Fatty acid composition differences between adipose depot sites in dairy and beef steer breeds

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Abstract The objective of the study was to compare fatty acid composition of longissimus dorsi (LD) and kidney fat (KF) in Holstein steers (HS), Simmental steers (SS) and Chinese LongDong Yellow Cattle steers (CLD). All steers received the same nutrition and management but in different locations. Cattle were harvested at approximately 550 kg and fatty acid composition of longissimus dorsi and kidney fat was analyzed in samples taken after 3 days of aging. There was evidence ($P<0.05$) that C18:3n6 was greater in KF than LD in CLD cattle but not in HS or SS cattle. Percentage C18:1n9, C18:2n6, C18:3n3, and n6 fatty acids were greater in LD than KF for all breeds ($P<0.05$), but the difference between fat sources for n6 in CLD cattle was smaller than the other two breeds. The LD had greater percentage of polyunsaturated fatty acids (PUFA), monounsaturated fatty acids (MUFA), and a greater ratio of n6:n3 PUFAs compared to the KF in each breed ($P<0.05$). The Δ^9 -desaturase catalytic activity index was greater in LD than in KF in each breed group ($P<0.05$). Percentage cis-9, trans-11 CLA was greater in KF than LD in HS ($P<0.05$) but not SS or CLD cattle. These results indicate fatty acid percentages generally differed between longissimus dorsi fat and kidney fat. Further, there was some indication that some of these differences between fatty acid deposition sites were not consistent across breed group.

Keywords Breed · Longissimus dorsi · Kidney fat · FAME composition

Introduction

The overall health benefits of balanced fatty acid intake in humans has been well established and include benefits for cardiovascular health, cognitive function and development, and control of inflammation (van den Elsen et al. 2012). As reviewed by Wood et al. (2008), the FA composition of adipose tissue and muscle in meat animals is affected by a number of factors including diet, total fat content, breed, genotype, age, and gender. Composition also differs among adipose depot sites throughout the bovine carcass (Turk and Smith 2009). They concluded that substantial differences exist in fatty acid composition across fat depots, which may be useful in formulating value-added processed beef products. Other work has demonstrated that fatty acid composition differs among tissues in dairy cattle (Jiang, et al. 2013).

Recent interest in the function of fatty acids in human health has focused on polyunsaturated fatty acids (PUFA), particularly conjugated linoleic acids (CLA), arachidonic acid (AA), cis-5,8,11,14,17-eicosapentaenoic acid (EPA) and cis-4,7,10,13,19-docosahexaenoic acid (DHA). Primarily, CLA's are isomeric derivatives of 18:2 (n6) that exhibit potent anticarcinogenic properties (Park and Pariza 1998). However, CLA (cis-9, trans-11) may be the only biologically active CLA isomer (Fritsche et al. 1999). The fatty acids DHA and AA present in human milk are essential for infant retina and central nervous system development and maintenance. Further, DHA and EPA have been associated with protection against cardiovascular disease. Effects of DHA and EPA include lowering of triglyceride levels by decreasing very low-density lipoprotein (VLDL) synthesis, increasing antithrombotic activity by decreasing platelet aggregation, lowering of blood pressure, and antiatherogenic activity (Zollner and Tato 1992; Horrocks and Yeo 1999; Macajova et al. 2004). Monounsaturated fatty acids (MUFA) have not been clearly shown to have effects on human cholesterol levels (Scientific Review Committee 1990).

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The beef cattle industry in China is developing rapidly and there is opportunity in the meat fabrication process to develop products with improved fatty acid profiles. Common breeds in western China include Holstein, Simmental, and Chinese Yellow Cattle. Differences in fatty acid profiles between fat depots in these breeds can indicate potentials for development of newer, healthier products. Consequently, the objectives of this investigation were to study the influence of adipose depot sites on the composition of fatty acids in Holstein steers, Simmental steers, and Chinese LongDong Yellow Cattle steers as well as the consistency of fat depot differences across breeds.

Materials and methods

Animals and harvest

Animal care and use was consistent with the animal care and use standards of Gansu Agricultural University and animals were harvested in accordance with national standards of humane food animal harvesting and processing.

