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Summary with Implications

Steers were fed a diet containing dry rolled corn, steam flaked corn, dry rolled corn with 30% dried distillers grains, or steam flaked corn with 30% dried distillers grains. Strip loins from upper 2/3 Choice and Select-grade carcasses were obtained to evaluate the effects of diet and quality grade on shelf life characteristics. Strip loins were aged for 2, 9, 16, or 23 days. Results suggest that steaks from cattle fed steam flaked corn (with or without dried distillers grains) and from cattle fed dried distillers grains (regardless of corn type) had higher levels of many unsaturated fatty acids, more discoloration, and greater lipid oxidation compared to the dry rolled corn treatments or the no dried distillers grains treatments, respectively. Feeding of dry rolled corn or diets without dried distillers grains maintained red color better during retail display. Choice-grade steaks had significantly higher levels of unsaturated fatty acids like 18:2 and total polyunsaturated fatty acids than Select-grade steaks but did not differ in color stability or oxidation. These data indicate the longest shelf life will occur when cattle are fed diets containing dry rolled corn (versus steam flaked corn) or without dried distillers grains (versus with dried distillers grains) and that both steam flaked corn and distillers grains have a negative impact on shelf life. Quality grade did not affect color stability.

Introduction

Discounted meat, caused by discoloration, costs the meat industry $1 billion annually. Currently, supplementation of dried distiller grains (DDGS) in the diet is commonly utilized to improve animal growth and performance. However, feeding DDGS to cattle has also been shown to deposit more polyunsaturated fatty acids (PUFA's) in the lean phospholipid bilayer than corn-based diets. That increases potential lipid and myoglobin oxidation which can lead to shorter shelf life and development of off/rancid flavors. This may be further influenced with the processing method of corn. Substitution of steam flaked corn (SFC) for dry rolled corn (DRC) has been found to improve certain growth traits, due to improved absorption of nutrients. A greater understanding on how these dietary treatments can impact shelf life can be valuable in deciding what cattle are fed. Consequently, this study was conducted to determine the effects of feeding SFC or DRC (with and without DDGS) and quality grade on shelf life during retail display.

Procedure

A total of 240 steers were dispersed among 24 pens (10 head/pen) and fed for 202 d on diets containing DRC, DRC+ 30% DDGS, SFC, or SFC+ 30% DDGS. A minimum of one Upper 2/3 Choice and one Select grade strip loin were selected from each pen. Pens without one of each grade were not sampled. In total, 15 Select and 21 Upper 2/3 Choice carcasses were selected from each diet. Strip loins from both sides of each carcass were halved and randomly assigned to one of four aging periods (2, 9, 16, and 23 d). After aging, loins were fabricated into longissimus steaks and trimmed of all subcutaneous fat. Steaks utilized for color and fatty acids were 1 inch thick, while beef steaks for measurement of oxidative rancidity (TBARs) were 0.75 inch thick. After fabrication, steaks used for color analysis and TBARs were overwrapped with oxygen permeable film on foam trays and placed under retail display (RD) for 7 d at 3°C. Steaks for fatty acid profile were analyzed at 2 d postmortem.

Discoloration score (percent discoloration) was measured daily, during the retail display, for 7 d. Scores were evaluated by five trained panelists with 0% being no discoloration, and 100% being complete surface discoloration. Instrumental color was measured daily with a Minolta Colorimeter set with a D65 illuminant, 2° observer (CR-400, Minolta Camera Company, Osaka, Japan). Measurements were obtained by averaging six readings from different sections of the surface on the strip steak. The CIE L*, a*, and b* values refer to lightness, redness, and yellowness, respectively.

One gram (g) of powdered Longissimus lumborum was analyzed using gas chromatography. Fatty acids were extracted, separated using a Chrompack CP-Sil 88 capillary column, and identified by retention times in comparison to known commercial standards. The percentage of fatty acids were determined by relative peak areas in the chromatograph. Those values were adjusted with the percent fat in the sample to mg/100 g tissue.

