Effects of grain processing and dietary lipid source on performance, carcass characteristics, plasma fatty acids, and sensory properties of steaks from finishing cattle

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Effects of grain processing and dietary lipid source on performance, carcass characteristics, plasma fatty acids, and sensory properties of steaks from finishing cattle[1,2]

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ABSTRACT: An experiment was conducted to evaluate the effects of grain processing and lipid addition to finishing diets on cattle performance, carcass characteristics, and meat quality. Eighty Hereford × Angus steers (384 kg ± 17 kg of BW) were fed diets containing steam-flaked corn (SFC) or dry-rolled corn (DRC) with and without the addition of tallow (SFC/Fat and DRC/Fat) or steam-flaked corn with ground flaxseed (SFC/Flax). Ribeye steaks from steers fed SFC, SFC/Fat, or SFC/Flax were used to evaluate the effects of fat source on meat quality. Cattle fed SFC and SFC/Fat tended to have greater ADG, G:F, HCW, and USDA yield grade, compared with those fed DRC and DRC/Fat ($P < 0.10$). Steaks from steers fed SFC/Flax developed a detectable off-flavor ($P < 0.05$) compared with steaks from steers fed SFC and SFC/Fat, and steaks from steers fed SFC retained desirable color longer than those from steers fed SFC/Flax ($P < 0.05$). Feeding SFC/Flax increased deposition of α-linolenic acid in muscle tissue compared with feeding SFC or SFC/Fat ($P < 0.01$). Dietary treatment did not cause differences in tenderness, juiciness, or flavor intensity. Ground flaxseed can replace tallow in finishing diets without loss in performance, but flax may affect flavor and color stability of beef. Feeding flaxseed can effectively alter composition of carcass tissues to yield beef that is high in n-3 fatty acids.

Key words: steam-flaked corn, dry-rolled corn, flaxseed, essential fatty acid

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INTRODUCTION

Tallow is frequently an economical source of energy for cattle rations and is high in SFA. Elliot et al. (1999) demonstrated that as the amount of SFA increased in dietary fat, ruminal lipolysis decreased, thereby resulting in decreased total tract digestibility and an increase in the flow of triglycerides to the duodenum. Flaxseed contains approximately 41% lipid, 73% of which is PUFA.

Previous studies demonstrated that fatty acid composition of bovine tissues can be influenced by dietary regimens (Rule et al., 1994; Mandell et al., 1997). In ruminants, altering tissue fatty acid composition is difficult, because unsaturated fatty acids are extensively biohydrogenated by rumen microorganisms (Demeyer and Doreau, 1999). Previously demonstrated incorporation of dietary PUFA into edible tissues suggests that at least a portion of fatty acids can escape biohydrogenation by ruminal microorganisms (Lough et al., 1992; Rule et al., 1994). Casutt et al. (2000) observed increased concentrations of α-linolenic acid in adipose tissue of Brown Swiss bulls fed flaxseed, and Focant et al. (1998) demonstrated that feeding linseed oil to lactating dairy cows increased n-3 fatty acid deposition in soft tissues.

Notable effects of n-3 fatty acids in human diets include improved immunity (Harbige, 1998), reduced risk of cardiovascular disease (Alexander, 1998), and antiinflammatory relief for rheumatoid arthritis (Belch and Muir, 1998). Given the potential health benefits associated with consumption of n-3 fatty acids, increasing the concentration of α-linolenic acid in edible tissues of beef could provide an alternative means of increasing intake of these fatty acids. Most pertinent to the underlying purpose of this study, Medeiros et al. (2007) demonstrated that feeding n-3 fatty acid-enriched beef to rats resulted in increased n-3 fatty acid content in heart and liver membranes and decreased cholesterol levels. The objectives of this investigation were to determine the effects of differences

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Table 1. Composition of the experimental diets (100% DM basis)