Holstein steers (HS, $n=24$), Simmental steers (SS, $n=26$) and Chinese LongDong Yellow Cattle steers (CLD, $n=27$) were randomly selected from 200 steers fed (Table 1.) and managed under similar conditions at three different locations. Locations were similar in altitude, mean annual temperature, and mean annual precipitation (Table 2.). All animals were subjected to a conditioning period of 14 d prior to the 180 d feeding trial. Rations for different growth periods were formulated according to NRC requirements for the class and weight of the animals (Table 3.) and the same formulations were fed at all locations. All animals were slaughtered at a commercial facility 5–8 km from the research centers. Carcasses were aged for 72 h at 4 °C. After aging, longissimus muscle and kidney fat tissue (*fat source*) were removed, individually vacuum packaged, identified by animal number and frozen at –20 °C until analyzed. All samples were collected from the right side of the carcass and analyzed in duplicate.

Table 1 Gender, age (mo), initial weight (kg), and harvest weight (kg) for each location and breed

Location (Breed)	Gender	Age	Initial weight	Slaughter weight
Lin Tao (HS) ^a	male	12–14	310±4.9	551±5.2
Kang Le (SS) ^a	male	12–14	329±4.7	548±5.0
PingLiang (CLD) ^a	male	12–14	318±4.6	553±5.0

^a HS Holstein steers, SS Simmental steers, CLD Chinese LongDong Yellow Cattle

Table 2 Location altitudes, mean temperatures, and mean annual precipitation

Location (Breed)	Altitude (m)	Mean temperature (°C)	Mean precipitation (mm)
Lin Tao (HS) ^a	2700	7.0	382
Kang Le (SS) ^a	1874	7.0	400
PingLiang (CLD) ^a	2000	8.5	575

^a HS Holstein steers, SS Simmental steers, CLD Chinese LongDong Yellow Cattle

Fatty acid analysis

Frozen samples were thawed 12 h prior to analyses at 4 °C. Total lipids were extracted from 5 g of muscle and 3 g of kidney fat in duplicate with chloroform/methanol (2:1, V/V) by homogenization (Ultra Turrax, 3×15 s, 12000 rpm.) at room temperature, as described by Folch et al. (1957) with some modifications. Fatty acid methyl esters (FAME) were prepared as follows from the methods described by Peng et al. (2010). Extracted lipids (approximately 10 mg) were combined with hexane (2 mL) followed by addition of 2 M methanolic KOH (0.2 mL). The resulting solution was vortexed at room temperature for 2 min. After centrifugation (3000 rpm), a sample of the hexane layer was transferred to a clean tube, distilled water (2 mL) was added and the sample was vortexed for 2 min. After vortexing, the sample was centrifuged at 5000 rpm for 5 min. The hexane layer in the sample was then collected for GC analysis. Derivatized methyl esters of fatty acids were separated and quantified by gas chromatograph (model 6890 N, Agilent Technology, Wilmington, DE, USA). The column used for the chromatographic separations was a 100 m×0.25 mm×0.2 µm film thickness, fused-silica column (SP-2560; Sigma-Aldrich, Co., St. Louis, MO). Nitrogen was used as the carrier gas, with a split ratio of 100:1 and 1 mL/min column flow. Injector temperature was set at 260 °C. The initial oven temperature was programmed at 140 °C and maintained for 4 min, then increased to 230 °C at 4 °C/min, held at 230 °C for 10 min, then raised to 240° at 2 °C/min and maintained at 10 min. Thirty-eight FAME preparations (Supelco 37 Component FAME mix and CLA, cis-9, trans-11 standard, Sigma, St. Louis, MO) were injected separately to relate the peaks to known FAME. Additionally, a standard mixture of these 38 FAME's was injected once before each group of 20 samples, to facilitate the comparison of retention times for each FAME. The retention times used to calculate concentrations from areas under these peaks were those of the adjacent FAME in the standard mixture. The fatty acid concentration was expressed as individual fatty acid composition as a percent of total fatty acid composition.

