Survey of the fatty acid composition of Canadian beef: Backfat and longissimus lumborum muscle

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Aldai, N., Dugan, M. E. R., Rolland, D. C. and Kramer, J. K. G. 2009. **Survey of the fatty acid composition of Canadian beef: Backfat and longissimus lumborum muscle.** Can. J. Anim. Sci. **89**: 315–329. A survey of Canadian retail beef was undertaken with emphasis on the *trans* fatty acid (TFA) and conjugated linoleic acid (CLA) isomers, and compared with current health recommendations. Thirty striploin steaks were collected in the winter and summer from major grocery stores in Calgary (Alberta, Canada). Steak fatty acid compositions (backfat and longissimus lumborum muscle analysed separately) showed minor seasonal differences with lower total saturates ($P < 0.05$) and higher total monounsaturates ($P < 0.01$) in winter, but no differences in total polyunsaturated fatty acids. The ratio of n-6 and n-3 polyunsaturated fatty acid in longissimus lumborum averaged 5.8. The average TFA content in longissimus lumborum was 0.128 g 100 g^{-1} serving size, and 10*t*-18:1 was found to be the predominant isomer (32% of total *trans*), while vaccenic acid was second most abundant (15% of total *trans*). The CLA content in longissimus lumborum was similar to that of backfat, ranging from 0.43 to 0.60% of total fatty acids and rumenic acid represented 60% of total isomers. Overall, there is still room for improvement in the saturated, mono- and polyunsaturated fatty acid composition of Canadian beef to meet general dietary guidelines for human consumption and additional targets should include reducing 10*t*-18:1 while increasing both rumenic and vaccenic acids.

Key words: Beef, conjugated linoleic acid, survey, *trans* fatty acids, vaccenic acid

Aldai, N., Dugan, M. E. R., Rolland, D. C. et Kramer, J. K. G. 2009. **Les acides gras dans le bœuf canadien : gras dorsal et longissimus lumborum.** Can. J. Anim. Sci. **89**: 315–329. Les auteurs ont entrepris une enquête sur le bœuf canadien vendu au détail en insistant sur les isomères des acides gras *trans* (AGT) et de l'acide linoléique conjugué (ALC), puis ils ont comparé leurs résultats aux recommandations actuelles relatives à la santé. À cette fin, ils ont recueilli trente beefsteaks d'entrecôte dans les principales épiceries de Calgary (Alberta, Canada) en hiver et en été. La composition en acides gras de la viande (analyse distincte du gras dorsal et du longissimus lumborum) révèle de faibles variations saisonnières, avec une plus basse concentration totale d'acides gras saturés ($P < 0,05$) et une concentration plus élevée d'acides gras mono-insaturés ($P < 0,01$) en hiver, sans écart au niveau de la concentration totale d'acides gras polyinsaturés. Le ratio entre les AGP n-6 et n-3 dans le longissimus lumborum s'établissait en moyenne à 5,8. Le longissimus lumborum was renferme en moyenne 0,128 g d'AGT par portion de 100 g et l'isomère prédominant est le 10*t*-18:1 (32 % de la concentration totale d'AGT), l'acide vaccénique arrivant au deuxième rang (15 % de la concentration totale d'AGT). Le lngissimus lumborum contient autant d'ALC que le gras dorsal, soit de 0,43 à 0,60 %, l'acide ruménique constituant 60 % de l'ensemble des isomères. Globalement, en ce qui concerne la composition en acides gras mono et polyinsaturés, le bœuf canadien a encore du chemin à faire avant de respecter les directives générales eu égard à l'alimentation humaine, et on devrait envisager de réduire le ratio de 10*t*-18:1 ainsi qu'accroître la concentration des acides vaccénique et ruménique.

Mots clés: Bœuf, ALC, acides gras *trans*, acide vaccénique

The fat content and fatty acid composition of beef are outstanding aspects of quality that consumers consider important as they focus on the healthiness and nutritional value of all commercial foods (Scollan et al. 2006). Current recommendations for human health in many countries suggest reducing the level of total dietary fat (<15–30%), saturated fatty acids (SFA) (<10%, particularly limiting the intake of 14:0 and 16:0), and n-6 polyunsaturated fatty acids (PUFA) (<5–8%), while increasing the intake of n-3 PUFAs (>1–2%) of total energy intake to maintain a n-6/n-3 ratio of <5:1, and a P:S ratio above 0.4 (World Health Organization 2003). With mounting evidence that *trans* fatty acids (TFA) are linked to increased risk for cardiovascular disease

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Abbreviations: Ag$^+$-HPLC, silver-ion high performance liquid chromatography; BCFA, branched-chain fatty acid; CLA, conjugated linoleic acid; DMA, dimethylacetal; GC, gas chromatography; MUFA, monounsaturated fatty acid; OCFA, odd-chain fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; TFA, *trans* fatty acid

(Mensink et al. 2003), many countries have introduced mandatory labelling of the total TFA content in foods, which includes TFA with isolated double bonds, but excludes conjugated linoleic acid (CLA) (Ratnayake and Zehaluk 2005). Consequently, some healthy *trans* fats may be included in the total TFA label, such as vaccenic acid (11t-18:1), while all CLA isomers, healthy (i.e., rumenic acid 9c,11t-18:2) or otherwise, are excluded. This has specific implications with regard to dairy and meat products from ruminants. In the Danish regulations, ruminant products are excluded (Ratnayake and Zehaluk 2005), on the assumption that these TFA are of no concern since they are thought to be mainly vaccenic and rumenic acids, both of which have been shown to have beneficial health effects (Belury 2002; Ip et al. 2003). However, several reports are now showing that the TFA and CLA pattern in ruminant products can be altered depending on the diet fed and can result in increased levels of total TFA, specifically 10t-18:1 (Purchas et al. 2005; Roy et al. 2006; Cruz-Hernandez et al. 2007). In addition, the *trans*-18:1 isomers, notably 10t-18:1, can be found at increased levels in intensively finished beef (Dugan et al. 2007) and this TFA isomer has been shown to be atherogenic in humans (Hodgson et al. 1996) and in animal models (Bauchart et al. 2007; Roy et al. 2007).

Surveys of the fatty acid composition of Canadian beef products are limited (Ma et al. 1999; Beef Information Centre 2008; Health Canada 2008) and the detailed fatty acid composition (including *trans* and CLA isomers) of Canadian beef at the retail level is currently not available. Therefore, the present survey was undertaken to elucidate the fatty acid composition of Canadian beef available at the retail level and to see how it compares with current health recommendations. In Canada, 65% of beef is finished in the province of Alberta (CanFax Research Services 2008), and for the present survey, sampling was limited to major retail outlets in Calgary, Alberta, Canada.

MATERIALS AND METHODS

Sample Collection and Preparation
Striploin steaks from Canada A/AA Grade (youthful) beef were collected on one day in February (winter, $n = 30$) and one day in July (summer, $n = 30$) 2007, from the four major grocery store chains in Calgary (Alberta, Canada) with one steak collected per store per time period. Beef was collected in summer as animals slaughtered during this time period would likely have been placed in the feedlot directly after weaning, while animals slaughtered in early winter would likely be pastured as yearlings prior to entering the feedlot in the fall (Basarab et al. 2005). Precise details of production systems for beef used in the present study are unknown. After collection, samples were stored on ice in insulated picnic coolers and transported to the laboratory in Lacombe (Alberta, Canada).

From the striploin steak 5 g of backfat was sampled from the mid-point of the steak and stored separately at $-80°C$. The steak was then trimmed of remaining subcutaneous and seam fat and the epimysium (outer layer of connective tissue), and the longissimus lumborum muscle was comminuted using a Robot Coupe Blixer BX3 (Robot Coupe USA Inc., Ridgeland, MS). A subsample of 15–20 g was stored at $-80°C$ for subsequent fatty acid determinations.

