# Subcutaneous fat composition of youthful and mature Canadian beef: emphasis on individual conjugated linoleic acid and *trans*-18:1 isomers

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Dugan, M. E. R., Rolland, D. C., Aalhus, J. L., Aldai, N. and Kramer, J. K. G. 2008. **Subcutaneous fat composition of youthful and mature Canadian beef: emphasis on individual conjugated linoleic acid and *trans*-18:1 isomers.** Can. J. Anim. Sci. **88**: 591–599. A comprehensive evaluation of the fatty acid composition of subcutaneous adipose tissue from beef cattle produced in western Canada was undertaken to determine if the current Canadian grading system is able to distinguish classes of animals with value added potential due to their fatty acid composition. Grades included youthful Canadian Yield Grade 1 A/AA beef, under (YUTM) and over (YOTM) 30 mo of age and the four mature grades (D1, D2, D2 and D4). Subcutaneous fat between the 12th and 13th ribs over the longissimus muscle was obtained from 18–21 animals per grade. Fatty acids were analyzed using a combination of silver-ion HPLC and GC with a highly polar 100 m column. There were no differences in total *trans*-18:1 content amongst grades, but adipose tissue from grade D1, D2 and D4 had more 11*t*-18:1 than YUTM ($P < 0.05$), whereas adipose tissue from YUTM carcasses had more 10*t*-18:1 than all other grades ($P < 0.05$). Adipose tissue from YUTM carcasses also had less total CLA ($P < 0.05$) than the D grades, mainly due to a lower level of 9*c*,11*t*-CLA, but they had slightly more 7*t*,9*c*-CLA and 10*t*,12*c*-CLA ($P < 0.05$). Adipose tissue from YOTM and D grades contained more n-3 fatty acids relative to YUTM (0.56% vs. 0.29%; $P < 0.05$) and lower n-6:n-3 ratios ($P < 0.05$). Overall, older animals (YOTM and D grades) had adipose tissue compositions with higher levels of fatty acids with reported health benefits. Taken together, these higher levels may provide opportunities for value added marketing if regulatory authorities allow claims for their enrichment based on demonstrated health benefits. Higher concentrations of beneficial fatty acids, however, need to be considered within the context of the complete fatty acid profile and it would be important to demonstrate their advantages in the presence of relatively high levels of saturated fatty acids.

**Key words:** CLA, *trans*, vaccenic acid, rumenic acid, beef, adipose tissue

Dugan, M. E. R., Rolland, D. C., Aalhus, J. L., Aldai, N. et Kramer, J. K. G. 2008. **Composition du gras sous-cutané des bovins canadiens jeunes et matures avec insistance sur l'acide linoléique conjugué et ses isomères *trans*-18:1.** Can. J. Anim. Sci. **88**: 591–599. Les auteurs ont procédé à une évaluation complète de la composition des acides gras présents dans le tissu adipeux sous-cutané des bovins élevés dans l'Ouest canadien afin de déterminer si le système de classement actuel permet de distinguer les animaux à valeur ajoutée supérieure en raison de la composition de leurs acides gras. Ils se sont penchés sur la viande des jeunes bovins canadiens de catégorie 1 A/AA de moins (YUTM) et de plus de 30 mois (YOTM) et des quatre classes de bovins matures D1, D2, D2 et D4. Le tissu adipeux sous-cutané du *longissimus* situé entre la 12$^e$ et la 13$^e$ côte a été prélevé chez 18 à 21 sujets par catégorie. Les acides gras ont été analysés par CLHP à ions d'argent et chromatographie gazeuse sur une colonne très polaire de 100 m. Aucune variation de la concentration totale d'ALC *trans*-18:1 n'a été observée entre les différentes catégories, mais le tissu adipeux des sujets D1, D2 et D4 présentait plus d'ALC 11*t*-18:1 que les sujets YUTM ($P < 0,05$), alors que le tissu adipeux des carcasses YUTM présentait plus d'ALC 10*t*-18:1 que le tissu adipeux des autres catégories ($P < 0,05$). Le tissu adipeux des carcasses YUTM renfermait aussi moins d'ALC ($P < 0,05$) que celui des carcasses de catégorie D, principalement à cause d'une plus faible concentration d'ALC 9*c*,11*t*. Toutefois, il contenait légèrement plus d'ALC 7*t*,9*c* et 10*t*,12*c* ($P < 0,05$). Le tissu adipeux des sujets YOTM et D renfermait plus d'acides gras n-3 que celui des sujets YUTM (0,56% c. 0,29%; $P < 0,05$) et son ratio n-6:n-3 était plus bas ($P < 0,05$). En général, les animaux plus âgés (YOTM et catégorie D) ont un tissu adipeux renfermant plus d'acides gras bons pour la santé. Collectivement, ces concentrations plus élevées pourraient ouvrir la porte à un marketing axé sur la valeur ajoutée, si les organismes de réglementation autorisent les allégations de viande enrichie reposant sur des avantages évidents pour la santé. Néanmoins, on devrait envisager la concentration supérieure d'acides gras bénéfiques en regard du profil complet des acides gras, et il importe de prouver que les avantages persistent en dépit d'une concentration relativement élevée d'acides gras saturés.