	Diets[1]				
Item	SFC	SFC/Fat	DRC	DRC/Fat	SFC/Flax
Steam-flaked corn	79.6	75.6	—	—	69.6
Dry-rolled corn	—	—	79.6	75.6	—
Ground flaxseed	—	—	—	—	10.0
Alfalfa hay	8.0	8.0	8.0	8.0	8.0
Molasses	4.0	4.0	4.0	4.0	4.0
Tallow	—	4.0	—	4.0	—
Salt	0.30	0.30	0.30	0.30	0.30
Limestone	1.15	1.15	1.15	1.15	1.15
Monocalcium phosphate	0.12	0.12	0.12	0.12	0.12
Urea	1.19	1.19	1.19	1.19	1.19
Soybean meal	3.06	3.06	3.06	3.06	3.06
Vitamin-mineral mix[2]	0.29	0.29	0.29	0.29	0.29
Monensin-tylosin premix[3]	2.23	2.23	2.23	2.23	2.23
CP,[4] %	14.2	13.9	14.2	13.9	15.8

[1]SFC = steam-flaked corn; SFC/Fat = steam-flaked corn plus 4% tallow; DRC = dry-rolled corn; DRC/Flax = dry-rolled corn plus 10% ground flaxseed; SFC/Flax = steam-flaked corn plus 10% ground flaxseed
[2]Provided (per mg of diet): 8.0 mg of Cu, 0.10 mg of Co, 50 mg of Mn, 0.25 mg of Se, 50 mg of Zn, 2,650 IU of vitamin A, and 20 IU of vitamin E.
[3]Provided 33 mg/kg of monensin and 11 mg/kg of tylosin of diet DM in a ground corn carrier.
[4]Analyzed CP, %.

in grain processing or sources of dietary lipids on performance and meat quality in finishing steers.

MATERIALS AND METHODS

This study was conducted in accordance with procedures approved by the Kansas State University Institutional Animal Care and Use Committee.

To minimize differences in gastrointestinal fill, 80 Hereford × Angus steers (384 kg of BW ± 17 kg) were adapted to a common diet based on dry-rolled corn for 7 d before the experiment was initiated. Animals were stratified by initial BW and allotted, within strata, to 5 experimental treatments, with a total of 16 steers per treatment. The experiment was conducted as a randomized complete block design, with each animal as the experimental unit. Dietary treatments were as follows: steam-flaked corn (SFC), steam-flaked corn plus 4% tallow (SFC/Fat), dry-rolled corn (DRC), dry-rolled corn plus 4% tallow (DRC/Fat), or steam-flaked corn plus 10% ground flaxseed (SFC/Flax). Composition of experimental diets is shown in Table 1. Steers were implanted with Component-TES (Vetlife Inc., Norcross, GA) and placed into individual pens and fed their respective diets once daily to allow ad libitum consumption for 85 d.

On d 85, steers were individually weighed and shipped 145 km to a commercial slaughter facility and slaughtered after a 4-h period, after which carcass data were obtained. Liver abscess scores and HCW were obtained at slaughter. Percentage of KPH, 12th-rib fat thickness, marbling score, LM area, USDA yield grade, and USDA quality grade were obtained after a 24-h chill. Dressing percentages were calculated, on an individual basis, as HCW divided by final live BW.

After a 24-h chill, wholesale ribs were removed from the left side of each carcass. Ribs were sealed in vacuum packages and aged for 21 d (the current trend in high-value branded beef is for 21-d aging) at 4°C. Steaks (1 steak per side; 2.54-cm thick) were cut from the caudal end of the rib and were used for the following analyses: fatty acid composition, retail display color stability, sensory characteristics, and fatty acid oxidation potential (thiobarbituric acid reactive substances, **TBARS**). Similar locations within the steaks were utilized for common assay. Steaks were individually vacuum-packaged and frozen at –14°C to facilitate grinding, except for steaks used in the retail display color evaluation. Assessment of color change during retail display was initiated immediately after cutting of the steaks.

Blood was collected from steers (15 h postfeeding) 14 d before slaughter into heparinized vacuum tubes (BD, Franklin Lakes, NJ) and immediately placed in ice before centrifuging at 1,200 × *g* for 20 min to recover plasma. Plasma (250 μL) was combined with 2 mL of boron trifluoride [112% (wt/wt) in methanol] and subsequently was heated in a water bath for 60 min at 60°C for transmethylation. Upon cooling, the addition of 2 mL of water and 0.5 mL of hexane allowed the methyl esters to be extracted and transferred to a vial for subsequent quantification of the methylated fatty acids by gas chromatography for fatty acid analysis of beef samples. A ribeye steak from each steer was coarsely ground through a plate grinder and subsampled. Ribeye samples (1 g) were extracted by using 20 mL of a 1:2 (vol/vol) chloroform and methanol solution (Nelson, 1991). After lipid extraction, samples were dried under N_2 and subjected to transmethylation in the presence of 2 mL of boron trifluoride for 60 min at