Fatty Acid Analysis
Backfat samples (50 mg) were freeze-dried and directly methylated with sodium methoxide and lipids were extracted from 1 g of freeze-dried muscle sample using a mixture of chloroform-methanol (1:1, vol/vol) (Kramer et al. 1998). Each sample was homogenized in 5 mL of methanol, and then 5 mL of chloroform was added and homogenized again. The mixture was filtered through a sintered glass filter funnel. The homogenizer (Cyclone IQ2, VirTis Company, Gardiner, NY) was rinsed with another 10 mL of chloroform-methanol (1:1, vol/vol) and filtered through the same glass funnel and pooled with the first extract. The final volume was adjusted to contain exactly 20 mL chloroform-methanol (1:1, vol/vol) and 9 mL 0.88% potassium chloride solution and 1 drop of 6 N hydrochloric acid were added. The solution was mixed and centrifuged $(600 \times g)$ to separate phases. The bottom organic layer (chloroform) was removed and another 10 mL of chloroform were added to rinse the aqueous phase again (methanolwater), mixed and centrifuged. The bottom organic layer was collected and pooled with the first one. The chloroform was evaporated using a rotary evaporator (Büchi, Model R-114, Labortechnik, Switzerland) and total lipids were dissolved in 15 mL of chloroform. Lipid aliquots (10 mg) from each steak were methylated separately using acidic (methanolic HCl) and basic (sodium methoxide) reagents (Kramer et al. 2008). The fatty acid methyl esters were analyzed using the gas chromatography (GC) and Ag^+-HPLC equipment and methods outlined by Cruz-Hernandez et al. (2004), and the *trans*-18:1 isomers were analyzed using two complementary GC temperature programs (Dugan et al. 2007; Kramer et al. 2008).

Statistical Analysis
Fatty acid composition data for backfat (%) and meat (% and mg 100 g^{-1} meat) were analyzed as a one-way ANOVA with collection period as the main effect using PROC MIXED (SAS Institute, Inc. 2001). Polynomial regressions incorporating linear and quadratic coefficients were also conducted using the GLM procedure of SAS to evaluate the relationship between selected biohydrogenation products of PUFA. For instances where the quadratic effects were not significant $(P > 0.05)$ data were reprocessed with only the linear effect.

RESULTS AND DISCUSSION

Backfat Composition

Backfat SFA composition for both collection periods is summarized in Table 1. Samples collected in summer had significantly more SFA than samples collected in winter (44.2 and 41.8%, respectively; $P = 0.005$) and this was mostly attributed to the higher percentage of 16:0 in summer samples ($P < 0.001$), which is the major SFA in beef (Rule et al. 1995). Percentages of 12:0 and 14:0 were also significantly higher in samples from summer than winter ($P < 0.001$), while the odd-chain fatty acids (OCFA) 17:0 and 19:0 were significantly higher in winter samples. No differences in total branched-chain fatty acids (BCFA) were observed; however, 15:0*anteiso* was slightly lower in winter ($P = 0.027$) while 17:0*anteiso* ($P = 0.003$) and 18:0*iso* ($P = 0.031$) were higher. As found in previous studies (Dugan et al. 2007) 17:0*anteiso* and 17:0*iso* were the most abundant BCFAs. Differences in SFA likely relate to climatic differences. Colder temperatures in winter increase $\triangle^9$-desaturase activity converting SFA to monounsaturated fatty acids (MUFA), which is required to maintain fat in a fluid state (Tume 2004). Colder temperatures in winter also increase rates of digesta passage from the rumen (Kennedy et al. 1977), which may limit time available for biohydrogenation of PUFA to SFA. In addition, increased rates of passage would alter rumen volatile fatty acid production in favour of proprionate instead of acetate (Kennedy et al. 1977), with acetate being the major precursor for even-chain fatty acid synthesis, while proprionate is a precursor for OCFA synthesis.

Backfat MUFA composition for both collection periods is summarized in Table 2. In contrast to SFA,

the total monounsaturated percentage was significantly higher in winter than in summer (54.8 and 52.5%, respectively; $P = 0.006$) attributed mainly to the *cis*-monounsaturates (51.2 and 48.6%, respectively; $P = 0.008$). These differences are likely related to the aforementioned climatic differences noted for SFA. In general, there were no significant differences in the content of the *trans*-MUFA between collections, except for two minor isomers (15*t*- and 16*t*-18:1). Across collection periods, the total *trans*-18:1 averaged $3.77 \pm 0.16\%$ and ranged from 1.38 to 7.23%. This high variability in total *trans*-18:1 content may be due to several factors including individual animal variation combined with differences in production systems and management practices (i.e., age/live weight at slaughter, genetics, feeding strategies, usage of antibiotics) (Dannenberger et al. 2004; Eifert et al. 2006; Aldai et al. 2007; Dugan et al. 2008).The major isomer found was 10*t*-18:1 ($1.64 \pm 0.12\%$, ranged from 0.15 to 4.55%), which was twofold greater than the second most abundant isomer 11*t*-18:1 ($0.73 \pm 0.04\%$, ranged from 0.20 to 1.55%). These results were intermediate to results obtained with

Table 1. Saturated fatty acid composition (percentages) of backfat from winter and summer collections

Fatty acid (%)	Winter	Summer	SEM[z]	P
12:0	0.05	0.08	0.002	<0.001
14:0	2.69	3.50	0.065	<0.001
15:0*iso*	0.11	0.12	0.005	0.395
15:0*anteiso*	0.16	0.19	0.007	0.027
15:0	0.58	0.63	0.019	0.253
16:0*iso*	0.16	0.21	0.018	0.185
16:0	23.0	25.8	0.229	<0.001
17:0*iso*	0.36	0.36	0.009	0.664
17:0*anteiso*	0.87	0.73	0.022	0.003
17:0	1.61	1.37	0.056	0.041
18:0*iso*	0.16	0.14	0.004	0.031
18:0	11.9	11.0	0.337	0.200
19:0	0.10	0.05	0.002	<0.001
20:0	0.09	0.08	0.004	0.068
17:0-cyclo[y]	0.05	0.05	0.003	0.964
Σ BCFA[z]	1.82	1.75	0.046	0.430
Σ SFA[z]	41.8	44.2	0.420	0.005

[z]SEM, standard error of the mean; BCFA, branched fatty acids (includes *iso* and *anteiso*); SFA, saturated fatty acids.
[y]11-cyclohexylundecanoic acid.

Table 2. Monounsaturated fatty acid composition (percentages) of backfat from winter and summer collections

Fatty acid (%)	Winter	Summer	SEM[z]	P
9*c*-14:1	1.01	1.27	0.067	0.059
9*c*-15:1	0.03	0.03	0.002	0.827
7*c*-16:1	0.05	0.08	0.004	0.002
9*c*-16:1	4.05	4.92	0.193	0.029
11*c*-16:1	0.27	0.27	0.016	0.888
13*c*-16:1	0.09	0.11	0.006	0.132
9*c*-17:1	1.52	1.29	0.044	0.012
9*c*-18:1[y]	40.8	37.5	0.383	<0.001
11*c*-18:1	1.92	1.79	0.041	0.132
12*c*-18:1	0.15	0.20	0.010	0.012
13*c*-18:1	0.59	0.50	0.022	0.045
14*c*-18:1	0.03	0.04	0.001	<0.001
15*c*-18:1	0.18	0.21	0.010	0.174
9*c*-20:1	0.14	0.11	0.004	<0.001
11*c*-20:1	0.34	0.25	0.011	<0.001
Σ *cis* MUFA	51.2	48.6	0.468	0.008
11*t*/12*t*-16:1	0.02	0.02	0.001	0.082
6*t*/7*t*/8*t*-18:1	0.22	0.21	0.013	0.824
9*t*-18:1	0.27	0.28	0.012	0.832
10*t*-18:1	1.62	1.65	0.117	0.906
11*t*-18:1	0.71	0.75	0.040	0.675
12*t*-18:1	0.15	0.17	0.008	0.211
13*t*/14*t*-18:1[x]	0.39	0.36	0.020	0.392
15*t*-18:1	0.13	0.41	0.017	<0.001
16*t*-18:1	0.12	0.09	0.006	0.045
Σ *trans* MUFA	3.63	3.95	0.161	0.332
Σ 10*t*- & 11*t*-18:1	2.34	2.40	0.118	0.796
11*t*-/10*t*-18:1	0.60	0.70	0.075	0.508
Σ MUFA	54.8	52.5	0.395	0.006

[z]SEM, standard error of the mean; MUFA, monounsaturated fatty acids.
[y]Coelution with 10*c*-18:1.
[x]Coelution with 6*c*/7*c*/8*c*-18:1.

animals finished on a 73% barley grain diet (2.13% 10*t*-18:1 and 0.77% 11*t*-18:1; Dugan et al. 2007) or a 81% barley grain diet (0.82% 10*t*-18:1 and 0.54% 11*t*-18:1; Aldai et al. 2008a). The aforementioned two *trans*-18:1 isomers represented 63% of the total *trans*-18:1 content and the higher levels of total *trans*-18:1 were associated with higher levels of 10*t*-18:1, and not vaccenic acid (11*t*-18:1) as demonstrated in Fig. 1.