**Mots clés:** ALC, *trans*, acide vaccénique, acide ruménique, bœuf, tissu adipeux

The diagnosis of bovine spongiform encephalopathy (BSE) in Canadian cattle in 2003 led to the disruption of normal trade and the need to domestically market all

**Abbreviations: CLA,** conjugated linoleic acid; **PUFA,** polyunsaturated fatty acid; **MUFA,** monounsaturated fatty acid; **SFA,** saturated fatty acid; **YUTM,** youthful under 30 mo of age; **YOTM,** youthful over 30 mo of age.

beef from animals over 30 mo of age. The resultant oversupply of manufacturing beef depressed prices and highlighted the need to develop strategies to recover value from older animals. Recovering value from beef over 30 mo of age can be assisted by identifying which characteristics are either equivalent or superior to beef from animals under 30 mo of age. Overall quality is dependant on appearance, eating quality and also nutritive value. Surveys of the fatty acid composition of Canadian beef are limited (Ma et al. 1999) and nothing is known about the detailed fatty acid composition of different grades of Canadian beef, particularly its conjugated linoleic acid (CLA) and *trans*-18:1 isomeric profiles. Higher levels of rumenic acid (9*c*,11*t*-CLA) may add value to beef due to its purported roles in the prevention and possible treatment of several diseases including diabetes, obesity and some types of cancer (Belury 2002; Ip et al. 2003). In addition, vaccenic acid (11*t*-18:1) may share the same potential in light of the fact that humans can desaturate it to form rumenic acid (Turpeinen et al. 2002). Our laboratory has recently, however, demonstrated that the major *trans* isomer in beef fed a high barley diet is 10*t*-18:1 rather than 11*t*-18:1 (Dugan et al. 2007). In feedlot finished (<30 mo) beef fed a diet containing 73% barley, we found 4.25% total *trans* fatty acids in subcutaneous fat, which included 2.13% 10*t*-18:1 and only 0.77% 11*t*-18:1. This may be problematic as feeding rabbits 10*t*-18:1 has been found to negatively affect their plasma lipid and lipoprotein profiles (Bauchart et al. 2007; Roy et al. 2007) and both 9*t*- and 10*t*-18:1 are associated with the development coronary heart disease in humans (Hodgson et al. 1996). Feeding ruminants diets with high levels of barley (i.e., low fiber, high starch) reduces rumen pH, alters the bacterial flora and causes a shift in the biohydrogenation pathway towards producing 10*t*-18:1 instead of 11*t*-18:1 (Bauman and Griinari 2003). Diets for physiologically mature beef animals (>30 mo of age) typically contain high levels of forage, while the majority of youthful beef (<30 mo) in western Canada are finished in feedlots on diets containing high levels of barley. The present work was, therefore, undertaken to compare the fatty acid composition of subcutaneous adipose tissue from mature beef (D grades) and physiologically youthful Canada Yield Grade 1 A/AA beef over (YOTM) and under (YUTM) 30 mo of age to determine if the present grading system is able to distinguish carcasses with a more desirable, and perhaps more valuable, fatty acid composition.