Thiobarbituric acid reactive substances were measured with 5 g of powdered beef steak at 2, 9, 16, 23 d of aging as a measure of oxidative rancidity. Results from the TBARs protocol are expressed in mg of malonaldehyde per kg of muscle tissue.

Color data were analyzed as a 2×2×2 factorial with a split plot design. Day of retail display served as a repeated measure. The processing method of corn, presence or absence of DDGS, and quality grade served as the main plot factors and aging period was the split-plot factor. Fatty acid profile was analyzed as a 2×2×2 factorial. The TBARs data were analyzed as a 2×2×2 split-split plot design. The first split plot was aging period, and the second split-plot was day of retail display. Pen was the experimental unit and data were analyzed using PROC GLIMMIX program of SAS with LSMEANS statement. Statistical significance was determined at $P<0.05$ and trends noted at $P<0.10$.

Table 1. Amount of fatty acids for strip steaks from steers fed different processed corn diets of DRC (dry rolled corn) or SFC (steam flaked corn)

Fatty Acid, mg/100g	DRC	SFC	SEM	P value
C10:0	3.74	5.59	1.05	0.314
C12:0	6.13	6.23	0.78	0.952
C13:0	2.21	1.37	0.69	0.516
C14:0	213.53	223.00	10.67	0.650
C14:1	74.56	63.95	5.65	0.274
C15:0	31.83	34.00	1.94	0.559
C15:1	65.03	62.10	4.49	0.743
C16:0	1610.54	1616.92	68.01	0.963
C16:1T	22.65	21.65	1.05	0.624
C16:1	254.00	237.12	13.49	0.508
C17:0	74.67	84.94	5.56	0.284
C17:1	84.45	86.07	4.26	0.850
C18:0	710.08	715.18	33.82	0.941
C18:1T	109.39^{b}	320.85^{a}	64.97	<0.0001
C18:1	2129.77	1968.75	158.61	0.600
C18:1V	245.79	196.16	136.91	0.857
C18:2T	34.81	30.08	2.27	0.203
C18:2	328.79^{b}	414.82^{a}	30.22	0.019
C18:3ω6	1.39	0.48	0.47	0.251
C18:3ω3	12.72^{b}	15.53^{a}	1.05	0.045
C20:1	30.30	33.08	2.56	0.572
C20:3	19.43	18.22	0.96	0.505
C20:4ω6	62.71	62.16	4.73	0.954
C22:1	2.32	2.30	2.11	0.995
C22:4	2.68	1.43	0.73	0.334
C22:5	15.55	16.66	1.05	0.584
Other	16.20	4.79	6.25	0.445
SFA	2652.74	2687.22	113.74	0.880
UFA	3498.91	3551.42	137.25	0.849
MUFA	3018.28	2992.04	125.85	0.918
PUFA	480.63	559.38	32.17	0.095
Trans	166.85^{b}	372.59^{a}	63.64	0.0001
ω6	64.10	62.64	4.72	0.878
ω3	12.72^{b}	15.53^{a}	1.05	0.045
Total Lipids	0.06	0.06	0.0024	0.87

^{a,b} Means in the same row without common superscripts differ (*P*<0.05)