Backfat PUFA composition and calculated ratios (P/S, n-6/n-3) of both collection periods are presented in Table 3. A higher percentage of n-3 PUFA in samples collected in winter was anticipated given that these animals likely gained more weight on pasture relative to animals going directly to the feedlot after weaning (Realini et al. 2004; Dugan et al. 2007). However, this was not the case as the effect of pasture on beef fatty acid composition can be rapidly lost with a short period of concentrate finishing before slaughter (Aldai et al. 2008b). In general, no significant differences were found for the methylene interrupted n-6 and n-3 PUFA (except for 20:3n-6; $P < 0.001$), calculated ratios and CLA. Across collection periods, total CLA averaged $0.57 \pm 0.02\%$ and ranged from 0.27 to 1.22%. The major CLA isomer was 9*c*,11*t*-18:2 ($0.35 \pm 0.02\%$, ranged from 0.08 to 0.93%) followed by 7*t*,9*c*-18:2 ($0.08 \pm 0.001\%$, ranged from 0.01 to 0.15%). Results for the total and individual CLA isomers are similar to values previously reported for barley-finished beef (Dugan et al. 2007; Aldai et al. 2008a). In general, the content (%) of total CLA was associated with higher levels of the major isomer (i.e., 9*c*,11*t*-18:2), but not the second most abundant isomer (i.e., 7*t*,9*c*-18:2) as shown in Fig. 2.

The P/S and n-6/n-3 ratios from the backfat tissue of these striploin steaks were comparable with values obtained in backfat tissue from concentrate-finished (73–81% barley) beef cattle (Dugan et al. 2007; Aldai et al. 2008a).

Muscle Composition
Compared with backfat (Tables 1, 2 and 3), muscle contained more identifiable fatty acids (Tables 4, 5 and

Table 3. Polyunsaturated fatty acid composition (percentages) of backfat from winter and summer collections

Fatty acid (%)	Winter	Summer	SEM[z]	P
Methylene interrupted				
18:2n-6	1.56	1.53	0.058	0.810
20:2n-6	0.03	0.03	0.001	0.107
20:3n-6	0.08	0.06	0.003	<0.001
20:4n-6	0.06	0.05	0.004	0.169
22:4n-6	0.03	0.03	0.003	0.353
18:3n-3	0.20	0.22	0.012	0.361
20:3n-3	0.03	0.03	0.004	0.978
20:5n-3	0.02	0.02	0.004	0.978
22:5n-3	0.04	0.03	0.003	0.062
22:6n-3	0.02	0.02	0.002	0.171
c,t & c,c Dienes				
9*c*,13*t*/8*t*,12*c*-18:2	0.24	0.23	0.008	0.558
8*t*,13*c*-18:2	0.10	0.10	0.004	0.798
9*c*,12*t*-18:2	0.08	0.07	0.003	0.072
11*t*,15*c*-18:2	0.12	0.09	0.009	0.135
9*c*,15*c*-18:2	0.12	0.13	0.005	0.618
Conjugated linoleic acids				
9*c*,11*t*-18:2	0.38	0.33	0.023	0.243
7*t*,9*c*-18:2	0.08	0.08	0.004	0.879
11*t*,13*c*-18:2	0.01	0.01	0.001	0.832
10*t*,12*c*-18:2	0.01	0.02	0.001	0.093
9*t*,11*c*-18:2	0.05	0.04	0.003	0.258
Σ PUFA[z]	2.07	2.00	0.069	0.631
Σ n-6 PUFA	1.76	1.69	0.060	0.551
Σ n-3 PUFA	0.31	0.31	0.015	0.861
Σ c,t & c,c Dienes	0.66	0.62	0.018	0.289
Σ CLA	0.60	0.54	0.025	0.254
P:S[y]	0.05	0.05	0.002	0.266
n-6/n-3	5.99	6.04	0.221	0.905

[z]SEM, standard error of the mean; PUFA, polyunsaturated fatty acids CLA, conjugated linoleic acids.
[y]P:S, polyunsaturated to saturated fatty acid ratio.

6). The additional methyl esters quantified in muscle included those of long-chain SFA (21:0, 22:0, 24:0), *cis*- and *trans*-MUFA (10*c*-16:1, 12*c*-16:1, 5*c*-17:1, 7*c*-17:1, 11*c*-17:1, 5*t*-18:1), methylene interrupted PUFA (18:3n-6), some additional dienes (9*t*,12*t*-18:2, 9*t*,12*c*-18:2) and dimethylacetals derived from plasmalogens (DMA;
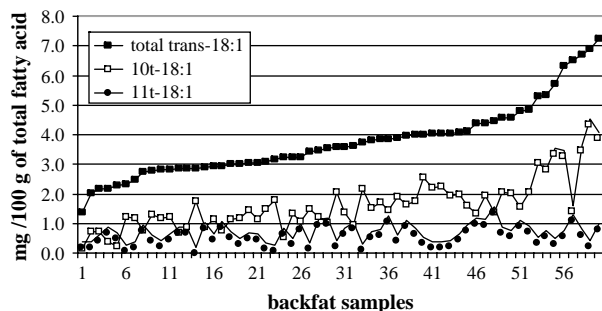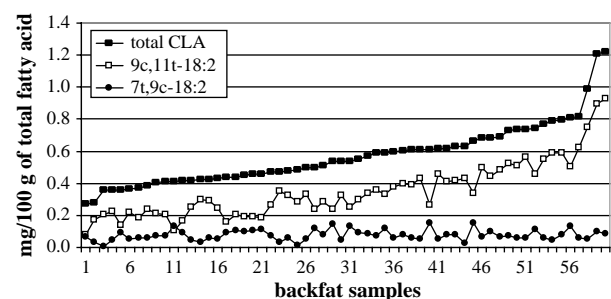

Fig. 1. Abundance of 10*t*-18:1 and 11*t*-18:1 as percent of total lipids after sorting all backfat samples in increasing order of total *trans*-18:1 (*n* = 60).

Fig. 2. Relative abundance of 9*c*,11*t*-18:2 and 7*t*,9*c*-18:2 as percent of total lipids after sorting all backfat samples in increasing order of total CLA (*n* = 60).