## MATERIALS AND METHODS

### Carcasses

Carcasses were selected every 2 wk over a period of 20 wk from July through November 2004 from a commercial abattoir, and transported to the Lacombe Research Centre. Grading was conducted according to the Livestock and Poultry Carcass Grading Regulations (SOR/92-541) as per the Canada Agricultural Products Act (http://laws.justice.gc.ca/en/C-0.4/SOR-92-541/index.html?). Physiological maturity was evaluated on the basis of ossification. For physiologically youthful carcasses, chronological age was estimated based on dentition according to Lawrence et al. (2001), with animals over 30 mo of age having more than two permanent incisor teeth erupted. Grades included: YUTM (youthful on the basis of spinal process ossification, with A or AA marbling and dentition indicating less than 30 mo of age), YOTM (youthful on the basis of spinal process ossification, with A or AA marbling and dentition indicating greater than 30 mo of age), D1 (mature based on spinal process ossification, less than 15 mm grade fat, excellent muscling), D2 (mature based on spinal process ossification, less than 15 mm grade fat, medium muscling or yellow fat), D3 (mature based on spinal process ossification, less than 15 mm grade fat, deficient muscling), D4 (mature based on spinal process ossification, greater or equal to 15 mm grade fat). An attempt to select two carcasses per grade per collection period was made to yield 20 carcasses per grade, but due to limited availability during one collection week, only 18 carcasses were collected for YUTM and YOTM and 21 carcasses were collected for each of the D grades.

### Fatty Acid Analysis

Carcasses were selected and shipped from a commercial packing plant to the Lacombe Research Centre and, upon arrival, 1 g of subcutaneous fat was sampled over the longissimus muscle between the 12th and 13th ribs. Fat samples were freeze dried, directly methylated with sodium methoxide and the fatty acid methyl esters (FAME) were analyzed using the GC and $Ag^+$-HPLC equipment and methods outlined by Cruz-Hernandez et al. (2004), except *trans*-18:1 isomers were analyzed using two complementary GC temperature programs (Dugan et al. 2007; Kramer et al. 2008) instead of preparatory $Ag^+$-TLC separation prior to isothermal GC separation at 120°C.

### Statistical Analysis

Percent fatty acid composition data were analyzed as a one-way ANOVA using carcass grade as the main effect using PROC MIXED (SAS Institute, Inc. 2001). Means were separated using Tukey's mean separation test with $P \leq 0.05$ being considered significant.

## RESULTS AND DISCUSSION

Subcutaneous fat was chosen to be analyzed for this study since this tissue is quite sensitive to changes in diet and rumen function. This is due to adipose tissue having a high proportion of neutral lipids which accumulate greater levels of polyunsaturated fatty acid (PUFA) biohydrogentation products relative to polar lipids (Fritsche et al. 2001; Nuernberg et al. 2005). In addition, subcutaneous fat is easily accessible, inexpensive and levels of *trans*-18:1 and CLA have been reported to be linearly related to those found in muscle (Basarab et al. 2007).

## Saturated Fatty Acids

There were no differences in levels of total saturated fatty acid (SFA) in adipose tissue amongst grades ($P > 0.05$; Table 1), and the major fatty acids included 16:0 (24.7–26.4% of total FAME), 18:0 (10.3–14.1%) and 14:0 (3.0–3.57%). There were several differences for individual SFA with the D3 grade exhibiting the most differences having less 14:0 than the D2 and D4 grades, less 16:0 than the D1, D2 and D4 grades, and slightly more 18:0 than the D4 grade ($P < 0.05$). The D3 grade is characterized by emaciation with <15 mm backfat at the grade site and a deficiency of muscling. Typically higher proportions of dairy breeds fall into this grade due to their low levels of backfat, or beef cows, which have not (re)gained condition after spring calving and suckling calves through summer grazing. Higher levels of 18:0 have also been noted for pasture versus concentrate fed beef cattle (Enser et al. 1998; Dannenberger et al. 2004; Basarab et al. 2006). In addition, higher levels of 18:0 and lower levels of 16:0 and 14:0 are typical of wild elk, deer and antelope under natural grazing conditions (Cordain et al. 2002) and for wild muskox (Dugan et al. 2007). The levels of 14:0, 16:0 and 18:0 in adipose tissue from D3 carcasses were, however, not different from YUTM and YOTM carcasses. Some similarity between dairy and finishing beef diets (i.e., a lower forage to concentrate ratio) might, therefore, have played a role.