60°C. Upon cooling, the addition of 2 mL of water and 1 mL of hexane allowed the fatty acid methyl esters to be extracted and transferred to a vial. Separation of fatty acid methyl esters in plasma and meat samples was performed on a flame ionization gas chromatograph (Hewlett Packard model 5890, series II, Palo Alto, CA) equipped with a Hewlett Packard 23 column (0.32-mm i.d.) using He as the carrier gas at a flow rate of 1 mL/min. Initial temperature was 60°C for 4 min, and this was followed by an increase of 20°C/min to a final temperature of 195°C.

Color was evaluated after individual steaks (2.54-cm thick) were placed onto polystyrene thermal insulation trays with meat pads (Dri-Loc 50, Cryovac Sealed Air Corporation, Duncan, SC) and overwrapped with polyvinyl chloride film [MAPAC M (23,250 mL/m^2 per 24 h, 72 ga), Bordon Packaging and Industrial Products, North Andover, MA]. After packaging, steaks were placed under retail display lighting at 1,614 lx (40W Deluxe Warm White, Philips Lighting Company, Somerset, NJ) in a refrigerated walk-in cooler (FS4C, Butcher Boy, Harvard, IL). Temperature was maintained at 1.6°C throughout the display period. Steak color was analyzed instrumentally throughout a 7-d display for International Commission on Illumination L*, a*, and b* values for illuminant A and for reflectance from 400 to 700 nm, with 10-nm increments by using a Miniscan XE Spectrophotometer (3.18-cm diam. aperture, Hunter Associates Laboratory, Reston, VA). Hue angle, saturation index, and 630 nm:580 nm ratios (greater values of the 630 nm:580 nm ratio indicate more redness) were calculated (AMSA, 1991). Each steak was scanned at 3 locations within the LM, and measurements were subsequently averaged to obtain values for each time point. Steaks were scanned on d 0, 3, 5, and 7 while being aged in vacuum packages for 21 d at 14°C.

Descriptive attribute sensory evaluations of the ribeye steaks were conducted with a 7-member panel trained according to AMSA (1995) guidelines. Before product testing, panelists were oriented to flavor, texture, and aroma attributes of a sample to ensure equivalent scores. Steaks were thawed and subsequently cooked to 71°C in a DFG-102 CH-3 Blodgett modified broiler oven (GS Blodgett Company Inc., Burlington, VT). Temperature was monitored by thermocouples attached to a Doric Minitrend 205 (Vas Engineering, San Francisco, CA) temperature monitor. Cooked steaks (2.54-cm thick) were cut into 1.27 × 1.27 × 2.54-cm pieces for evaluation. Each treatment was given a 2-letter code, and order of presentation was randomized for each test session. Panelists were instructed to place each sample (parallel or perpendicular) horizontally on their molars to evaluate 6 texture attributes. Unsalted crackers and deionized rinse water were consumed between individual samples, which were presented approximately 3 min apart. Samples were scored according to an 8-point scale and scored to the nearest ½ point. Panelists were also asked to record the presence of off-flavors.

Lipid oxidation was measured through content of TBARS. Ten grams of frozen sample (–20°C or below) was pulverized in liquid N2. The pulverized sample was combined with 15 mL of 7.2% perchloric acid solution and then 20 mL of cold water to precipitate the protein and malonaldehyde. Samples were gravity-filtered through Whatman No. 2 filter paper (Whatman International Ltd., Maidstone, United Kingdom), and the filtrate was combined with 5 mL of 0.02 *M* thiobarbituric acid reagent (1.4415 g of thiobarbituric acid and 500 mL of deionized water) and stored for 15 to 18 h in complete darkness. Absorbance was measured on a spectrometer at 550 nm. Values are reported as milligrams of malonaldehyde per kilogram of steak.