Table 3 Feedlot rations for all locations (% DM basis)

Item	Weight stage (kg)						
	275–315	315–360	360–405	405–450	450–495	495–540	540–585
Corn	53.17	74.28	78.75	81.38	84.49	86.64	75.47
Linseed cake	30.34	19.27	14.66	10.92	7.71	5.48	12.14
Limestone	1.15	0.76	0.61	0.45	0.35	0.30	0.47
Salt	4.19	–	–	–	–	–	–
Calcium hydrophosphate	–	–	0.09	0.16	0.20	0.20	–
Sodium bicarbonate	2.23	–	–	1.42	1.45	1.48	2.38
Premix ^a	8.91	5.69	5.89	5.68	5.81	5.90	9.54
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

^a Vitamin-mineral premix: A, D₃, E, Niacin, Mn, Zn, Fe, Cu, Se, I, Co plus carrier

Statistical analyses

Fatty acid composition percentages, class totals (saturated, monounsaturated, polyunsaturated, n3, and n6) and the n6:n3 ratio were analyzed with PROC MIXED of SAS (Cary, NC, USA) using a linear model that included the effects of location (fixed), steer in location (random), fat source (fixed), location x fat source (fixed) and steer x fat source in location (random). Tests of fat source within location were done using t statistics at $P < 0.05$ with $P < 0.10$ denoting a trend.

Results and discussion

Least square means and standard errors for fatty acid composition percentages, class totals (saturated [SFA], monounsaturated [MUFA], polyunsaturated [PUFA], n3, and n6) and the n6:n3 ratio for each breed and fat source are given in Table 4. The primary fatty acids in fat from each breed and fat source were palmitic acid (C16:0) and stearic acid (C18:0) for SFA, oleic acid (C18:1n7) for MUFA, and linoleic acid (18:2 n6) for PUFA. Generally, results of analyses were similar to those reported by Raes et al. (2003), Realini et al. (2004) and Varela et al. (2004).

Mean saturated fatty acid (SFA) was greater in KF than LD in each breed group ($P < 0.05$). In HS, SS, and CLD cattle, SFA content of KF was 7.85, 15.14, and 15.67 % greater ($P < 0.05$) than LD, respectively. Stearic acid (C18:0) was the primary fatty acid contributing to these differences. There was little evidence of fat source differences for palmitic acid (C16:0) in any breed but C18:0 was greater in KF ($P < 0.05$) than LD in all breeds. The C18:0 percentage for KF was 5.24, 7.43, 11.36 % greater than LD in HS, SS, and CLD cattle, respectively ($P < 0.05$). Lauric acid (C12:0), myristic acid (C14:0) and arachidic acid (C20:0) were secondary fatty acids contributing to these differences. The concentration of C14:0, C12:0 and C20:0 were greater in KF than LD for all breeds

($P < 0.05$) except C12:0 in CLD cattle. Similar to our results, Jiang et al. (2013) found that saturated fatty acid percentage was highest in kidney and omental fat and lesser in muscle in Jersey cattle. It is generally accepted that saturated fatty acids increase the risk of cardiovascular disease by raising low-density lipoprotein (LDL) cholesterol. However, not all saturated fatty acids contribute to increased LDL; the SFA's lauric (C12:0), myristic (C14:0), and palmitic acids (C16:0) are associated with increased LDL cholesterol, whereas stearic acid (C18:0) does not affect LDL cholesterol levels (Molkentin 1999). Further, in our study, percentage of pentadecanoic acid (C15:0), cis-11-eicosenoic acid (C21:0) and lignoceric acid (C24:0) were greater in KF than LD from each breed groups ($P < 0.05$). However, behenic acid (C22:0) and tricosanoic acid (C23:0) were lesser in KF than LD for all breeds ($P < 0.05$). Fat source differences for the odd fatty acid undecanoic acid (C11:0) were similar. Percentage C17:0 was lesser in KF than LD from HS cattle but greater in KF than LD in CLD cattle ($P < 0.05$) while C13:0 percentage was greater in KF than LD in HS cattle ($P < 0.05$). Butyric acid (C4:0) was greater in KF than LD ($P < 0.05$) in HS and CLD but not SS. Caproic acid (C6:0), caprylic acid (C8:0), and decanoic acid (C10:0) were greater in KF than LD ($P < 0.05$) only in HS cattle. Molkentin (1999) found that C4:0 had anticarcinogenic properties and short-chain fatty acids, in general, have been shown to reduce serum cholesterol and triglyceride levels. In the present study, the SCFA percentage (C4:0, and C6:0) of KF for HS cattle were 0.10 and 0.12 % greater ($P < 0.05$) than LD, respectively. In CLD cattle, C4:0 percentage of KF was 0.11 % greater than LD ($P < 0.05$). There was little evidence of fat source differences in either SCFA for SS cattle.