Table 4. Saturated fatty acid composition (mg 100 g^{-1} of meat and percentages) of longissimus lumborum from winter and summer collections

	Winter	Summer	SEM[z]	P	Winter	Summer	SEM	P
Fatty acid	4,304	3,636	232.9	0.157				
Σ FAME		(mg 100 g^{-1} of meat)				(% of total FAME)		
12:0	1.28	1.31	0.105	0.884	0.03	0.03	0.001	0.055
14:0	97.2	89.7	6.292	0.558	2.22	2.40	0.050	0.081
15:0iso	3.43	3.38	0.267	0.932	0.08	0.09	0.004	0.214
15:0anteiso	4.60	4.80	0.289	0.725	0.11	0.13	0.005	0.024
15:0	19.0	16.9	1.163	0.365	0.44	0.46	0.013	0.560
16:0DMA	36.1	34.7	0.965	0.480	0.98	1.07	0.055	0.386
16:0iso	5.49	5.38	0.360	0.875	0.13	0.14	0.005	0.214
16:1DMA	1.61	1.45	0.047	0.093	0.04	0.04	0.002	0.515
16:0	1036	890	57.38	0.210	24.0	24.3	0.180	0.405
17:0iso	13.2	12.3	0.701	0.511	0.31	0.34	0.007	0.033
17:0anteiso	21.9	18.9	1.344	0.272	0.50	0.51	0.011	0.686
17:0	57.5	48.3	3.593	0.206	1.33	1.31	0.039	0.758
18:0DMA	19.6	18.9	0.499	0.513	0.54	0.58	0.028	0.428
18:0iso	4.82	4.42	0.327	0.537	0.11	0.12	0.003	0.511
18:1DMA	1.69	1.83	0.118	0.551	0.04	0.05	0.003	0.051
18:0	502	456	29.18	0.427	11.8	12.5	0.206	0.062
19:0	3.30	2.84	0.268	0.390	0.08	0.08	0.004	0.762
20:0	3.42	2.97	0.223	0.325	0.08	0.08	0.003	0.404
21:0	0.89	0.85	0.046	0.622	0.02	0.02	0.001	0.256
22:0	2.30	2.28	0.103	0.905	0.06	0.07	0.002	0.120
24:0	1.32	0.94	0.075	0.014	0.03	0.03	0.002	0.164
17:0-cyclo[y]	3.28	3.47	0.209	0.657	0.08	0.10	0.003	0.060
Σ BCFA[z]	53.4	49.2	3.176	0.504	1.25	1.34	0.029	0.148
Σ DMA[z]	58.9	56.9	1.411	0.471	1.60	1.76	0.083	0.359
Σ SFA[z]	1,778	1,561	99.26	0.280	41.3	42.7	0.296	0.026

[z]SEM, standard error of the mean; BCFA, branched fatty acids (includes iso and anteiso); DMA, dimethylacetals; SFA, saturated fatty acids.
[y]1-cyclohexylundecanoic acid.

16:0DMA, 16:1DMA, 18:0DMA, 18:1DMA). The aforementioned methyl ester derivatives were either not detected or below quantification limits in the backfat samples. Considering the lipid complexity of meat samples and the chemical nature of all lipid structures, accurate and reliable methods were required for detailed fatty acid analyses (Cruz-Hernandez et al. 2006; Santercole et al. 2007; Kraft et al. 2008). For meat samples, this included base-catalyzed methylation to analyze CLA isomers, which are acid sensitive (Kramer et al. 1997), and acid-catalyzed methylation required for the analysis of plasmalogens and sphingolipids, which contribute up to 15% of the total meat polar lipids (Horrocks 1972).

The total intramuscular fatty acid content (mg 100 g^{-1} of meat) and SFA composition (mg 100 g^{-1} meat and percentages) of both collection periods are summarized in Table 4. Total intramuscular fatty acids were not statistically different between collection periods (average value of 3970 mg 100 g^{-1} of meat; $P = 0.157$). In terms of absolute contents, there were no differences between collections for SFA (except for 24:0; $P = 0.014$), BCFA and DMA. Plasmalogen synthesis is not fully understood, and it is believed that several factors influence this

process (Snyder et al. 1985). Both breed (Kraft et al. 2008) and diet (Dannenberger et al. 2006) differences have been reported to affect the total fatty aldehyde content in beef animals. Expressed as percentages, however, few significant differences were found. The percentage of 15:0anteiso and 17:0iso were higher ($P < 0.05$) in summer although no difference was found for the total BCFA. Total SFA was significantly higher in summer compared with winter (42.7 and 41.3%, respectively; $P = 0.026$), and this was mostly attributed to trends for higher percentages of 14:0 ($P = 0.081$) and 18:0 (second most abundant SFA; $P = 0.062$), but compared with backfat differences in SFA were rather limited. As postulated for backfat, the reason for a lower SFA content in samples collected in winter could be related to the ambient temperature (Duncan and Garton 1967). However, such differences resulting from direct temperature effects are more likely to occur in backfat (subcutaneous fat) because of the temperature homeostasis of deeper tissues. Intracellular fatty acid composition changes to maintain constant lipid fluidity and allow for normal metabolic function. This regulation appears to be primarily achieved by $\triangle^9$-desaturase activity (Kouba et al. 1999), with activity being greater in cooler tissues.

Table 5. Monounsaturated fatty acid composition (mg 100 g^{-1} of meat and percentages) of longissimus lumborum from winter and summer collections

Fatty acid	Winter	Summer	SEM^z	P	Winter	Summer	SEM	P
	(mg 100 g^{-1} of meat)				(% of total FAME)			
9c-14:1	27.3	22.1	2.010	0.205	0.61	0.58	0.026	0.529
9c-15:1	3.08	2.56	0.119	0.032	0.08	0.08	0.003	0.699
7c-16:1	6.40	5.93	0.354	0.510	0.15	0.16	0.002	0.011
9c-16:1	158	132	9.311	0.167	3.68	3.57	0.089	0.521
10c-16:1	1.67	1.43	0.105	0.245	0.04	0.04	0.001	0.858
11c-16:1	8.73	6.79	0.575	0.097	0.20	0.18	0.007	0.251
12c-16:1	1.05	1.00	0.068	0.754	0.03	0.03	0.001	0.139
13c-16:1	3.64	2.98	0.192	0.092	0.09	0.08	0.003	0.482
5c-17:1	1.37	1.32	0.075	0.741	0.03	0.04	0.001	0.209
7c-17:1	1.31	1.30	0.075	0.945	0.03	0.04	0.001	0.097
9c-17:1	58.5	45.5	3.219	0.048	1.37	1.26	0.038	0.128
11c-17:1	1.49	1.76	0.103	0.212	0.04	0.05	0.002	<0.001
9c-18:1^y	1735	1362	100.3	0.069	39.6	37.3	0.315	<0.001
11c-18:1	80.3	66.6	4.123	0.101	1.89	1.84	0.025	0.259
12c-18:1	4.70	4.59	0.302	0.848	0.11	0.13	0.007	0.190
13c-18:1	22.1	15.8	1.430	0.032	0.49	0.42	0.014	0.013
14c-18:1	1.35	1.44	0.081	0.592	0.03	0.04	0.001	0.008
15c-18:1	5.88	6.15	0.400	0.739	0.14	0.17	0.007	0.028
9c-20:1	3.70	3.16	0.249	0.277	0.08	0.09	0.002	0.739
11c-20:1	9.67	7.21	0.621	0.053	0.22	0.20	0.006	0.177
Σ cis MUFA	2,135	1,692	121.0	0.072	48.9	46.2	0.359	<0.001
11t/12t-16:1	1.82	1.56	0.103	0.212	0.04	0.04	0.001	0.951
5t-18:1	1.21	0.95	0.101	0.197	0.03	0.03	0.002	0.234
6t/7t/8t-18:1	5.78	6.58	0.557	0.474	0.14	0.18	0.010	0.055
9t-18:1	9.45	9.05	0.684	0.772	0.22	0.24	0.009	0.189
10t-18:1	44.7	46.1	5.815	0.908	1.01	1.21	0.089	0.247
11t-18:1	19.1	17.5	1.259	0.519	0.45	0.50	0.021	0.290
12t-18:1	4.77	4.46	0.309	0.618	0.11	0.13	0.006	0.181
13t/14t-18:1^x	9.66	10.5	0.635	0.531	0.23	0.30	0.014	0.027
15t-18:1	7.82	8.27	0.458	0.627	0.18	0.24	0.007	<0.001
16t-18:1	3.35	3.42	0.206	0.873	0.08	0.10	0.004	0.022
Σ trans MUFA	108	108	8.739	0.972	2.49	2.96	0.118	0.051
Σ 10t- & 11t-18:1	63.8	63.6	6.339	0.982	1.46	1.71	0.088	0.154
11t-/10t-18:1	0.63	0.66	0.079	0.829				
Σ MUFA	2,243	1,801	127.2	0.087	51.4	49.2	0.327	0.001

^{z}SEM, standard error of the mean; MUFA, monounsaturated fatty acids.
^{y}Coelution with 10c-18:1.
^{x}Coelution with 6c/7c/8c-18:1.