Performance and carcass data were analyzed by ANOVA as a 2 × 2 + 1 randomized complete block design by using the MIXED procedure (SAS Inst. Inc., Cary, NC). The experimental unit was the individual animal blocked by weight. Mean separation was accomplished through contrasts comparing SFC and SFC/Fat vs. DRC and DRC/Fat and SFC and DRC vs. SFC/Fat and DRC/Fat. Treatment means were compared by using the LSD comparison for SFC/Fat vs. SFC/Flax for performance, carcass, and blood data. The GLM procedure of SAS was used for analysis of sensory evaluations, color profile, and spectral data (630:580) of ribeye steaks, with pairwise comparisons used to compare means of dietary treatments. The MIXED procedure of SAS was used for analysis of TBARS and plasma and ribeye fatty acid concentration. Means and contrasts were considered significantly different when the *F*-test was < 0.05, with an *F*-test of < 0.10 considered as a tendency approaching significance.

RESULTS AND DISCUSSION

Diets are shown in Table 1. The CP concentration of the SFC/Flax diet was greater than that of other treatments. Long-chain fatty acid concentrations of dietary lipid sources are presented in Table 2. Flaxseed contained more PUFA than tallow, and tallow had high concentrations of SFA and MUFA. Steers fed diets containing flaked grain tended to have greater ADG (Table 3), resulting in a tendency toward greater HCW compared with HCW of steers fed diets containing rolled corn ($P < 0.10$). Daily gain and G:F were similar ($P = 0.60$) for steers fed diets with flaxseed vs. tallow in diets containing steam-flaked corn. Dry matter intake did not differ among diets ($P = 0.43$), and G:F tended to be improved for steers fed SFC and SFC/Fat diets, compared with performance of steers fed diets containing DRC ($P < 0.10$), which was similar to results observed by Zinn (1987). In the current study, adding tallow to diets of finishing steers resulted in less s.c. fat deposition over the 12th rib, compared with not adding tallow ($P < 0.01$; Table 3), which is in agreement with previous research (Bock et al.,

Table 2. Long-chain fatty acid concentrations of dietary lipid ingredients

Item	Ingredient	
	Tallow	Flaxseed
Total fatty acids, % of DM	79.5	34.8
Fatty acid, % of total fatty acids		
C14:0	3.2	—
C16:0	24.9	6.4
C16:1	3.2	—
C18:0	22.5	3.1
C18:1	43.6	20.3
C18:2	2.3	15.9
C18:3	0.3	54.2
C20:5	—	—
C22:5n-6	—	—
C22:6n-3	—	—

1991; Bindel et al., 2000). There were no differences in percentages of carcasses grading USDA Choice or in KPH among diets ($P = 0.55$). Yield grade tended to be lower ($P < 0.10$) for steers fed dry-rolled corn than for steers fed steam-flaked corn. Contrary to the current study, observations from Bindel et al. (2000) noted a linear increase in KPH, decreased LM area, and increased yield grade with increasing fat inclusion (0 to 4%) in finishing heifer diets. In the present experiment, incidence of liver abscesses tended to be greater for steers fed SFC and SFC/Fat ($P < 0.10$) than for those fed DRC or DRC/Fat.

Plasma concentrations of fatty acids are presented in Table 4. Feeding SFC/Flax to steers increased ($P <$

Table 4. Plasma long-chain fatty acids[1] from cattle fed diets supplemented with tallow or flaxseed

Fatty acid	Diet[2]			
	SFC	SFC/Fat	SFC/Flax	SEM
C11:0	5.0	8.1	10.4	2.8
C12:0	14.2	14.6	7.2	5.5
C13:0	2.2^{b}	6.9^{ab}	12.8^{a}	3.3
C14:0	16.9	17.8	11.7	2.9
C14:1	1.7^{cd}	2.5^{c}	0.0^{d}	1.0
C15:0	13.7^{cd}	14.0^{c}	9.4^{d}	1.8
C15:1	1.9^{d}	7.9^{cd}	10.3^{c}	3.1
C16:0	185^{a}	257^{b}	198^{a}	14.2
C16:1	2.8^{a}	20.0^{b}	5.5^{a}	2.4
C17:1	11.6	14.5	7.2	2.8
C18:0	1,466	1,406	908	409
C18:1n-9	256	94	248	96
C18:1n-9c	217	200	120	43
C18:2	1,212	1,287	1,317	102
C18:3n-6	13.7^{ab}	20.4^{a}	7.4^{b}	3.1
C18:3n-3	12^{a}	33^{a}	275^{b}	19
C20:2	31	24	3	16
C20:3	392	24	130	190
C20:4n-6	33	35	31	9.8
C22:0	22	10	13	8.1

^{a,b}Within a row, means without a common superscript letter differ ($P < 0.05$).