SFA- Saturated Fatty Acids

UFA- Unsaturated Fatty Acids

MUFA- Monounsaturated Fatty Acids

PUFA- Polyunsaturated Fatty Acids

Trans- Trans-unsaturated Fatty Acids

Results

Processing method of corn (DRC versus SFC) had an impact on the amount and type of fatty acids present in the meat. Fatty acids such as linoleic acid (18:2) and some trans-unsaturated fats, in general, were found in significantly higher (*P*<0.05) amounts (mg/100 g of tissue) in beef steaks from cattle fed SFC than beef steaks from DRC diet (Table 1). Linoleic acid (18:2), palmitelaidic (16:1T), and polyunsaturated fatty acids (PUFAs) were significantly higher (*P*<0.05) in beef steaks from cattle fed DDGS than the diets without DDGS (Table 2). An interaction between processing method of corn and presence or absence of DDGS was seen in a few of the fatty acids. Steaks from cattle fed DRC had significantly higher levels (*P*<0.05) of pentadecanoic acid (C15:0) compared to DRC with DDGS and SFC with DDGS had significantly higher levels (*P*<0.05) of the other, unidentified fatty acids, compared to DRC with DDGS (Table 3). The only interaction (*P*<0.05) between processing method of corn and quality grade was for elaidic acid (18:1 T) and trans-unsaturated fatty acids, with higher levels being seen in Choice-grade beef steaks from cattle fed SFC compared to all other diets. Quality grade was only significant for fatty acid profile and was not shown to be significant for any of the other measurements. An effect of marbling was also found with Choice-grade steaks having significantly higher levels of unsaturated fatty acids like 18:2 and total polyunsaturated fatty acids than Select-grade steaks but no differences in color stability or oxidation.

Discoloration and redness (a*) have profound impacts on consumer decisions to purchase beef at retail. Both color traits were influenced by length of cooler storage and day of retail display. The simulated retail display conditions in our laboratory are colder than those typically observed in retail stores. This provides the opportunity to more carefully study changes in color characteristics during retail display. No differences in any color trait were observed within the first 4 d of retail display. Effects of corn processing method and presence or absence of DDGS were apparent following 5–7 d of retail display. For all treatments, discoloration tended to increase, and redness tended to decrease during days 5–7 of retail display following 2 and 9 d of aging (Figures 1–4). Differences in discoloration and redness between DRC and SFC were significant following 16 and 23 d of storage, with steaks from cattle fed SFC exhibiting significantly more discoloration (Figure 1) and reduced redness (Figure 3) than steaks from cattle fed DRC after 6 or 7 d under simulated retail display conditions. Steaks from cattle fed diets containing DDGS, compared to diets without DDGS, showed the same results, in that the presence of DDGS in the diet resulted in significant increases (*P*<0.05) in discoloration (Figure

Table 2. Amount of fatty acids for strip steaks from steers fed with or without DDGS (dried distiller grains)

Fatty Acid, mg/100g	NO DDGS	DDGS	SEM	P value
C10:0	4.91	4.42	0.91	0.79
C12:0	7.14	5.22	0.96	0.23
C13:0	2.21	1.37	0.69	0.52
C14:0	232.84	203.69	13.31	0.17
C14:1	76.17	62.35	6.20	0.16
C15:0	35.78	30.05	2.47	0.13
C15:1	63.40	63.73	4.41	0.97
C16:0	1618.65	1608.81	68.05	0.94
C16:1T	19.91[b]	24.39[a]	1.64	0.035
C16:1	260.30	230.82	15.19	0.25
C17:0	83.34	76.27	5.12	0.46
C17:1	89.74	80.78	4.96	0.30
C18:0	649.43	775.83	49.73	0.072
C18:1T	237.65	192.60	25.76	0.32
C18:1	2088.46	2010.06	153.32	0.80
C18:1V	99.05	342.91	153.28	0.38
C18:2T	31.14	33.75	1.96	0.48
C18:2	316.24[b]	427.37[a]	36.41	0.003
C18:3ω6	0.47	1.40	0.47	0.24
C18:3ω3	14.00	14.25	1.05	0.85
C20:1	28.36	35.03	3.10	0.18
C20:3	17.51	20.15	1.17	0.15
C20:4ω6	60.41	64.45	4.87	0.67
C22:1	0.00	4.62	2.50	0.28
C22:4	0.95	3.15	0.90	0.095
C22:5	16.10	16.10	1.00	1.00
Other	3.64	17.35	7.39	0.24
SFA	2634.31	2705.65	115.16	0.76
UFA	3422.41	3627.92	148.75	0.46
MUFA	2963.02	3047.29	127.96	0.74
PUFA	459.39[b]	580.63[a]	41.75	0.013
Trans	288.70	250.74	25.34	0.41
ω6	60.88	65.85	4.92	0.60
ω3	14.00	14.25	0.67	0.85
Total Lipids	0.061	0.064	0.0026	0.55

[a,b] Means in the same row without common superscripts differ (P<0.05)

SFA- Saturated Fatty Acids

UFA- Unsaturated Fatty Acids

MUFA- Monounsaturated Fatty Acids

PUFA- Polyunsaturated Fatty Acids

Trans- Trans-unsaturated Fatty Acids

2) and reductions in redness (Figure 4) after 6–7 day of retail display following extended storage (16 and 23 d).