Mean MUFA was greater in LD than KF in all three breed groups ($P < 0.05$). In HS, SS, and CLD cattle, MUFA content of KF was 3.94, 3.96, and 8.88 % lesser ($P < 0.05$) than LD, respectively. These differences were influenced by palmitoleic (C16:1n7) and oleic acid (C18:1n9) content. The percentage of C16:1n7 and C18:1n9 were greater in LD than KF for all

Table 4 Least squares means and standard errors for fatty acid composition (FA) of longissimus dorsi and kidney adipose tissue (%)

FA	Holstein steers		Simmental steers		LongDong steers	
	KF ¹	LD ¹	KF ¹	LD ¹	KF ¹	LD ¹
C4:0	0.15±0.01 ^a	0.05±0.01 ^b	0.11±0.01	0.11±0.01	0.21±0.01 ^a	0.10±0.01 ^b
C6:0	0.13±0.02 ^a	0.01±0.02 ^b	0.08±0.02	0.03±0.02	0.12±0.22	0.11±0.02
C8:0	0.09±0.02 ^a	0.01±0.02 ^b	0.04±0.02	0.02±0.02	0.06±0.02	0.10±0.02
C10:0	0.19±0.02 ^a	0.07±0.02 ^b	0.16±0.02	0.11±0.02	0.14±0.02	0.11±0.02
C11:0	0.09±0.01 ^a	0.01±0.01 ^b	0.06±0.01 ^a	0.01±0.01 ^b	0.03±0.01	0.01±0.01
C12:0	0.24±0.02 ^a	0.05±0.02 ^b	0.15±0.02 ^a	0.07±0.02 ^b	0.12±0.02	0.11±0.02
C13:0	0.07±0.01 ^a	0.01±0.01 ^b	0.03±0.01	0.02±0.01	0.01±0.01	0.01±0.01
C14:0	4.16±0.16 ^a	2.11±0.16 ^b	3.88±0.16 ^a	2.08±0.15 ^b	4.03±0.17 ^a	2.70±0.15 ^b
C15:0	0.54±0.03 ^a	0.30±0.03 ^b	0.66±0.03 ^a	0.40±0.03 ^b	0.47±0.03 ^a	0.28±0.03 ^b
C16:0	25.73±0.60	25.02±0.60	27.52±0.60	26.21±0.59	27.10±0.64	25.78±0.58
C17:0	1.04±0.07 ^b	1.38±0.07 ^a	1.01±0.07	1.12±0.07	1.08±0.08 ^a	0.77±0.07 ^b
C18:0	22.98±0.56 ^a	17.74±0.56 ^b	25.05±0.56 ^a	17.62±0.58 ^b	24.77±0.60 ^a	13.41±0.53 ^b
C20:0	2.21±0.09 ^a	0.00±0.01 ^b	2.43±0.09 ^a	0.00±0.01 ^b	0.99±0.09 ^a	0.00±0.01 ^b
C21:0	0.31±0.04 ^a	0.00±0.01 ^b	0.33±0.04 ^a	0.00±0.01 ^b	0.23±0.04 ^a	0.00±0.01 ^b