^{c,d}Within a row, means without a common superscript letter differ ($P < 0.10$).

[1]Values expressed as micrograms of fatty acid per milliliter of plasma.

[2]SFC = steam-flaked corn; SFC/Fat = steam-flaked corn plus 4% tallow; SFC/Flax = steam-flaked corn plus 10% ground flaxseed.

Table 3. Performance and carcass traits of finishing steers fed diets differing in grain processing and fat source

Item	Diets[1]					
	SFC	SFC/Fat	DRC	DRC/Fat	SFC/Flax	SEM
Steers, n	16	16	16	16	16	—
Initial BW, kg	402	406	409	403	403	17
Final BW,[2] kg	557	555	541	537	555	24
DMI, kg/d	9.72	9.20	9.62	9.47	9.18	0.55
ADG,[2] kg	1.83	1.75	1.56	1.58	1.80	0.15
G:F[2]	0.18	0.19	0.16	0.17	0.20	0.0053
Carcass-adjusted gain,[3] kg/d	1.85	1.82	1.49	1.57	1.78	0.139
HCW,[2] kg	345	345	330	330	342	14.8
USDA yield grade[2]	2.69	2.81	2.56	2.25	2.63	0.138
USDA Choice, %	50	50	75	56	69	15.8
Marbling score[4,5]	Sl^{85}	Sm^{21}	Sl^{94}	Sl^{86}	Sm^{04}	18.91
Fat over 12th rib,[2,6] cm	1.09	1.02	0.97	0.86	1.07	0.019
LM area,[6] cm	82	84	80	84	82	0.22
KPH, %	2.1	2.2	2.1	2.1	2.2	0.10
Liver abscesses, %	25	0.00	12.5	0.00	0.00	7.91

[1]SFC = steam-flaked corn; SFC/Fat = steam-flaked corn plus 4% tallow; DRC = dry-rolled corn; DRC/Fat = dry-rolled corn plus 4% tallow; SFC/Flax = steam-flaked corn plus 10% ground flaxseed.

[2]DRC and DRC/Fat different from SFC and SFC/Fat ($P < 0.10$).

[3]Carcass-adjusted gain = [(HCW/0.6164) – initial weight]/85.

[4]Sl = slight; Sm = small marbling classifications; superscripts indicate the degree (0 to 99) of marbling within a classification.

[5]SFC/Fat different from Flax ($P < 0.10$).

[6]DRC and SFC different from DRC/Fat and SFC/Fat ($P < 0.10$).

Table 5. Long-chain fatty acids[1] from ribeye steaks of cattle fed diets supplemented with tallow or flaxseed

	Diet[2]			
Fatty acid	SFC	SFC/Fat	SFC/Flax	SEM
C10:0	0.036	0.016	0.023	0.01
C11:0	0.000	0.006	0.070	0.03
C12:0	0.4	0.4	0.5	0.14
C13:0	0.000	0.002	0.043	0.01
C14:0	4.6	4.6	5.0	0.54
C14:1	1.16	1.20	1.24	0.18
C15:0	0.79	0.79	0.84	0.10
C15:1	1.1	1.3	1.5	0.25
C16:0	33.4	25.5	30.4	3.62
C16:1	2.9	4.9	3.6	0.65
C17:0	1.22	1.88	1.31	0.19
C17:1	1.43	1.36	0.89	0.18
C18:0	7.4	11.3	10.2	1.32
C18:1	37.9	38.0	32.3	4.25
C18:2n-6	6.3[a]	6.6[ab]	8.4[b]	0.86
C18:3n-3	0.24[c]	0.29[c]	2.10[d]	0.12
C20:0	0.04	0.00	0.03	0.02
C20:3	0.10	0.35	0.34	0.12
C20:4	0.73	0.68	0.70	0.15
C20:5	0.00	0.24	0.04	0.13
C24:0	0.02	0.09	0.20	0.04
C24:1	0.000	0.026	0.000	0.01

[a,b]Within a row, means without a common superscript letter differ ($P < 0.10$).
[c,d]Within a row, means without a common superscript letter differ ($P < 0.01$).
[1]Values expressed as a percentage of fat content.
[2]SFC = steam-flaked corn; SFC/Fat = steam-flaked corn plus 4% tallow; SFC/Flax = steam-flaked corn plus 10% ground flaxseed.