Detrimental effects of SFC (versus DRC) and DDGS (versus diets without DDGS) were also observed with oxidation (TBARs) following 7 d of retail display, regardless of storage time (Figures 5 and 6). Steaks did not differ in oxidation level at the beginning of the retail period. Not surprisingly, exposure to oxygen, as occurs during retail display, is required for oxidation to occur. Lipid oxidation is associated with rancidity and discoloration, so feeding SFC or DDGS may have detrimental effects to retail value of beef steaks compared to DRC or No DDGS. This suggests that the DRC diet (without DDGS) is better able to maintain visual desired color than SFC or DDGS and thus would take longer to be discounted.

Results suggest that beef steaks from cattle fed SFC or DDGS have a reduced color and lipid stability compared to DRC or No DDGS, and accordingly lead to a reduced shelf life. Furthermore, fatty acid profile showed higher levels of key fatty acid(s) like linoleic acid and PUFAs in SFC+ DDGS compared to DRC and Choice steaks compared to Select steaks. Thus, diet composition can impact beef shelf life.

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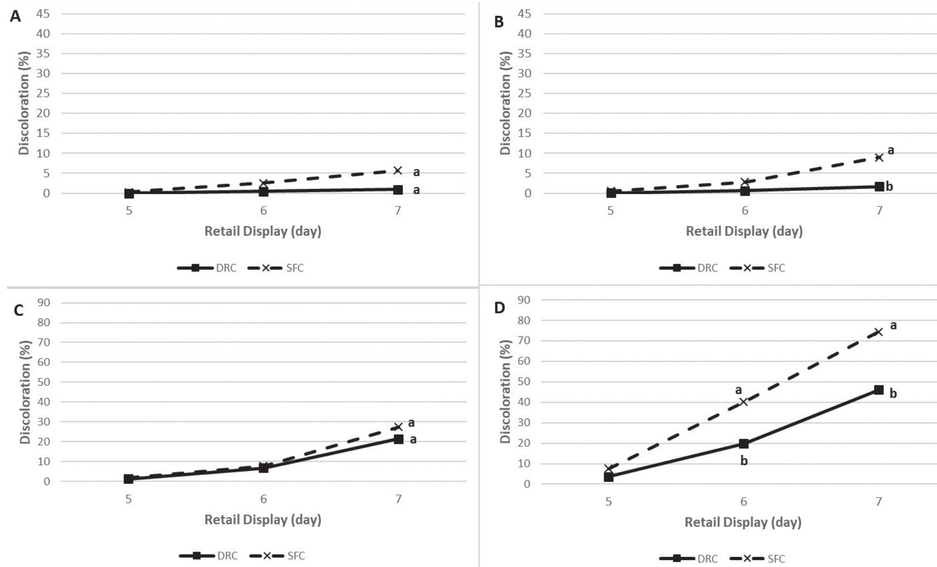

Figure 1. Discoloration (%) of strip loin steaks (*L. lumborum*) from steers fed either dry rolled corn (DRC), or steam flaked corn (SFC) with 2, 9, 16, and 23 d of aging at 7 d retail display.