C22:0	0.00±0.01 ^b	0.21±0.01 ^a	0.01±0.01 ^b	0.23±0.01 ^a	0.00±0.02 ^b	0.06±0.01 ^a
C23:0	0.25±0.17 ^b	3.76±0.17 ^a	0.07±0.17 ^b	1.07±0.17 ^a	0.01±0.18 ^b	1.41±0.16 ^a
C24:0	0.40±0.05 ^a	0.00±0.05 ^b	0.82±0.05 ^a	0.00±0.05 ^b	0.31±0.05 ^a	0.00±0.04 ^b
C14:1	0.69±0.05	0.58±0.05	0.51±0.05	0.43±0.05	0.63±0.05	0.67±0.04
C15:1	0.55±0.02 ^a	0.00±0.02 ^b	0.59±0.02 ^a	0.00±0.02 ^b	0.39±0.03 ^a	0.02±0.02 ^b
C16:1n7	1.07±0.14 ^b	2.61±0.14 ^a	1.76±0.14 ^b	2.67±0.14 ^a	1.96±0.15 ^b	3.67±0.13 ^a
C17:1	0.21±0.13 ^b	0.73±0.13 ^a	0.36±0.18 ^b	1.40±0.18 ^a	0.14±0.19 ^b	0.64±0.17 ^a
C18:1n9 ²	32.61±0.91 ^b	34.93±0.93 ^a	30.20±0.91 ^b	32.63±0.89 ^a	33.46±0.97 ^b	40.78±0.86 ^a
C20:1	0.15±0.03 ^a	0.14±0.03 ^b	0.10±0.03 ^a	0.05±0.03 ^b	0.38±0.03 ^a	0.16±0.03 ^b
C24:1	0.10±0.03 ^b	0.55±0.03 ^a	0.00±0.03 ^b	0.55±0.03 ^a	0.00±0.03 ^b	0.14±0.03 ^a
C18:2 ³	1.04±0.44 ^b	9.70±0.44 ^a	0.81±0.44 ^b	8.93±0.43 ^a	0.93±0.47 ^b	4.75±0.42 ^a
C18:3n6	0.21±0.09	0.11±0.09	0.32±0.09	0.08±0.09	1.09±0.10 ^a	0.00±0.08 ^b
C18:3n3	0.24±0.04 ^b	0.58±0.04 ^a	0.23±0.03 ^b	0.50±0.04 ^a	0.34±0.04 ^b	0.58±0.04 ^a
C20:2	0.04±0.03 ^b	0.47±0.03 ^a	0.14±0.03 ^b	0.42±0.03 ^a	0.09±0.03 ^b	0.31±0.03 ^a
CLA9c11t	0.10±0.02 ^a	0.01±0.02 ^b	0.08±0.02	0.07±0.02	0.01±0.02	0.02±0.02
C20:3n6	0.03±0.03 ^b	0.58±0.04 ^a	0.09±0.05 ^b	0.53±0.05 ^a	0.05±0.05 ^b	0.54±0.03 ^a
C20:3n3	0.01±0.02	0.00±0.02	0.05±0.02	0.03±0.02	0.01±0.02	0.00±0.02
C20:4n6	0.01±0.09 ^b	0.20±0.09 ^a	0.01±0.09 ^b	0.34±0.09 ^a	0.00±0.09 ^b	0.85±0.08 ^a
C22:2	0.24±0.22	0.00±0.21	0.01±0.22 ^b	2.21±0.22 ^a	0.05±0.23	0.00±0.20
C20:5	0.06±0.02 ^b	0.20±0.02 ^a	0.02±0.02 ^b	0.22±0.02 ^a	0.00±0.02 ^b	0.23±0.02 ^a

Table 4 (continued)

