levels reported in this study. The fat content differences between the samples used in the studies are probably responsible for these differences. On a cooked basis, meat from cattle finished on the soyoil diet had the highest ($P < 0.05$) level of both the *cis*-9, *trans*-11 isomer and total CLA followed by the grain and pasture diets with meat from cattle finished on the feedlot diet having the lowest ($P < 0.05$). Total CLA values on a mg/g fat basis in the cooked state are similar to those reported by Shantha et al. (1994) and Ma et al. (1999) for meat from feedlot, grain supplement, and pasture feeding regimes with values for meat from the soyoil diet being higher. Data from this study indicate that in the cooked state or as meat is consumed, the inclusion of pasture in the diet will increase the total CLA content of the meat when cattle are finished to a constant fat endpoint.

Fatty acid composition comparisons between muscles are presented in Table 4. In the raw state, TB had the highest ($P < 0.05$) fat percentage but no difference ($P > 0.05$) in moisture content between muscles was observed. In the cooked state, fat content differed ($P < 0.05$) by muscle with LD having a higher percentage of fat than TB which was higher than SM. Fat percentages, in both the raw and cooked states, are similar to values reported by Smith, Savell, Smith, and Cross (1989). No differences ($P > 0.05$) were detected in percentage moisture between muscles. The concentration of monounsaturated fatty acids was higher ($P < 0.05$) in cooked SM and TB than LD. In the cooked state, the amount of polyunsaturated fatty acids and ratio of polyunsaturated:saturated fatty acids was highest ($P < 0.05$) for SM, followed by TB and lowest ($P < 0.05$) for LD. The N6:N3 fatty acid ratio was higher ($P < 0.05$) for SM than LD and TB.

In the cooked state, SM was the lowest ($P < 0.05$) in the *cis*-9, *trans*-11 isomer on a mg/g sample basis (data not shown) and TB was the highest ($P < 0.05$) on a mg/g fat basis. Values reported in the present study for total CLA on a mg/g fat basis in the raw and cooked states are similar to the high end of the range reported by Shantha et al. (1994) and Ma et al. (1999) for different steaks. On a mg/g sample basis in the cooked state, Ma et al. (1999) reported similar values for total CLA content to the present study. However, Shantha et al. (1994) reported much higher CLA contents for ground beef than the present

Table 4
Mean fatty acid composition ± SE, expressed as fatty acid methyl esters, (mg / g fat) stratified of beef by muscle ($n = 46$/muscle)

Fatty acid	*Longissimus lumborum*	*Semimembranosus*	*Triceps brachii*
Raw			
Moisture (%)	72.8 ± .2	72.6 ± .2	72.5 ± .2
Fat (%)	4.2^b ± .2	3.8^b ± .2	5.3^a ± .2
SFA[d]	450.51 ± 16.06	363.85 ± 16.06	350.32 ± 16.06
MUFA[e]	369.74 ± 16.24	345.52 ± 16.24	346.65 ± 16.24
PUFA[f]	57.99 ± 2.06	58.60 ± 2.06	59.53 ± 2.06
Total UFA[g]	427.73 ± 17.71	404.12 ± 17.71	406.18 ± 17.71
PUFA:SFA	0.14 ± 0.01	0.17 ± 0.01	0.18 ± 0.01
N6:N3	22.44 ± 3.60	32.44 ± 3.60	22.70 ± 3.60
CLA			
cis-9, *trans*-11[h]	6.15 ± 0.33	6.80 ± 0.33	7.17 ± 0.33
trans-10, *cis*-12[i]	0.45 ± 0.08	0.35 ± 0.08	0.27 ± 0.08
cis-9, *cis*-11[j]	0.00^b ± 0.07	0.32^a ± 0.07	0.00^b ± 0.07
trans-9, *trans*-11[k]	2.03 ± 0.56	2.69 ± 0.56	1.81 ± 0.56
Total CLA	8.64 ± 0.73	9.83 ± 0.73	9.25 ± 0.73
Cooked			
Moisture (%)	63.0 ± .3	62.3 ± .3	62.2 ± .3
Fat (%)	7.2^a ± .2	4.6^c ± .2	6.4^b ± .2
SFA	321.43 ± 9.68	295.84 ± 9.68	311.42 ± 9.68
MUFA	271.30^b ± 9.19	287.97^a ± 9.19	295.18^a ± 9.19
PUFA	47.28^c ± 2.14	71.56^a ± 2.14	63.71^b ± 2.17
Total UFA	318.58 ± 10.19	359.53 ± 10.19	361.31 ± 10.19
PUFA:SFA	0.16^c ± 0.01	0.25^a ± 0.01	0.21^b ± 0.01
N6:N3	17.81^b ± 2.38	26.80^a ± 2.38	16.64^b ± 2.42
CLA			
cis-9, *trans*-11	5.10^b ± 0.27	5.15^b ± 0.27	6.08^a ± 0.27
trans-10, *cis*-12	0.16 ± 0.13	0.45 ± 0.13	0.15 ± 0.13
cis-9, *cis*-11	0.00 ± 0.02	0.00 ± 0.02	0.04 ± 0.02
trans-9, *trans*-11	1.34 ± 0.15	1.58 ± 0.15	1.71 ± 0.15
Total CLA	6.60^b ± 0.35	7.18^{ab} ± 0.35	7.93^a ± 0.35