[a,b] Means in the same row without common superscripts differ ($P<0.05$)

A: Discoloration 2 days aged loins (at 45% y-axis)

B: Discoloration 9 days aged loins (at 45% y-axis)

C: Discoloration 16 days aged loins (at 90% y-axis)

D: Discoloration 23 days aged loins (at 90% y-axis)

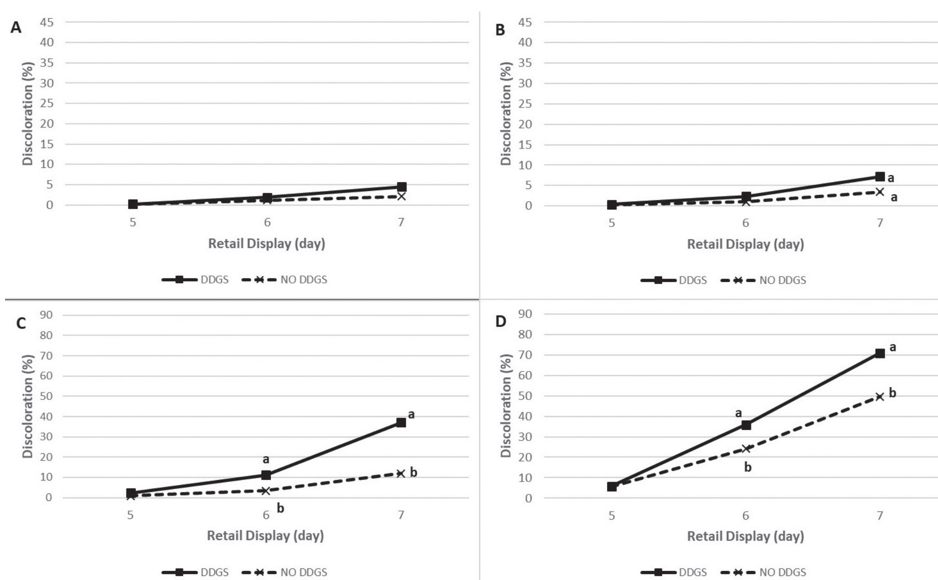

Figure 2. Discoloration (%) of strip loin steaks (*L. lumborum*) from steers fed either with Dried Distiller Grains (DDGS) or without DDGS (No DDGS) with 2, 9, 16, and 23 d of aging at 7 d retail display.

[a,b] Means in the same row without common superscripts differ ($P<0.05$)

A: Discoloration 2 days aged loins (at 45% y-axis)

B: Discoloration 9 days aged loins (at 45% y-axis)

C: Discoloration 16 days aged loins (at 90% y-axis)

D: Discoloration 23 days aged loins (at 90% y-axis)

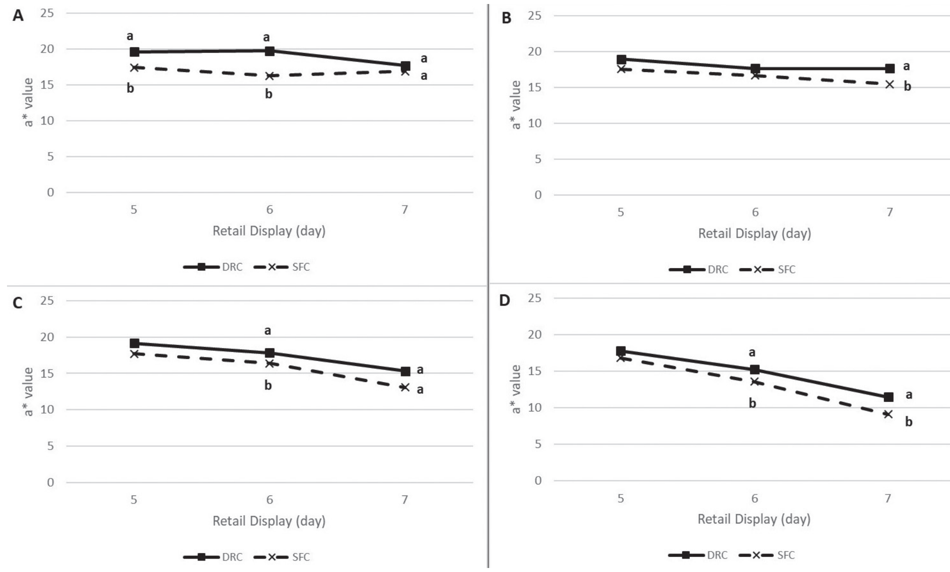

Figure 3. Redness (a*) of strip loin steaks (*L. lumborum*) from steers fed either Dry Rolled Corn (DRC), or Steam Flaked Corn (SFC) with 2, 9, 16, and 23 d of aging at 7 d retail display.