Levels of branched chain fatty acids (BCFA) were consistently lower in adipose tissue from YUTM carcasses relative to D2 carcasses ($P < 0.05$). The YUTM animals would typically be finished on diets containing a high proportion of barley, and barley versus grass fed cattle have previously been shown to accumulate lower levels of BCFA (Duncan and Garton 1978). In addition, D2 cows are characterized by firm to slightly soft and white to yellow fat, and elevated BCFA may have contributed to fat softness as previously demonstrated in lamb (Miller et al. 1980; Busboom et al. 1981) and beef (Aldai et al. 2004).

## Monounsaturated Fatty Acids

There were no differences in the level of total monounsaturated fatty acid (MUFA) amongst grades ($P < 0.05$; Table 2). Oleic acid (*c*9-18:1) was the most abundant *cis*-MUFA (36.1–37.7% of FAME) and no differences in its levels were detected amongst grades ($P > 0.05$). Concentrate feeding has previously been found to increase levels of 9*c*-18:1 by 1–2% relative to grazing on pasture (Dannenberger et al. 2004; Basarab et al. 2007), but these differences were found under rigid experimental conditions in animals of similar age. In the present experiment, D grade carcasses would presumably have been animals grazing or consuming more forage than YOTM and YUTM, but any differences due to diet may have been lost since increasing maturity also leads to increased levels of 9*c*-18:1 (Wood et al. 2008). In contrast to major *cis*-MUFA, small differences were found for several minor *cis*-MUFA (9*c*-14:1, 7*c*-16:1,

**Table 1. Saturated fatty acid (SFA) composition of subcutaneous fat from beef of different grades (% fatty acid composition)**

| Fatty acid | Grade[z] | | | | | | |
|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D4 | YOTM | YUTM | SE[y] |
| 10:0 | 0.05 | 0.06 | 0.05 | 0.05 | 0.05 | 0.04 | 0.003 |
| 12:0 | 0.08 | 0.09 | 0.08 | 0.08 | 0.08 | 0.07 | 0.005 |
| 14:1*iso* | 0.07*ab* | 0.08*a* | 0.08*a* | 0.07*ab* | 0.07*ab* | 0.04*b* | 0.006 |
| 14:0 | 3.37*ab* | 3.57*a* | 3.00*b* | 3.57*a* | 3.07*ab* | 3.30*ab* | 0.138 |
| 15:0*iso* | 0.30*ab* | 0.38*a* | 0.33*ab* | 0.33*ab* | 0.27*b* | 0.17*c* | 0.023 |
| 15:0*anteiso* | 0.26*ab* | 0.32*a* | 0.32*a* | 0.27*ab* | 0.26*ab* | 0.22*b* | 0.020 |
| 15:0 | 0.54 | 0.55 | 0.56 | 0.54 | 0.57 | 0.64 | 0.029 |
| 16:0*iso* | 0.26*ab* | 0.31*a* | 0.32*a* | 0.27*ab* | 0.28*ab* | 0.23*b* | 0.018 |
| 16:0 | 26.4*a* | 26.4*a* | 24.7*c* | 26.3*ab* | 24.8*bc* | 24.9*bc* | 0.550 |
| 17:0*iso* | 0.45*c* | 0.54*ab* | 0.56*a* | 0.48*abc* | 0.46*bc* | 0.45*c* | 0.020 |
| 17:0*anteiso* | 0.77*bc* | 0.90*ab* | 0.92*a* | 0.82*abc* | 0.80*abc* | 0.74*c* | 0.032 |
| 17:0 | 1.11*b* | 1.09*b* | 1.20*b* | 1.05*b* | 1.28*ab* | 1.51*a* | 0.072 |
| 18:0*iso* | 0.18 | 0.20 | 0.21 | 0.19 | 0.20 | 0.17 | 0.009 |
| 18:0 | 10.7*ab* | 12.0*ab* | 14.1*a* | 10.3*b* | 12.9*ab* | 12.4*ab* | 0.897 |
| 19:0 | 0.07*b* | 0.08*ab* | 0.10*a* | 0.07*b* | 0.08*ab* | 0.07*b* | 0.006 |
| 20:0 | 0.12*bc* | 0.16*ab* | 0.20*a* | 0.12*bc* | 0.14*abc* | 0.10*c* | 0.014 |
| Total BCFA[x] | 2.29*bc* | 2.74*a* | 2.73*ab* | 2.42*abc* | 2.33*abc* | 2.01*c* | 0.110 |
| Total SFA | 44.8 | 46.8 | 46.8 | 44.6 | 45.4 | 45.0 | 1.181 |