[a,b,c] Means within a row lacking a common superscript differ ($P < 0.05$).
[d] SFA = saturated fatty acid.
[e] MUFA = monounsaturated fatty acid.
[f] PUFA = polyunsaturated fatty acid.
[g] UFS = unsaturated fatty acid.
[h] *cis*-9, *trans*-11 may also contain minor amounts of *trans*-7, *cis*-9 and *cis*-8, trans-10 isomers (Fritsche et al., 2000).
[i] *trans*-10, *cis*-12 may also contain minor amounts of *cis*-12, *trans*-14 (Fritsche et al., 2000).
[j] *cis*-9, *cis*-11 may also contain minor amounts of *trans*-11, *cis*-13; *cis*-7, *cis*-9; and *cis*-8, *cis*-10 isomers (Fritsche et al., 2000).
[k] *trans*-9, *trans*-11 may also contain minor amounts of *trans*-8, *trans*-10 and *trans*-10, *trans*-12 isomers (Fritsche et al., 2000).

study. Differences in fat contents between the present study and Shantha et al. (1994) may explain the differences in CLA contents.

No muscle by feeding regime interactions ($P > 0.05$) existed for fatty acid composition in the cooked state. However, in the raw state, muscle by feeding regime interactions ($P < 0.05$) existed for monounsaturated fatty acids, total unsaturated fatty acids, saturated fatty acids, polyunsaturated:saturated fatty acid ratio and N6:N3 fatty acid ratio (Fig. 2). Data from monounsaturated, total saturated, and saturated fatty acids indicate that diet and muscle contribute equally to the interaction. Differences in monounsaturated, total unsaturated and saturated fatty acids due to diet have been observed by others (Laborde et al., 2002; Nurenberg et al., 2002; O'Sullivan et al., 2004). However, a lack of difference in concentrations of saturated and unsaturated fatty acids due to diet has been observed by other researchers (Dannenberger et al., 2004; Dhiman et al., 2005; Engle & Spears, 2004; Griswold et al., 2003). The interaction for the N3:N6 fatty acid ratio indicates a trend toward an elevated amount in meat for cattle finished on feedlot diets. This agrees with the findings of Nurenberg et al. (2002).

Muscle by feeding regime interactions ($P < 0.05$) for CLA content existed in the raw state for the *cis*-9, *trans*-11 isomer on a mg/g fat basis, and in the cooked state for *trans*-9, *trans*-11 isomer on a mg/g fat basis (Fig. 3). In agreement with Griswold et al. (2003), the *cis*-9, *trans*-11 isomer in the raw state, concentration in all three muscles was the highest ($P < 0.05$) for the soyoil diet. Gibb et al. (2004) reported higher *cis*-9, *trans*-11 isomer concentrations in muscle of cattle fed whole sunflower seeds which were high in fat.