0.05) plasma concentrations of C18:3n-3 (α-linolenic acid) and tended to reduce ($P < 0.10$) plasma concentrations of C14:0, C14:1, C16:0, and C16:1. Steers fed SFC/Fat had increased ($P < 0.05$) plasma concentrations of C18:3n-6, compared with plasma C18:3n-6 content of steers fed SFC/Flax. Layne et al. (1996) showed that supplementing human diets with flaxseed increased plasma phospholipid concentrations of C18:3 in low-density lipoprotein, compared with consumption of fish oil or olive oil. There were no differences ($P = 0.86$) in plasma fatty acid concentrations of C18:2 (linoleic acid) and C20:4n-6 (arachidonic acid) for steers fed SFC, SFC/Fat, and SFC/Flax.

Feeding SFC/Flax to cattle tended to increase the content of linoleic acid (18:2) in steaks, compared with feeding SFC ($P < 0.10$; Table 5). Concentrations of α-linolenic acid (18:3n-3) were greater ($P < 0.01$) in steaks from cattle fed SFC/Flax than in steaks from cattle fed SFC or SFC/Fat, whereas steaks from steers fed SFC or SFC/Fat had α-linolenic acid values (18:3n-3) that were 90% lower than those from steers fed SFC/Flax. Steaks from steers fed SFC/Fat had greater concentrations of C16:0 and C16:1, compared with those of cattle fed SFC/Flax and SFC ($P < 0.05$). Arachidonic acid (C20:4) concentrations in steaks did not differ ($P = 0.96$) among the 3 diets.

Sensory panel results are reported in Table 6. Flavor intensity was not different among treatments. Steaks

Table 6. Sensory panel evaluations of ribeye steaks from cattle fed diets supplemented with tallow or flaxseed

	Diets[2]			
Item[1]	SFC	SFC/Fat	SFC/Flax	SEM
Myofibrillar tenderness	6.58	6.59	6.55	0.122
Juiciness	6.11	5.82	5.78	0.271
Flavor intensity	5.81	5.96	5.94	0.076
Connective tissue amount	7.36	7.39	7.25	0.094
Overall tenderness	6.70	6.73	6.65	0.120
Off-flavor intensity	7.69[a]	7.64[a]	7.36[b]	0.083
TBARS[3]	0.10[a]	0.09[a]	0.16[b]	0.021

[a,b]Within a row, means without a common superscript letter differ ($P < 0.02$).
[1]1 = extremely tough, dry, bland flavor, abundant connective tissue, or extremely tough; 8 = extremely tender, juicy, intense flavor, no connective tissue, or tender.
[2]SFC = steam-flaked corn; SFC/Fat = steam-flaked corn plus 4% tallow; SFC/Flax = steam-flaked corn plus 10% ground flaxseed.
[3]TBARS = thiobarbituric acid reactive substances (measured in mg of malonaldehyde/kg of steak).

Table 7. Color profiles, using illuminant A, on d 0, 3, 5, and 7 for steaks from cattle fed diets supplemented with tallow or flaxseed