[z]Grades: D1-D4 $n = 21$, YOTM (youthful over 30 mo) and YUTM (youthful under 30 mo) $n = 18$.
[y]SE, standard error.
[x]BCFA, branched chain fatty acids (includes *iso* and *anteiso*).
*a–c* Values are least square means and means across grades without a common letter are significantly different ($P < 0.05$).

**Table 2. Monounsaturated fatty acid (MUFA) composition of subcutaneous fat from beef of different grades (% fatty acid composition)**

| Fatty acid | Grade[z] | | | | | | |
|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D4 | YOTM | YUTM | SE[y] |
| 9*c*-14:1 | 1.42*a* | 1.23*ab* | 0.92*b* | 1.49*a* | 1.01*ab* | 1.06*ab* | 0.118 |
| 7*c*-16:1 | 0.17*b* | 0.20*b* | 0.25*a* | 0.17*b* | 0.20*b* | 0.20*b* | 0.011 |
| 9*c*-16:1 | 5.43 | 5.13 | 4.43 | 5.34 | 4.38 | 4.34 | 0.371 |
| 9*c*-17:1 | 1.03*ab* | 0.92*b* | 0.91*b* | 1.00*ab* | 1.06*ab* | 1.28*a* | 0.068 |
| 9*c*-18:1 | 37.0 | 36.1 | 37.0 | 37.2 | 37.7 | 37.3 | 0.887 |
| 11*c*-18:1 | 1.51*ab* | 1.23*b* | 1.37*ab* | 1.55*ab* | 1.46*ab* | 1.82*a* | 0.120 |
| 12*c*-18:1 | 0.08*b* | 0.07*b* | 0.08*b* | 0.09*b* | 0.10*ab* | 0.15*a* | 0.011 |
| 13*c*-18:1 | 0.44 | 0.37 | 0.47 | 0.46 | 0.40 | 0.45 | 0.054 |
| 15*c*-18:1 | 0.12*b* | 0.13*ab* | 0.12*b* | 0.13*ab* | 0.15*ab* | 0.17*a* | 0.010 |
| 16*c*-18:1 | 0.06*ab* | 0.05*b* | 0.06*ab* | 0.06*ab* | 0.07*ab* | 0.07*a* | 0.004 |
| 9*c*-20:1 | 0.16*ab* | 0.18*b* | 0.16*b* | 0.18*ab* | 0.14*ab* | 0.12*a* | 0.011 |
| 11*c*-20:1 | 0.19*abc* | 0.15*c* | 0.15*c* | 0.20*ab* | 0.18*bc* | 0.23*a* | 0.017 |
| total *trans* | 3.42 | 3.41 | 3.31 | 3.26 | 3.61 | 3.85 | 0.274 |
| MUFA | 50.5 | 48.7 | 48.7 | 50.6 | 49.8 | 50.2 | 1.126 |

[z]Grades: D1-D4 $n = 21$, YOTM (youthful over 30 mo) and YUTM (youthful under 30 mo) $n = 18$.
[y]SE, standard error.
*a–c* values are least square means and means across grades without a common letter are significantly different ($P < 0.05$).

9*c*-17:1, 11*c*-18:1, 12*c*-18:1, 15*c*-18:1, 16*c*-18:1, 9*c*-20:1 and 11*c*-20:1), but these were inconsistent and their explanations are not immediately apparent.