Consumer panel means are presented in Table 5. Consumers rated meat from the feedlot diet highest ($P < 0.05$) for overall like, liking of flavor, and liking of juiciness. No differences ($P > 0.05$) were detected between the other three feeding regimes for these attributes. Consumers did not discriminate ($P > 0.05$) with their ratings for liking of tenderness. It is important to note that on a

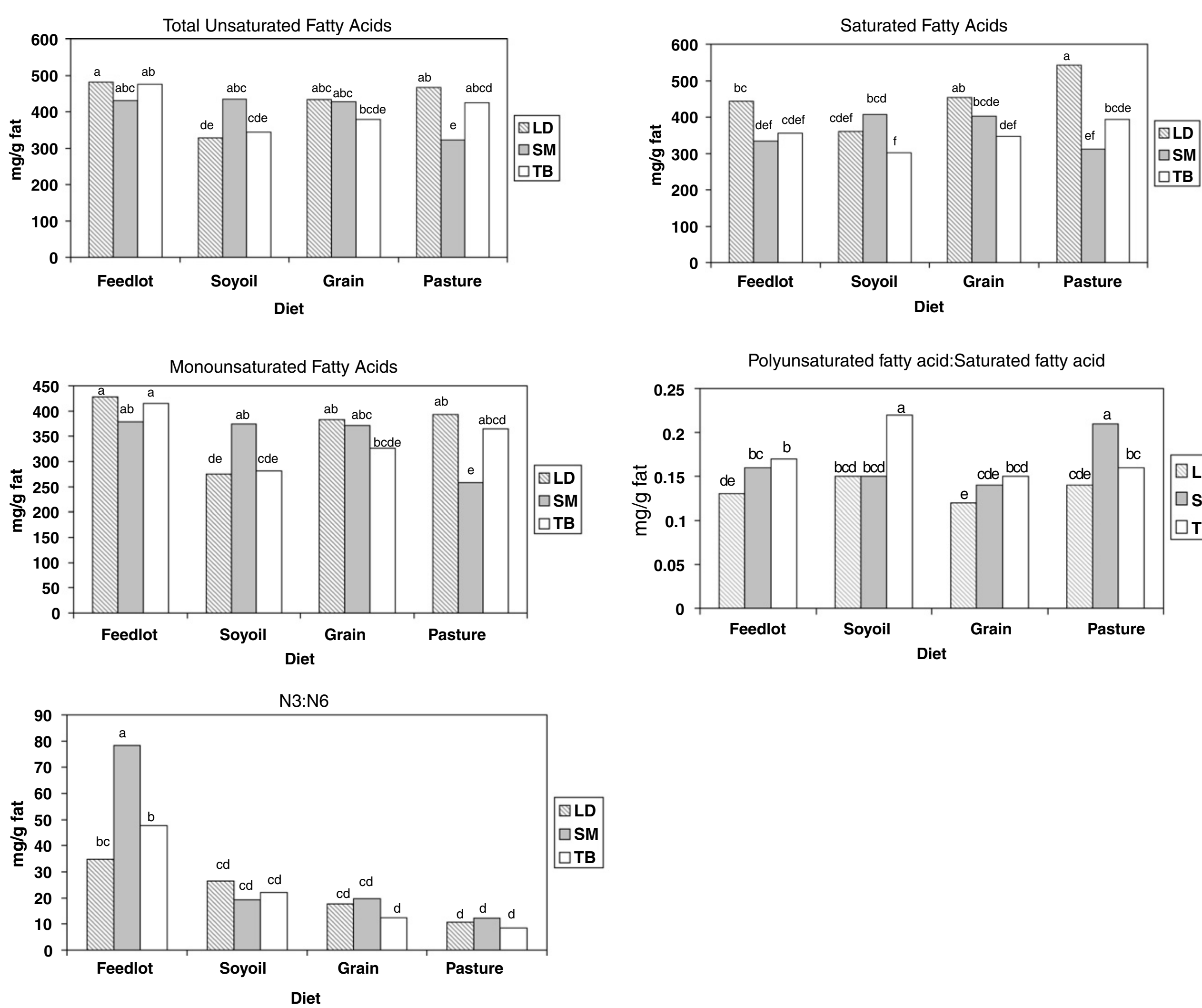

Fig. 2. Feeding regime by muscle interactions for fatty acid content, expressed as fatty acid methyl esters, of raw samples; where LD = *Longissimus lumborum*, SM = *Semimembranosus*, and TB = *Triceps brachii*. Means within a fatty acid graph lacking a common superscript differ ($P < .05$).

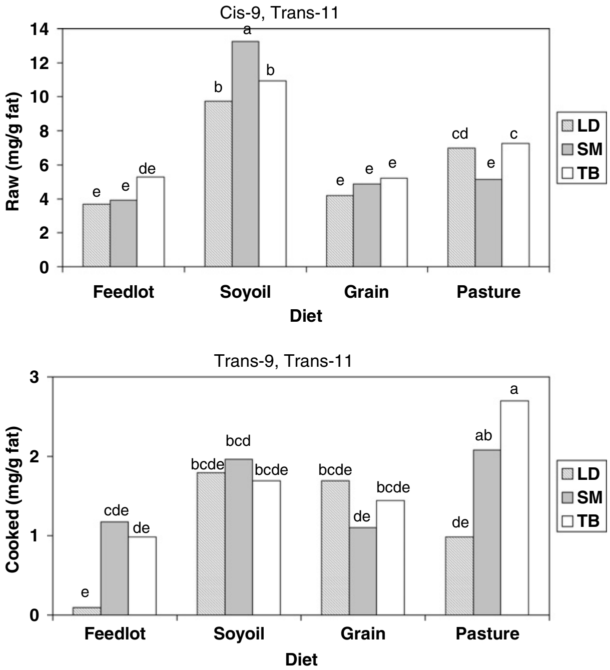

Fig. 3. Feeding regime by muscle interactions for conjugated linoleic acid (CLA) content, expressed as fatty acid methyl esters, of raw and cooked samples; where LD = *Longissimus lumborum*, SM = *Semimembranosus*, and TB = *Triceps brachii*. Means within a CLA graph lacking a common superscript differ ($P < .05$).

nine-point scale any rating above a 5.0 indicates that the attribute was found to be acceptable. Therefore, all meat was found to be acceptable by the consumer panel regardless of feeding regime.