[a,b] Means in the same row without common superscripts differ (P<0.05)

A: a* 2 days aged loins

B: a* 9 days aged loins

C: a* 16 days aged loins

D: a* 23 days aged loins

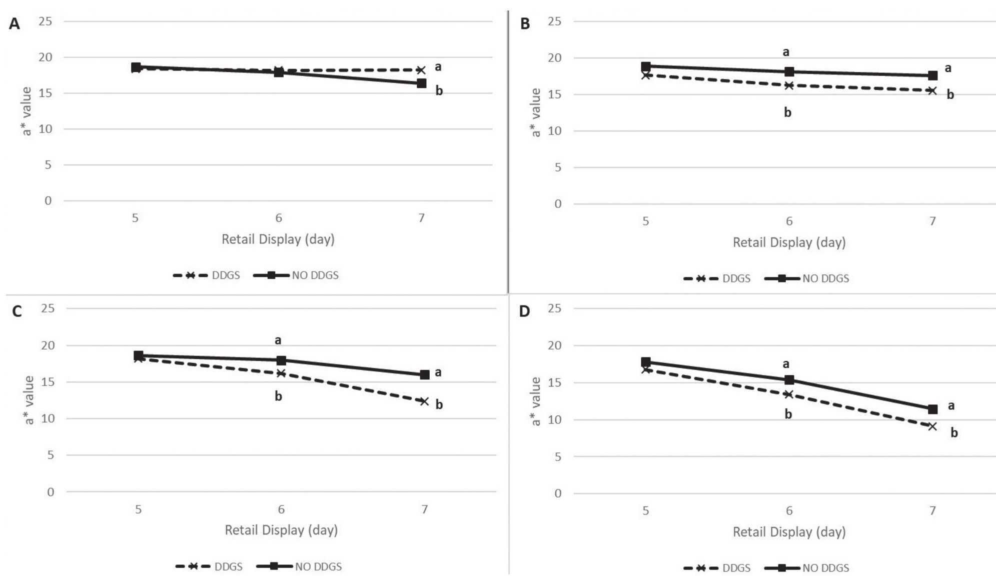

Figure 4. Redness (a*) of strip loin steaks (*L. lumborum*) from steers fed either with Dried Distiller Grains (DDGS) or without DDGS (No DDGS) with 2, 9, 16, and 23 d of aging at 7 d retail display.

[a,b] Means in the same row without common superscripts differ (P<0.05)

A: a* 2 days aged loins

B: a* 9 days aged loins

C: a* 16 days aged loins

D: a* 23 days aged loins

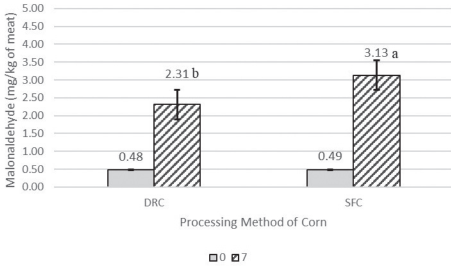

Figure 5. Lipid oxidation values (TBARs; mg malonaldehyde/ kg of meat) of strip steaks (*L. lumborum*) from steers fed either Dry Rolled Corn (DRC or Steam Flaked Corn (SFC) at 0 and 7 d retail display.
[a,b] Means within day without common superscripts differ ($P<0.05$)