Muscle MUFA composition is reported in Table 5. There was a tendency for higher absolute levels of total MUFA in winter compared with summer (2243 and 1801 mg 100 g^{-1} of meat, respectively; $P = 0.087$), which was mostly influenced by the *cis*-monounsaturates: 9c-15:1, 9c-17:1, and 13c-18:1 ($P < 0.05$), and 11c-16:1, 13c-16:1, 9c-18:1 and 11c-20:1 ($P < 0.1$). These differences are likely related to the aforementioned climatic differences noted for SFA. In addition, the numerically higher fat content of winter samples and the possible higher desaturase activity in fatter animals as found by Siebert et al. (2003) could also help to explain the higher MUFA content of winter samples. For *trans*-monounsaturates, no significant differences were found between collection periods. Across collection periods, the absolute content of total *trans*-18:1 averaged 108 ±

8.59 mg and ranged from 31.68 to 428.1 mg 100 g^{-1} of meat. The major isomer was 10t-18:1 (45.38 ± 5.77mg) ranging from 4.22 to 292.8 mg 100 g^{-1} of meat, followed by 11t-18:1 (18.31 ± 1.25 mg) ranging from 4.21 to 49.81 mg 100 g^{-1} of meat. High and variable levels of 10t-18:1 likely relate to unstable rumen conditions and altered bacterial populations when feeding highly fermentable concentrate based diets (Bauman and Griinari 2003; Dannenberger et al. 2004; Hristov et al. 2005) and may also in part relate to feeding monensin as a growth promoter (Gustafson and Bowen 1997). Monensin inhibits the growth of gram positive bacteria, including cellulolytic strains of *Butyrivibrio fibrisolvens* (Chen and Wolin 1979; Russell and Strobel 1989), which are known as the major producers of 11t-18:1 (Kepler et al. 1966). Even without dietary

Table 6. Polyunsaturated fatty acid composition (mg 100 g^{-1} of meat and percentages) of *Longissimus lumborum* from winter and summer collections

Fatty acid	Winter	Summer	SEM[z]	P	Winter	Summer	SEM	P
	(mg 100 g^{-1} of meat)				(% of total FAME)			
Methylene interrrupted								
18:2n-6	101.3	99.2	4.439	0.817	2.54	2.93	0.099	0.055
18:3n-6	1.24	1.12	0.065	0.375	0.03	0.03	0.002	0.871
20:2n-6	2.15	1.80	0.114	0.131	0.05	0.05	0.002	0.844
20:3n-6	9.63	8.62	0.330	0.129	0.25	0.26	0.011	0.590
20:4n-6	28.0	28.4	0.899	0.810	0.77	0.87	0.045	0.286
22:4n-6	4.57	3.72	0.226	0.064	0.11	0.11	0.006	0.965
18:3n-3	10.6	10.4	0.617	0.820	0.26	0.30	0.011	0.174
20:3n-3	1.42	1.43	0.119	0.943	0.03	0.04	0.003	0.254
20:5n-3	3.62	4.05	0.244	0.377	0.10	0.12	0.008	0.164
22:5n-3	9.57	9.49	0.428	0.931	0.27	0.29	0.017	0.524
22:6n-3	0.96	1.24	0.068	0.040	0.03	0.04	0.002	0.027
t,t; c,t & c,c Dienes								
9*t*,12*t*-18:2	1.49	1.45	0.092	0.802	0.04	0.04	0.002	0.530
9*c*,13*t*/8*t*,12*c*-18:2	7.28	6.72	0.385	0.472	0.17	0.19	0.005	0.080
8*t*,13*c*-18:2	3.77	3.40	0.195	0.347	0.09	0.10	0.003	0.223
9*c*,12*t*-18:2	2.40	2.30	0.110	0.643	0.06	0.07	0.002	0.056
9*t*,12*c*-18:2	1.35	1.16	0.087	0.279	0.03	0.03	0.002	0.444
11*t*,15*c*-18:2	3.86	4.39	0.452	0.564	0.09	0.11	0.007	0.055
9*c*,15*c*-18:2	7.87	5.67	0.440	0.015	0.18	0.16	0.004	0.002
Conjugated linoleic acids								
9*c*,11*t*-18:2	11.1	10.5	0.859	0.736	0.26	0.29	0.013	0.325
7*t*,9*c*-18:2	2.21	2.61	0.212	0.344	0.05	0.07	0.003	0.016
11*t*,13*c*-18:2	0.34	0.30	0.039	0.591	0.01	0.01	0.001	0.923
10*t*,12*c*-18:2	0.39	0.49	0.041	0.201	0.01	0.01	0.001	0.014
9*t*,11*c*-18:2	1.55	1.60	0.126	0.858	0.04	0.04	0.002	0.258
Σ PUFA[z]	173	169	6.053	0.768	4.44	5.03	0.168	0.085
Σ n-6 PUFA	147	143	5.430	0.716	3.75	4.25	0.148	0.098
Σ n-3 PUFA	26.2	26.6	1.171	0.873	0.69	0.78	0.034	0.172
Σ t,t; c,t & c,c Dienes	28.0	25.1	1.511	0.334	0.66	0.70	0.014	0.260
Σ CLA[z]	18.1	17.9	1.175	0.936	0.43	0.49	0.014	0.058
P:S[y]	0.11	0.12	0.004	0.230				
n-6/n-3	5.93	5.69	0.222	0.591				

[z]SEM, standard error of the mean; PUFA, polyunsaturated fatty acid; CLA, conjugated linoleic acid.
[y]P:S, polyunsaturated to saturated fatty acid ratio.

antibiotics, however, a shift towards 10*t*-18:1 production has been noted (Aldai et al. 2008a) and antibiotics other than monensin (ex., tylosin phosphate) have also been found to influence the *trans* fatty acid composition
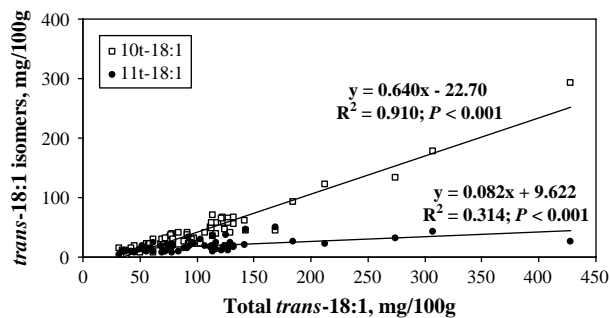

Fig. 3. Linear regressions between the total *trans*-18:1 and individual major *trans*-18:1 isomer contents (mg 100 g^{-1} of meat) in longissimus lumborum samples (*n* = 60).

of beef (Mir et al. 2008). Together, 10*t*- and 11*t*-18:1 represented 60% of the absolute content of total *trans*-18:1 in muscle. In addition, the absolute content of total *trans*-18:1 was linearly related to 10*t*-18:1 ($R^2 = 0.91$, $P < 0.001$), and 11*t*-18:1 ($R^2 = 0.31$, $P < 0.001$; Fig. 3), but the slope was shallower for 11*t*-18:1. Similar correlations were found when animals were fed a high concentrate diet (81% barley; Aldai et al. 2008a).