In summary, the amount of CLA in cooked meat can be increased by the inclusion of pasture, with or without grain supplementation, in the finishing diet compared to conventional feedlot diets. Pasture inclusion in the finishing diet was not detrimental to the eating quality of beef. Although feeding regime was able to increase the CLA content in cooked beef, it is important to note that, at the levels of CLA achieved in this study, one serving of beef per day would not be sufficient to achieve a dietary intake of CLA that has been shown to be beneficial in animal and human trials.

Table 5
Consumer panel ($n = 87$) means[A] (±SE) for beef *Longissimus lumborum* stratified by feeding regime

Consumer attribute	Feedlot	Soyoil	Grain	Pasture
Overall like	$6.5^b \pm 0.1$	$5.9^c \pm 0.1$	$5.8^c \pm 0.1$	$5.8^c \pm 0.1$
Liking of tenderness	6.3 ± 0.1	6.1 ± 0.1	6.1 ± 0.1	5.8 ± 0.1
Liking of flavor	$6.4^b \pm 0.1$	$5.6^c \pm 0.1$	$5.7^c \pm 0.1$	$5.7^c \pm 0.1$
Liking of juiciness	$6.5^b \pm 0.1$	$5.4^c \pm 0.1$	$5.5^c \pm 0.1$	$5.7^c \pm 0.1$

[b,c] Means within a row lacking a common superscript differ ($P < 0.05$).
[A] Based on a nine-point hedonic scale with 1 = Dislike extremely and 9 = Like extremely.

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