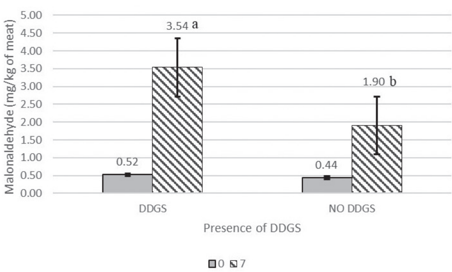

Figure 6. Lipid oxidation values (TBARs; mg malonaldehyde/ kg of meat) of strip steaks (*L. lumborum*) from steers fed either with Dried Distiller Grains (DDGS) or without DDGS (No DDGS) at 0 and 7 d retail display.
[a,b] Means within day without common superscripts differ ($P<0.05$)

Table 3. Amount of fatty acids for strip steaks from steers fed different processed corn diets of DRC (dry rolled corn) or SFC (steam flaked corn) and with or without DDGS (dried distiller grains)

Fatty Acid, mg/100g	DRC	DRC+DDGS	SFC	SFC+DDGS	SEM	P value
C15:0	39.97[a]	23.70[b]	31.59[ab]	36.41[ab]	15.59	0.0077
C16:1T	23.12[ab]	22.18[ab]	16.70[b]	26.60[a]	8.91	0.012
C17:0	89.70[ab]	59.65[b]	76.99[ab]	92.89[a]	32.80	0.021
C17:1	104.07[a]	64.83[b]	75.40[ab]	96.73[a]	40.36	0.0014
Total Lipids	0.064	0.059	0.057	0.068	0.012	0.097

[a,b] Means in the same row without common superscripts differ ($P<0.05$)

Table 4. Amount of fatty acids for either choice or select quality grade strip steaks

Fatty Acid, mg/100g	Choice	Select	SEM	P value
C10:0	6.55[a]	2.78[b]	1.41	0.0464
C12:0	8.35[a]	4.01[b]	1.48	0.01
C13:0	0.00[b]	3.58[a]	1.95	0.0094
C14:0	285.47[a]	151.05[b]	40.15	<0.0001
C14:1	86.39[a]	41.29[b]	24.96	<0.0001
C15:0	42.37[a]	23.46[b]	5.76	<0.0001
C15:1	74.57[a]	52.56[b]	7.74	0.019
C16:0	2087.33[a]	1140.13[b]	281.76	<0.0001
C16:1T	27.05[a]	17.25[b]	3.00	<0.0001
C16:1	312.31[a]	178.81[b]	58.18	<0.0001
C17:0	102.50[a]	57.11[b]	13.92	<0.0001
C17:1	108.80[a]	61.72[b]	14.24	<0.0001
C18:0	882.84[a]	542.43[b]	103.92	<0.0001
C18:1T	287.53[a]	142.72[b]	47.35	0.003
C18:1	2524.68[a]	1573.84[b]	313.59	0.0041
C18:1V	370.15	71.81	161.11	0.2829
C18:2T	41.25[a]	23.64[b]	5.40	<0.0001
C18:2	425.80[a]	317.81[b]	35.61	0.0041
C18:3ω6	0.23	1.64	1.76	0.081
C18:3ω3	17.76[a]	10.49[b]	2.20	<0.0001
C20:1	42.00[a]	21.38[b]	6.43	0.0002
C20:3	20.33	17.33	1.24	0.1053
C20:4ω6	63.15	61.71	8.61	0.8799
C22:1	2.32	2.30	2.11	0.9951
C22:4	1.57	2.54	1.72	0.4526
C22:5	14.44	17.77	2.53	0.1056
Other	16.08	4.91	6.58	0.2416
SFA	3415.41[a]	1924.54[b]	445.04	<0.0001
UFA	4426.09[a]	2624.24[b]	537.74	<0.0001
MUFA	3841.56[a]	2168.75[b]	498.97	<0.0001
PUFA	584.53[a]	455.49[b]	43.65	0.0086
Trans	355.83[a]	183.61[b]	54.71	0.0008
ω6	63.39	63.35	4.70	0.9967
ω3	17.76[a]	10.49[b]	2.20	<0.0001
Total Lipids	0.079[a]	0.046[b]	0.0098	<0.0001

[a,b] Means in the same row without common superscripts differ ($P<0.05$)