On a percentage basis, total MUFA were significantly higher in samples collected in winter compared with summer (51.4% and 49.2%, respectively; $P = 0.001$). The total MUFA were mainly influenced by the higher percentages of *cis*-monounsaturates (48.9% and 46.2% in winter and summer, respectively; $P < 0.001$), and more specifically by higher percentages of 9*c*-18:1 (39.6% and 37.3%, respectively; $P < 0.001$) and 13*c*-18:1 (0.49% and 0.42%, respectively; $P = 0.013$). Percentages of some *cis*-monounsaturates were, however, higher in summer than in winter samples (7*c*-16:1, 11*c*-17:1, 14*c*-18:1, 15*c*-18:1; $P < 0.05$), but these were minor

fatty acids and each represented less than 0.18% of total fatty acids. For total *trans*-monounsaturates, there was a tendency for a higher percentage in summer than in winter samples (2.96 and 2.49%, respectively; $P = 0.051$), which was mostly attributed to higher levels of 13*t*/14*t*-18:1, 15*t*-18:1 and 16*t*-18:1. The biochemical processes linking these *trans*-18:1 isomers are, however, not well understood. In general, across collection periods, higher levels of total *trans*-18:1 percentages were associated with higher levels of 10*t*-18:1, and did not appear to be associated with vaccenic acid (11*t*-18:1) (Fig. 4). Of all the striploin steaks analyzed, the steak shown in position #57 had a unique *trans*-18:1 isomer profile both in muscle (Fig. 4) and also in backfat (Fig. 1). In both these tissues from the same steak the TFA content was high, with 10*t*-18:1 as the main isomer (1.03 and 1.59% for muscle and backfat, respectively) followed closely by 11*t*-18:1 (0.80 and 1.29%, respectively) and 13*t*/14*t*-18:1 (0.78 and 1.16%, respectively). An explanation for the high 13*t*/14*t*-18:1 content in this particular steak is not immediately apparent.

Muscle PUFA composition and calculated ratios (P/S, n-6/n-3) are presented in Table 6. In general, there were no significant differences in the absolute content of the n-6 and n-3 PUFAs between collection periods, except 22:6n-3 (0.96 and 1.24 mg 100 g^{-1} of meat in winter and summer samples, respectively; $P = 0.040$), and in the *c/t* dienes, except for 9*c*,15*c*-18:2 (7.87 and 5.67 mg 100 g^{-1} of meat in winter and summer samples, respectively; $P = 0.015$). The significant difference in DHA (22:6n-3) was opposite of what would be expected based on the assumption that winter samples might be from animals with more dietary forage in their background, since grazing on forage has been shown to enhance 18:3n-3 conversion to DHA (Wood et al. 2008). Logically, the higher level of 9*c*,15*c*-18:2 could originate from 18:3n-3 supporting the theory that winter samples came from animals fed higher levels of forages. A pathway for 18:3n-3 biohydrogenation to 9*c*,15*c*-18:2 has not yet been proposed (Destaillats et al. 2005), but
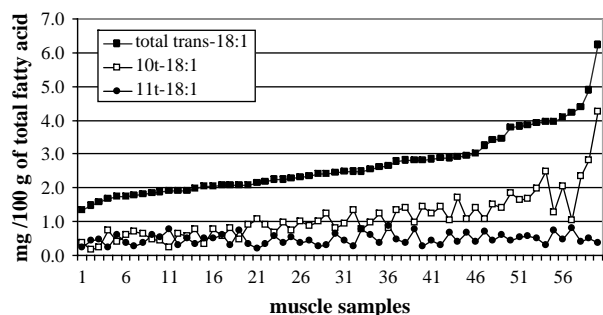
alternatively it could be an endogenous $\triangle^9$-desaturation product of 15*c*-18:1 (Mahfouz et al. 1980).

The P:S ratio in the lean meat was 0.11, indicating the meat was rather high in SFA. The recommended P:S ratio for humans is > 0.4 (Department of Health 1994; Williams 2000). Fortunately, 18:0 was the second most abundant SFA present at almost 30%, and this SFA is considered less atherogenic than either 16:0 or 14:0 (Grundy 1994). The n-6/n-3 ratio in the lean meat was 5.81, which is only slightly more than the recommended n-6/n-3 ratio of < 5 (Department of Health 1994; Williams 2000). This suggests that the balance of n-6 and n-3 PUFA in longissimus lumborum is nutritionally acceptable. Based on the recommended daily intakes of 1.6 g d^{-1} of total n-3 PUFA for men and 1.1 g d^{-1} for women (Gebauer et al. 2005), a 100 g serving of lean from striploin steaks would have provided 26.4 mg n-3 PUFA. The absolute content of total CLA in longissimus lumborum across collection periods averaged 18.0 ± 1.16 mg and ranged from 3.53 to 46.6 mg 100 g^{-1}. The major isomer was rumenic acid (9*c*,11*t*-18:2) (10.8 ± 0.85 mg) ranging from 1.43 to 35.0 mg 100 g^{-1} of meat, and this CLA isomer has been shown to have beneficial health effects (Ip et al. 1994; Roche et al. 2001). The next most abundant CLA isomer was 7*c*, 9*t*-18:2 (2.41 ± 0.21 mg) ranging from 0.66 to 10.5 mg 100 g^{-1} of meat. The absolute average content of the major CLA isomer (9*c*,11*t*-18:2) found in longissimus lumborum, albeit lower than the intake considered beneficial extrapolated from animal studies (3 g d^{-1} Ip et al. 1994), was intermediate to that found in sirloin tip roasts (5.0 mg 100 g^{-1} serving) and rib roasts (40.3 mg 100 g^{-1} serving) as reported by Ma et al. (1999) in Edmonton (Alberta, Canada). The two most abundant CLA isomers (9*c*,11*t*- and 7*t*,9*c*-18:2) not only represented 74% of the absolute amount of total CLA in muscle, but also showed linear relationships with the absolute amount of total CLA (9*c*,11*t*-18:2, $R^2 = 0.86$, $P < 0.001$; 7*t*,9*c*-18:2, $R^2 = 0.36$, $P < 0.001$; Fig. 5). However, the slope was shallower for 7*t*,9*c*-18:2. Several *trans*-18:1 and CLA isomers also appeared to be
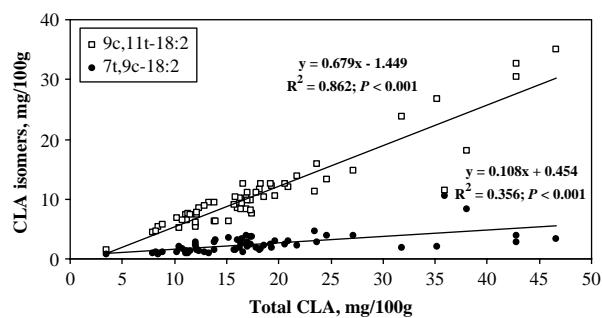
Fig. 4. Relative abundance of 10*t*-18:1 and 11*t*-18:1 as percent of total lipids after sorting all longissimus lumborum samples in increasing order of total *trans*-18:1 ($n = 60$).