The level of total *trans*-18:1 was not significantly different amongst grades ($P > 0.05$; Table 2), but several difference were noted for individual *trans*-18:1 (Fig. 1). Specifically, the most abundant *trans* isomer in adipose tissue from YOTM and D grade carcasses was *t*11-18:1, and for D1, D2 and D4 grades, these were significantly greater than the level found in adipose tissue from YUTM carcasses ($P < 0.05$). In YUTM, the most abundant *trans*-18:1 isomer was 10*t*-18:1 and this was significantly greater than levels found in adipose tissue from all other grades ($P < 0.05$). In addition, YUTM had greater levels of 6*t*-8*t*-18:1 relative to D1, D2 and D4 grades ($P < 0.05$). To our knowledge this is the first report of differences in *trans* fatty acid composition in different grades of Canadian beef. The pattern of *trans*-18:1 isomers in YUTM carcasses is similar to previous findings for adipose tissue from youthful beef fed high levels of barley (Hristov et al. 2005; Dugan et al. 2007), abomasal digesta from steers (Sackmann et al. 2003) and

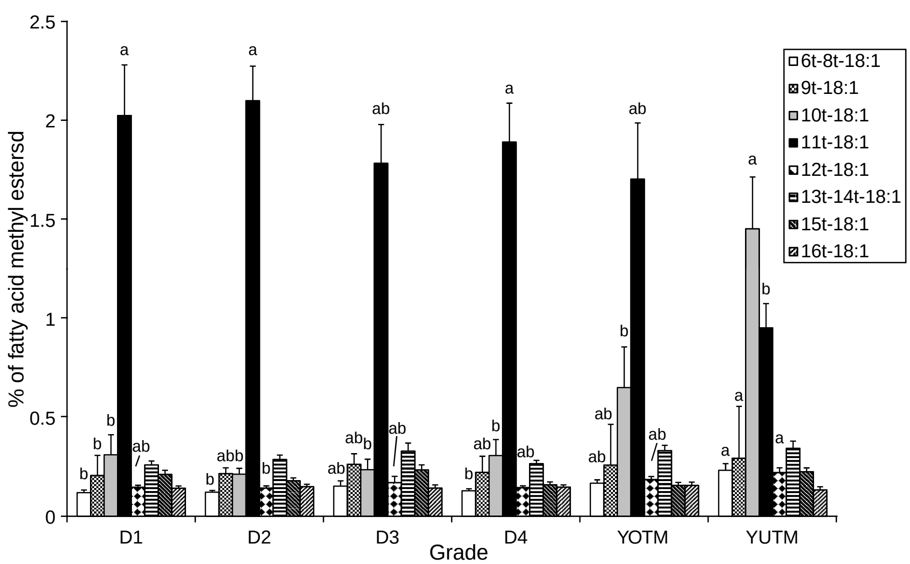


**Fig. 1.** Beef adipose tissue *trans*-18:1 composition. Bars and vertical lines represent mean ± SEM: $n = 18$ for youthful under 30 mo of age (YUTM) and youthful over 30 mo of age (YOTM) and $n = 21$ for Canadian D grades 1 to 4. For each isomer, bars not sharing the same letter designation are significantly different ($P < 0.05$).

sheep (Daniel et al. 2004) fed low forage to concentrate ratios, and lamb adipose and muscle tissues when finished on high concentrate diets (Bas et al. 2007). The YOTM and D grade carcasses all had 11*t*-18:1 as the most abundant *trans*-18:1 isomer, and this is consistent with a probable higher level of forage in the diet and lower fermentable carbohydrate. This phenomenon has been extensively investigated in dairy cattle (Piperova et al. 2002; Bauman and Griinari 2003; Nielsen et al. 2006) and linked to the buffering capacity of the forage, higher ruminal pH and a bacterial flora, which utilize the 11*t*-18:1 pathway for PUFA biohydrogenation. However, the exact dietary conditions for producing higher levels of 10*t*- or 11*t*-18:1 in beef still warrant further investigation since Lee et al. (2006) found steers fed high levels of concentrate (80% concentrate of which 66% was rolled barley) were able to maintain a higher proportion of 11*t*-18:1 in duodenal digesta, and Duckett et al. (2002) found that for corn-fed steers, a shift from 11*t*- to 10*t*-18:1 in duodenal digesta required free corn oil as opposed to corn with a high oil content. Despite not being able to define precise dietary conditions for the preferential deposition of 11*t*-18:1, the fact remains that Canadian beef from animals over 30 mo of age had a better *trans* fatty acid profile than beef under 30 mo based on their 11*t*- to 10*t*-18:1 ratio. It should be noted, however, that the effects of season were not taken into consideration in the present study as carcasses were collected from July through November. This may be a time when a higher proportion of grass-finished YOTM animals are slaughtered, and may in part explain why their fat composition was similar to D grades versus YUTM carcasses.