	Diets[1]			
Item	SFC	SFC/Fat	SFC/Flax	SEM
d 0				
L*	44.2	44.7	45.8	0.60
a*	32.3	32.6	31.5	0.63
b*	24.9	25.2	31.5	0.66
Hue angle[2]	37.6	37.6	37.2	0.19
Saturation index[2]	40.8	41.2	39.5	0.90
630:580	6.8	6.7	6.3	0.22
d 3				
L*	45.1	44.8	45.9	0.60
a*	31.7	31.4	30.7	0.45
b*	25.3	25.0	24.5	0.38
Hue angle	38.6	38.6	38.6	0.17
Saturation index	40.6	40.1	39.2	0.58
630:580	5.8	5.7	5.4	0.18
d 5				
L*	44.4	44.4	45.9	0.62
a*	29.8[a]	29.1[a]	27.5[b]	0.63
b*	23.9[a]	23.4[ab]	22.4[b]	0.48
Hue angle	38.9	38.9	39.3	0.25
Saturation index	38.2[a]	37.3[ab]	35.5[b]	0.77
630:580	5.2[a]	4.9[ab]	4.5[b]	0.20
d 7				
L*	45.2	44.2	45.1	0.59
a*	26.6[a]	25.6[ab]	22.9[b]	0.91
b*	20.9	20.6	19.6	0.50
Hue angle	38.3[a]	38.9[a]	41.0[b]	0.61
Saturation index	33.9[a]	32.8[ab]	30.2[b]	1.00
630:580	4.1[a]	3.9[ab]	3.3[b]	0.21

[a,b]Within a row, means without a common superscript letter differ ($P < 0.05$).
[1]SFC = steam-flaked corn; SFC/Fat = steam-flaked corn plus 4% tallow; SFC/Flax = steam-flaked corn plus 10% ground flaxseed.
[2]Saturation index = $(a^2 + b^2)^{-1/2}$; hue angle = $(b/a)^{\tan-1}$.

from steers fed SFC/Flax had a more pronounced off-flavor ($P < 0.02$), which may be attributable to the incorporation of α-linolenic acid from the SFC/Flax diet into soft tissues and its subsequent oxidation. This contention is supported by the increase ($P < 0.02$) in TBARS of steaks from cattle fed SFC/Flax, compared with results from other diets. Panelists described the off-flavor of steaks from steers fed SFC/Flax as metallic, rancid, cardboard, sour, and slightly bitter. Overall tenderness, juiciness, connective tissue amount, and myofibrillar tenderness were similar among steaks from steers fed the experimental diets ($P > 0.67$). Melton et al. (1982) showed that the flavor score in beef was significantly correlated with C14:0, C18:0, C18:1, and C18:3.

Instrumental values for color analyses are presented in Table 7. Values of L*, a measure of lightness, were similar among treatments on d 0, 3, 5, or 7 ($P > 0.31$). The a* value (measure of redness) was not different on d 0 and 3 for all 3 treatments. On d 5 and 7, however, steaks from steers fed SFC retained redness ($P < 0.05$) to a greater degree than steaks from those fed SFC/Flax or SFC/Fat ($P < 0.05$). On d 7, steaks from cattle fed SFC and SFC/Fat retained their red color to a greater degree than steaks from those fed SFC/Flax ($P < 0.05$). Values for a* decreased from 32.3, 32.6, and 31.5 on d 0 to 26.6, 25.6, and 22.9 on d 7 for steers fed SFC, SFC/Fat, and SFC/Flax, respectively, indicating that deterioration of redness for all treatments occurred as display lengthened. Values for b* (a yellow appearance measure) were decreased for steaks from steers fed SFC/Flax on d 5 vs. those from steers fed SFC ($P < 0.05$), and no difference was observed on d 7. Discoloration was greater for steaks from steers fed SFC/Flax on d 7 (greater hue angles; $P < 0.05$). On d 5 and 7, steaks from cattle fed SFC had a more vivid color appearance (saturation index) than that of steaks from cattle fed SFC/Flax ($P < 0.05$) but were not different than those from cattle fed SFC/Fat ($P > 0.05$). Retail display life of steaks from cattle fed the SFC/Flax diet was shorter than that of steaks from cattle fed SFC and SFC/Fat, as evidenced by changes in the ratios of 630 nm:580 nm. In contrast, Casutt et al. (2000) observed no differences in lightness, redness, and yellowness in kidney fat in Brown Swiss bulls fed the flaxseed equivalent to 3% lipids in the diet.

Ground flaxseed can be used to replace tallow in finishing diets to increase dietary lipid content with no loss in performance or changes in carcass traits of finishing steers. Feeding flaxseed to finishing cattle provides an effective means of elevating the n-3 fatty acid content of beef tissues and may have application for producing value-added beef products. Addition of antioxidants may be necessary to avoid premature oxidation of lipids in beef that is enriched with n-3 fatty acids.

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