FA	Holstein steers		Simmental steers		LongDong steers	
	KF ¹	LD ¹	KF ¹	LD ¹	KF ¹	LD ¹
C22:6	1.48±0.12 ^a	0.75±0.12 ^b	1.26±0.12 ^a	0.54±0.12 ^b	1.06±0.13 ^a	0.47±0.11 ^b
SFA	58.58±0.99 ^a	50.73±0.99 ^b	62.84±0.99 ^a	47.70±0.97 ^b	59.71±1.05 ^a	44.01±0.93 ^b
MUFA	35.60b±1.13 ^b	39.54±1.13 ^a	33.76±1.13 ^b	37.72±1.11 ^a	37.16±1.21 ^b	46.04±1.07 ^a
PUFA	3.48±0.65 ^b	12.45±0.66 ^a	3.02±0.66 ^b	13.99±0.64 ^a	3.24±0.70 ^b	7.40±0.62 ^a
UFA ⁴	40.53±0.95 ^b	50.43±0.95 ^a	36.78±0.95 ^b	51.76±0.93 ^a	40.36±1.01 ^b	53.57±0.89 ^a
PUFA:SFA	1.79±0.14	1.53±0.14	1.56±0.14	1.31±0.14	1.02±0.15	1.34±0.13
MUFA:SFA	0.59±1.06 ^a	0.78±1.06 ^b	0.54±1.06 ^a	0.79±1.04 ^b	0.62±1.13 ^a	1.05±1.00 ^b
n3	1.79±0.14	1.53±0.14	1.56±0.14	1.31±0.14	1.02±0.15	1.34±0.13
n6	1.29±0.47 ^b	10.42±0.47 ^a	1.23±0.47 ^b	10.10±0.46 ^a	2.07±0.50 ^b	5.72±0.44 ^a
n6:n3	0.99±0.36 ^b	7.00±0.35 ^a	1.27±0.35 ^b	8.40±0.35 ^a	2.71±0.40 ^b	4.84±0.33 ^a
DI6 ⁵	7.52±0.41 ^b	9.53±0.41 ^a	6.00±0.41 ^b	9.36±0.40 ^a	6.72±0.44 ^b	12.90±0.39 ^a
DI8 ⁶	58.77±0.82 ^b	66.42±0.82 ^a	54.67±0.81 ^b	66.16±0.81 ^a	57.36±0.86 ^b	75.16±0.77 ^a

^{a,b} Means in the same row and breed group with differing superscripts differ ($P<0.05$)¹ KF=kidney fat, LD=longissimus dorsi muscle² C18:1=sum of C18:1n9t+C18:1n9c³ C18:2=sum of C18:2n6t+C18:2n6c⁴ UFA=unsaturated fatty acid⁵ Index of Δ^9 -desaturase enzyme activity on the conversion of 16:0–16:1 n9=100[16:1 n9/(16:0+16:1 n9)]⁶ Index of Δ^9 -desaturase enzyme activity on the conversion of 18:0–18:1 n9=100[18:1 n9/(18:0+18:1 n9)]

breed groups ($P<0.05$). Similar to our results, Jiang et al. (2013) found MUFA percentage was greater in muscle and lesser in kidney and omental fat in Jersey. May et al. (1993) suggested that an elevated MUFA deposition in Wagyu cattle could have been due to increased Δ^9 -desaturase activity in adipose tissue rather than increased absorption. The Δ^9 -desaturase catalytic activity index in the present study was greater in LD than in KF in each breed group ($P<0.05$). Our results are similar to those of Jiang et al. (2013) who reported that the Δ^9 desaturase catalytic activity index was greater in muscle and lesser in omental and kidney fat ($P<0.05$). The MUFA:SFA ratios were also greater in LD than KF because Δ^9 -desaturase is responsible for converting C18:0 and other SFAs into their corresponding MUFA; greater values of Δ^9 -desaturase (C16) and (C18) indices are associated with greater desaturase activity (Zhang et al. 2007). Further, Stearoyl-CoA (Δ^9 -desaturase) converts 16:0 and 18:0 to their corresponding n9 MUFA. St. John et al. (1991) in bovine adipose tissue. Hausman et al. (2009) also reported that stearoyl-CoA desaturase (SCD), or Δ^9 -desaturase, is the enzyme responsible for the conversion of all SFA to their respective MUFA, as well as conversion of trans-vaccenic acid to rumenic acid (cis-9, trans-11 CLA).