Fig. 5. Linear regressions between the total CLA and individual major CLA isomer contents (mg 100 g^{-1} of meat) in longissimus lumborum samples ($n = 60$).
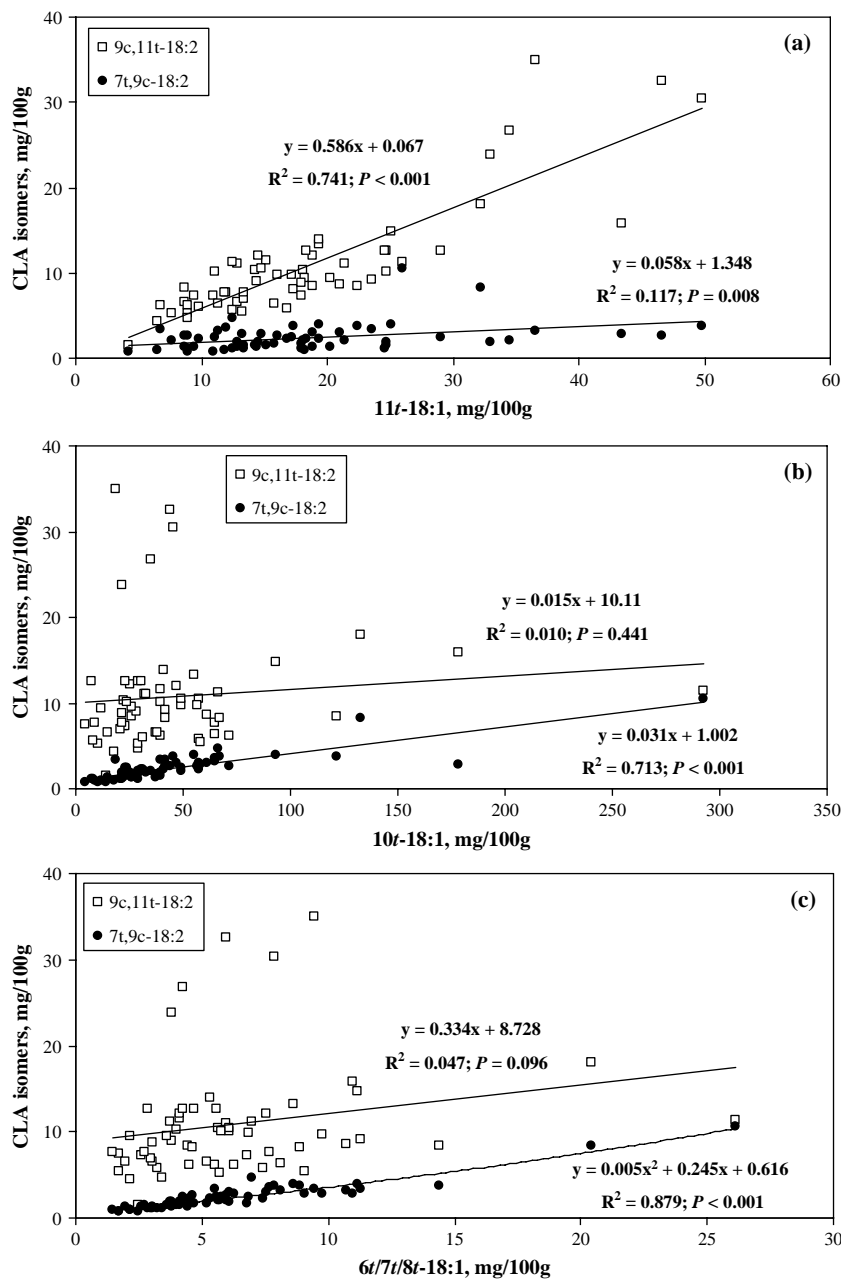
Fig. 6. Linear and quadratic regressions between the two major CLA isomers and $11t$-18:1 (a), $10t$-18:1 (b) and $6t/7t/8t$-18:1 (c) contents (mg 100 g^{-1} of meat) in longissimus lumborum samples ($n = 60$).

metabolically interrelated (Fig. 6). The well known precursor-product relationship of $11t$-18:1 and $9c,11t$-18:2 via the $\triangle^9$-desaturase enzyme (Griinari et al. 2000) also showed a positive and significant relationship in this study ($R^2 = 0.74$; $P < 0.001$). The second most abundant CLA isomer ($7t,9c$-18:2) was linearly related to $6t/7t/8t$-18:1 ($R^2 = 0.88$; $P < 0.001$) supporting the previous findings of Corl et al. (2002) that $7t$-18:1 is converted to $7t,9c$-18:2 by $\triangle^9$-desaturase; its relation-

ship to $10t$-18.1 ($R^2 = 0.71$; $P < 0.001$) was recently described (Aldai et al. 2008a).

On a percentage basis, longissimus lumborum collected in summer compared with winter had tendencies for higher levels of total PUFA (5.03 vs. 4.44%; $P = 0.085$) and n-6 PUFA (4.25 vs. 3.75%; $P = 0.098$; Table 4). This may be related to lower total fat in summer samples, lower neutral lipids and proportionately higher levels of PUFA rich phospholipids. Summer compared
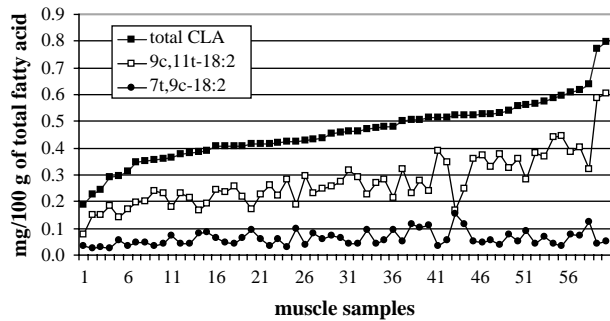
Fig. 7. Relative abundance of $9c,11t$-18:2 and $7t,9c$-18:2 as percent of total lipids after sorting all longissimus lumborum samples in increasing order of total CLA ($n = 60$).

with winter longissimus lumborum did, however, have the tendency for a greater percentage of total CLA (0.49 vs. 0.43%; $P = 0.058$), which was supported by higher percentages of $7t,9c$-18:2 and $10t, 12c$-18:2 ($P < 0.05$), but differences were rather low in magnitude and explanations for which are not immediately apparent. In general, across collection periods, higher levels of total CLA (%) were associated with higher levels of $9c,11t$-18:2 (%), but not $7t,9c$-18:2 (%) as demonstrated in Fig. 7.

Nutritional Assessment of the CLA and TFA Content of Striploin Steaks
In recent years there has been increased awareness of the potential benefits of rumenic ($9c,11t$-18:2) and vaccenic acids ($11t$-18:1) in the protection against cancer, diabetes and inflammatory diseases as demonstrated in both animal and cell models (Belury 2002; Ip et al. 2003). Some recent studies suggest that rumenic acid may even reduce the risk of certain cancers (Aro et al. 2000; Larsson et al. 2005) and acute myocardial infarction in humans (Warensjö et al. 2004). Ruminants are the major source of rumenic and vaccenic acids, but up to 20 CLA isomers (Sehat et al. 1999), and all possible $trans$-18:1 isomers from $4t$- to $16t$-18:1 (Fig. 8a) (Precht and Molkentin 1996; Fritsche et al. 2001; Cruz-Hernandez et al. 2004; Dannenberger et al. 2004) have been found in milk and meat fat of ruminants; as composition in meat and milk are quite similar. However, not all the CLA and $trans$-18:1 isomers have beneficial effects. For example, the CLA isomers $10t,12c$-18:2 (Baumgard et al. 2000) and $9t,11c$-18:2 (Perfield II et al. 2007) are associated with milk fat depression, and $10t,12c$-18:2 causes several other negative effects (Larsen et al. 2003; Terpstra 2004; Tricon et al. 2004), including neutralizing the beneficial effects of rumenic acid (Tricon et al. 2004). Likewise, vaccenic acid has been shown to have the same beneficial effects as rumenic acid since it is converted to rumenic acid in animals by $\triangle^9$-desaturase (Griinari et al. 2000; Turpeinen et al. 2002), while the remaining $trans$-18:1 isomers, other than vaccenic acid

($11t$-18:1), have been shown to be linked to increased risk for cardiovascular disease (Mensink et al. 2003).

When Canada (Department of Health 2003) and the United States (Department of Health and Human Services, Food and Drug Administration 2003) introduced regulations requiring mandatory declaration of the TFA content on food labels, total $trans$ was defined as the sum of all unsaturated fatty acids that contain one or more isolated double bonds, but it excluded CLA. Any foods containing less than 0.2 g per serving (or 2% of total fat content) in Canada, and less than 0.5 g per serving in the United States of America were considered free of TFA. Furthermore, this limit does not apply to food products for which the fat originates exclusively from ruminant meat or dairy products (Health Canada 2006). The exclusion of meat and dairy products from mandatory labelling of the TFA content was based on the assumption that ruminant fats consist mainly of vaccenic ($11t$-18:1) and rumenic ($9c,11t$-18:2) acids. CLA was excluded from mandatory labelling both in Canada and the United States of America because it was assumed that CLA from ruminants contains mainly $9c,11t$-18:2. Several studies have shown the potential health benefits associated with this CLA isomer (Belury 2002; Ip et al. 2003), and there were no negative reports of $9c,11t$-18:2 causing any lipoprotein changes in experimental animals (Department of Health and Human Services, Food and Drug Administration 2003).