## Polyunsaturated Fatty Acids

There were several differences in levels of individual PUFAs, and PUFA metabolites produced by rumen bacteria, and these were consistent with proposed dietary differences amongst grades based on SFA and *trans*-18:1 data. Levels of 18:2n-6 (linoleic acid) in adipose tissue from D grade carcasses and YOTM were not different, and these were significantly lower than the values found in YOTM ($P < 0.05$). The level of 18:2n-6 in adipose tissue from YUTM carcasses was comparable with previous reports when feeding a high concentrate diet (Dannenberger et al. 2004; Scollan et al. 2006; Dugan et al. 2007). In contrast, levels of 18:3n-3 (linolenic acid) were greater in D grade carcasses compared with YUTM ($P < 0.05$) and intermediate in YOTM, with levels of 18:3n-3 likely being linked to higher rates of forage consumption (Dannenberger et al. 2004; Scollan et al. 2006). Consequently n-6:n-3 ratios were lowest in adipose tissue for most D grade carcasses, intermediate in YOTM and highest for YUTM (Table 3). Adipose tissue from D grade and YOTM carcasses also had a higher level of 11*t*,15*c*-18:2 ($P < 0.05$), which is a product of ruminal biohydrogenation of 18:3n-3 and a direct precursor for 11*t*-18:1 production (Jenkins et al. 2008). It should be noted that the polar lipids in the muscle are a richer source of the long-chain n-3 PUFAs than adipose fat, but the latter does reflect the type of PUFAs present in the former (Fritsche et al. 2001; Basarab et al. 2007).

Total CLA was lower in adipose tissue from YUTM carcasses compared with D1, D2 and D4 carcasses ($P < 0.05$; Table 3), but all were not different than YOTM and D3 carcasses. The lower total CLA in YUTM carcasses was mainly due to a lower level of 9*c*,11*t*-CLA and 11*t*,13*c*-CLA ($P < 0.05$), but in contrast, YUTM had slightly higher levels of 7*t*,9*c*-CLA and 10*t*,12*c*-CLA ($P < 0.05$; Fig. 2). A higher level of 10*t*,12*c*-CLA is consistent with the higher level of 10*t*-18:1 found in adipose tissue from YUTM carcasses, since 10*t*,12*c*-CLA is a precursor for 10*t*-18:1 during 18:2n-6 biohydrogenation (Bauman and Griinari 2003; Wallace et al. 2007), and their combined accumulation is indicative of feeding high concentrate diets rich in rapidly fermentable carbohydrate (i.e., starch). Higher levels of 9*c*,11*t*-CLA and 11*t*,13*c*-CLA in YOTM and D grade carcasses are also consistent with consumption of a high forage diet containing a higher level of 18:3n-3 (Kraft et al. 2003; Kramer et al. 2004). Most 9*c*,11*t*-CLA is actually produced in the tissues by the action of $\Delta^9$-desaturase on 11*t*-18:1 absorbed from the digestive tract (Griinari et al. 2000), while 11*t*,13*c*-CLA was shown to be a metabolite of 18:3n-3 through bacterial isomerization of the 11*t*,15*c*-18:2 intermediate (Hino and Fukuda 2006). The higher levels of total CLA in adipose tissue from YOTM and D grade carcasses in the form of 9*c*,11*t*-18:2 with its reported potential health benefits, constitute an additional value-added opportunity for these animals relative to conventionally finished YUTM beef.

## Variation in Fatty Acid Composition

Adipose tissue from animals over 30 mo of age was on average shown to have higher levels of fatty acids with reported potential health benefits (i.e., 11*t*-18:1, 9*c*,11*t*-CLA and total n-3 fatty acids) compared with YUTM animals. Ranges in concentrations of these fatty acids within each grade were, however, quite broad (a minimum of a four- to fivefold difference between the lowest and highest concentrations) and had coefficients of variation ranging from 29 to 149%. Different grades of Canadian beef would, therefore, likely be too inconsistent to allow for enrichment claims as is. The development and use of rapid analytical methods (e.g., Azizian and Kramer 2005; Aldai et al. 2007) would prove useful in sorting carcasses with higher concentrations of beneficial fatty acids. In addition, dependent on the levels required, development of dietary and management strategies to consistently enrich beneficial fatty acids would also be of benefit.