Mean PUFA was greater in LD than in KF from each of the three breeds ($P<0.05$). In HS, SS, and CLD cattle, PUFA content of KF was 8.97, 10.97, and 4.16 % lesser ($P<0.05$) than LD, respectively. We detected eleven PUFA of the 38 fatty acids detected in the samples. All had significant fat source differences except percentage of cis-11,14,17-eicosatrienoic acid (C20:3n3). The concentration of linoleic acid (LA, C18:2n6), α -linolenic acid (ALA, C18:3n3), cis-11,14-eicosadienoic acid (C20:2), cis-8,11,14-eicosatrienoic acid (C20:3n6), arachidonic acid (AA, C20:4n6) and cis-5,8,11,14,17-eicosapentaenoic acid (EPA, C20:5) were greater in LD than in KF ($P<0.05$) for all breeds. In these PUFA, LA and ALA are considered essential fatty acids because they can not be biosynthesized in the human body and they must be provided in the diet from plant or animal sources to prevent symptoms of deficiency. The more unsaturated and longer n6 and n3 fatty acids may be biosynthesized from LA and ALA, respectively, or they may be obtained from the diet. Additionally, the most important products of PUFA biosynthesis were AA, which was derived from LA, and EPA and DHA, which were derived from ALA. However, the percentage of cis-4, 7, 10, 13, 19-Docosahexaenoic Acid (DHA, C22:6) was lesser in LD than in KF from each breed ($P<0.05$). The concentration of γ -linolenic acid (C18:3n6) was greater in KF than in LD from CLD steers ($P<0.05$) but not HS or SS steers. Percentage of cis-13,16-docosadienoic acid (C22:2) was greater in LD than in KF ($P<0.05$) from SS steers but not HS or CLD steers. The aforementioned results from our study were similar to the results of Jiang et al. (2013) who reported that PUFA percentage was greater in muscle and lesser in kidney and omental fat for Jersey cattle. Specifically, these differences

were attributed to differences in docosatetraenoic (C22:4n6), eicosatrienoic (C20:3n6), arachidonic (C20:4n6), and linoleic acid (C18:2n6).

In the present study, there was a difference observed in the concentration of CLA (cis-9, trans-11) only from HS steers, with CLA (cis-9, trans-11) percentage of KF 0.09 % greater ($P<0.05$) than LD. Dannenberger et al. (2005) reported that the percentage of CLA (cis-9, trans-11) was greatest in subcutaneous fat compare to longissimus dorsi muscle fat in German Holstein. However, Jiang et al. (2013) reported that CLA (cis-9, trans-11) percentage was not different between longissimus dorsi muscle fat and KF in Jersey.

Polyunsaturated fatty acids include the n6 and n3 fatty acid classes, essential for normal growth, development, reproduction, and overall human health. The recommended dietary n6:n3 ratio is 4 or less (Enser 2001). Omega-3 fatty acid percentages did not differ in adipose depot sites ($P>0.05$) for HS, SS and CLD steers. However, the content of n6 was greater in LD than KF for all breeds ($P<0.05$). The ratio of n6:n3 was greater in LD than KF in each breed ($P<0.05$). In HS, SS, and CLD cattle, n6:n3 ratio of KF was 6.01, 7.13, and 2.13 % lesser ($P<0.05$) than LD, respectively. Our results for n6:n3 differed from Jiang et al. (2013) who found that n6:n3 ratios were similar in lean muscle and intramuscular fat compared to other tissues studied. In the breed groups of our study, the n6:n3 ratio of the CLD breed in LD fat was close to the recommended dietary n6:n3 ratio but was higher than recommended levels in HS and SS due to lower percentage of n6 fatty acid in CLD. It is possible that steaks from CLD cattle may provide a meat product closer to the recommended n6:n3 ratio.

Conclusions

Fatty acid composition differed between longissimus dorsi muscle and kidney fat from different steers breed groups. The results indicated LD as a better source of PUFA and MUFA while KF had better ratio of the n6:n3 PUFAs in the different breed groups. Further, KF had a greater the concentration of CLA than LD for Holstein steers ($P<0.05$). There was evidence ($P<0.05$) that C18:3n6 was greater in KF than LD in CLD cattle but not in HS or SS cattle. The LA, ALA, EPA, and AA content were greater in LD than KF ($P<0.05$) for all breeds. Moreover, the DHA percentage was lesser in LD than in KF for each breed groups ($P<0.05$). The Δ^9 -desaturase catalytic activity index in the present study was greater in LD than in KF in each breed groups ($P<0.05$). Further research is needed to compare additional fat depots in Chinese LongDong cattle to other breeds to determine the potential for development of meat products with desirable fatty acid composition. Results from this study suggest that production of ground products extended with kidney fat may

be beneficial in production of products with a more desirable n6:n3 ratio.

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