The results of this survey show that the average total TFA content ($trans$-MUFA plus $trans,trans$-/$cis,trans$-dienes) in the longissimus lumborum was 0.128 g 100 g^{-1} serving, and vaccenic acid was on average 0.018 g 100 g^{-1} serving constituting only 15% (range 5 to 29%) of total TFA. In addition, the main $trans$-18:1 isomer in these steaks was not vaccenic acid, but $10t$-18:1 (Fig. 8b). An assessment of the CLA profiles of the striploin steaks in this study showed that about 60% of total CLA in both the longissimus lumborum and backfat was $9c,11t$-18:2, which was less than reported in other beef studies (73–78%, Fritsche et al. 2001; 80–82%, Nuernberg et al. 2005; 74–76%, Kraft et al. 2008). Very similar results were recently reported in a survey conducted in the United States of America., in which the lean portion of strip steaks from beef animals fed conventional diets was compared with exclusively grass-fed beef (Leheska et al. 2008). The average TFA content in the USA steaks from beef fed conventional diets was 0.266 g TFA 100 g^{-1} serving (6.04 g 100 g^{-1} fat and 4.4% fat content), and vaccenic acid was on average 0.022 g 100 g^{-1} serving or only 8.44% of TFA. In conventional USA beef, $10t$-18:1 was the major $trans$-18:1 isomer, while in grass-fed beef it was $11t$-18:1 (Fig. 8c). Furthermore, the fatty acid composition of Canadian beef was recently released by the Beef Information Centre (2008) and Health Canada (2008), indicating that across Canada the TFA content for striploin steak (longissimus lumborum) was 0.14 g and 0.22 100 g^{-1} serving, respectively, which were slightly higher than the
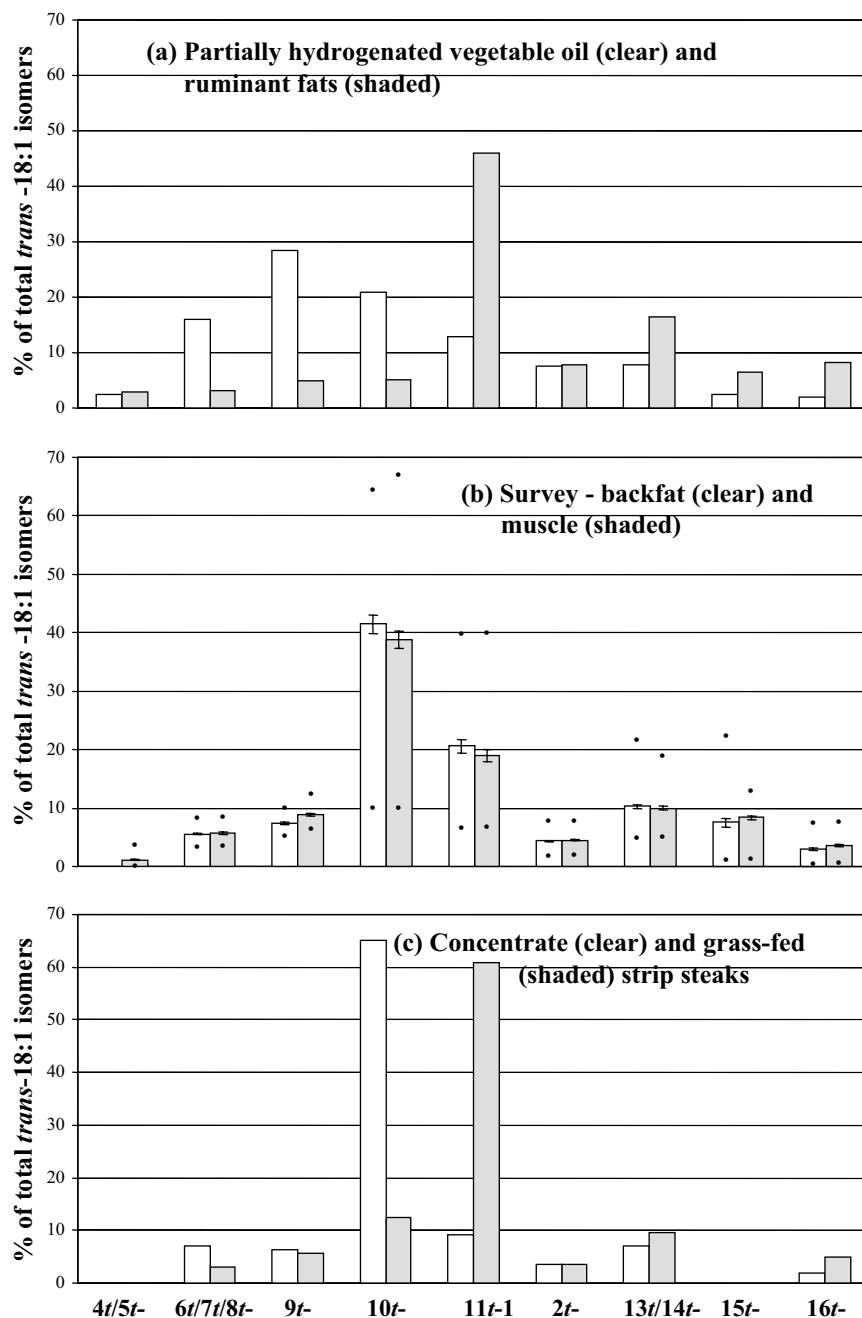
Fig. 8. Relative isomeric distribution of individual *trans*-18:1 isomers from (a) partially hydrogenated vegetable oils and ruminant fats (Wolff et al. 2000), (b) backfat and longissimus lumborum samples from the present study (maximum and minimum values also represented, $n = 60$) and (c) concentrate and grass-fed beef strip steaks (Leheska et al. 2008).

results obtained in the present survey (0.128 g 100 g^{-1} of serving). However, none of the aforementioned studies analysed individual *trans* isomers.

The current intensive feeding practices in beef and dairy production have led to increased levels of TFA and CLA other than vaccenic and rumenic acids in milk (Roy et al. 2006; Cruz-Hernandez et al. 2006; Eifert

et al. 2006) and meat of ruminants (Hristov et al. 2006; Kraft et al. 2008; Leheska et al. 2008; current study). Therefore, the exclusion of CLA and *trans*-18:1 isomers from mandatory labelling of *trans* fatty acids may need to be reconsidered as more is understood about their positive and negative physiological effects in humans. In the present survey, however, if beef was not excluded

because of the current regulations, only 6 of the 60 striploin steaks surveyed would have exceed the limit of 0.2 g 100 g^{-1} of serving in Canada. It was not possible to determine how many striploin steaks from the United States of America would have exceeded the limit of 0.2 g per serving size, since only the means were reported by Leheska et al. (2008). On the other hand, all the Canadian striploin steaks would have been considered *trans* fat free in the United States of America because of the higher permissible level of TFA of 0.5 g 100 g^{-1} serving (Department of Health and Human Services, Food and Drug Administration 2003).

CONCLUSIONS

Information is widely available on the fatty acid composition of various fat and muscle tissues in beef produced under different management systems. However, to our knowledge, this is the first report of the detailed fatty acid profile of Canadian beef at the retail level. It is well known that beef fat, in general, does not meet dietary guidelines for humans regardless of animal production practices and this is mainly because of the high SFA content and the low P:S ratio. However, it is important to note that 18:0 makes up 30% of SFA in beef, which has a neutral effect on human plasma cholesterol levels. Beef can also be a source of n-6 and n-3 PUFA, has a good n-6/n-3 ratio and can also be a source of vaccenic and rumenic acids. Based on a 100-g serving, the striploin steaks surveyed in the present study would not have been a good source of vaccenic and rumenic acids. Consequently, to meet general dietary guidelines for human consumption there is still room for improvement in the SFA, MUFA and PUFA composition of Canadian beef and additional targets should include reducing 10t-18:1 while increasing both rumenic and vaccenic acids.

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