## CONCLUSIONS

Adipose tissue from beef carcasses over 30 mo of age (YOTM and D grades) possessed fatty acid profiles

**Table 3. Polyunsaturated fatty acid (PUFA) composition of subcutaneous fat from beef of different grades (% fatty acid composition)**

| Fatty acid | Grade[z] | | | | | | SE[y] |
|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D4 | YOTM | YUTM | |
| *Methylene interrupted* | | | | | | | |
| 18:2n-6 | 0.88*b* | 0.86*b* | 0.99*b* | 0.92*b* | 1.13*b* | 1.57*a* | 0.065 |
| 18:3n-3 | 0.48*a* | 0.44*a* | 0.47*a* | 0.49*a* | 0.42*ab* | 0.24*b* | 0.046 |
| 20:3n-6 | 0.05 | 0.05 | 0.05 | 0.06 | 0.05 | 0.06 | 0.004 |
| 20:4n-6 | 0.03 | 0.03 | 0.04 | 0.03 | 0.04 | 0.04 | 0.15 |
| 20:5n-3 | 0.01*b* | 0.01*b* | 0.02*a* | 0.01*b* | 0.01*b* | 0.01*b* | 0.002 |
| 22:5n-3 | 0.05*ab* | 0.04*ab* | 0.06*a* | 0.05*ab* | 0.06*ab* | 0.03*b* | 0.008 |
| *total CLA*[x] | 1.04*a* | 1.01*a* | 0.89*ab* | 1.02*a* | 0.91*ab* | 0.66*b* | 0.078 |
| *non-CLA c,t dienes* | | | | | | | |
| 9*t*,12*t*-18:2 | 0.09 | 0.08 | 0.08 | 0.07 | 0.07 | 0.06 | 0.010 |
| 9*c*,13*t*/8*t*,13*c*-18:2 | 0.21*ab* | 0.19*ab* | 0.17*b* | 0.22*a* | 0.21*ab* | 0.22*a* | 0.012 |
| 8*t*,12*c*/9*c*12*t*-18:2 | 0.11*ab* | 0.10*ab* | 0.09*b* | 0.12*a* | 0.11*ab* | 0.11*ab* | 0.007 |
| 11*t*,15*c*-18:2 | 0.29*a* | 0.30*a* | 0.26*a* | 0.30*a* | 0.27*a* | 0.12*b* | 0.034 |
| 9*c*,15*c*-18:2 | 0.14 | 0.12 | 0.13 | 0.14 | 0.13 | 0.15 | 0.012 |
| *Summaries* | | | | | | | |
| PUFA | 1.61*b* | 1.54*c* | 1.75*ab* | 1.63*ab* | 1.84*ab* | 2.04*a* | 0.100 |
| non-CLA *c,t* dienes | 0.79*ab* | 0.75*ab* | 0.67*ab* | 0.81*a* | 0.76*ab* | 0.61*b* | 0.044 |
| n-3 | 0.57*a* | 0.52*a* | 0.58*a* | 0.58*a* | 0.52*a* | 0.29*b* | 0.053 |
| n-6 | 1.01*b* | 0.98*b* | 1.13*b* | 1.05*b* | 1.27*b* | 1.74*a* | 0.072 |
| n-6:n-3 | 2.39*bc* | 1.98*c* | 2.25*c* | 2.13*c* | 3.98*b* | 6.64*a* | 0.401 |

[z]Grades: D1-D 4 $n = 21$, YOTM (youthful over 30 mo) and YUTM (youthful under 30 mo) $n = 18$.
[y]SE, standard error.
[x]CLA, conjugated linoleic acid.
*a–c* Values are least square means and means across grades without a common letter are significantly different ($P < 0.05$).

strongly suggesting the consumption of greater amounts of forage versus concentrate. Consequently, this conferred a fatty acid profile which could be considered superior to that of conventionally finished beef (i.e., YUTM fed a high barley diet). Specifically, in all animals over 30 mo of age, 11*t*-18:1 was more abundant than 10*t*-18:1 and they had more 18:3n-3. They also had less 18:2n-6, a lower n-6:n-3 ratio, and had more CLA mainly in the form of 9*c*,11*t*-CLA. Taken together, these advantages may provide opportunities for value added

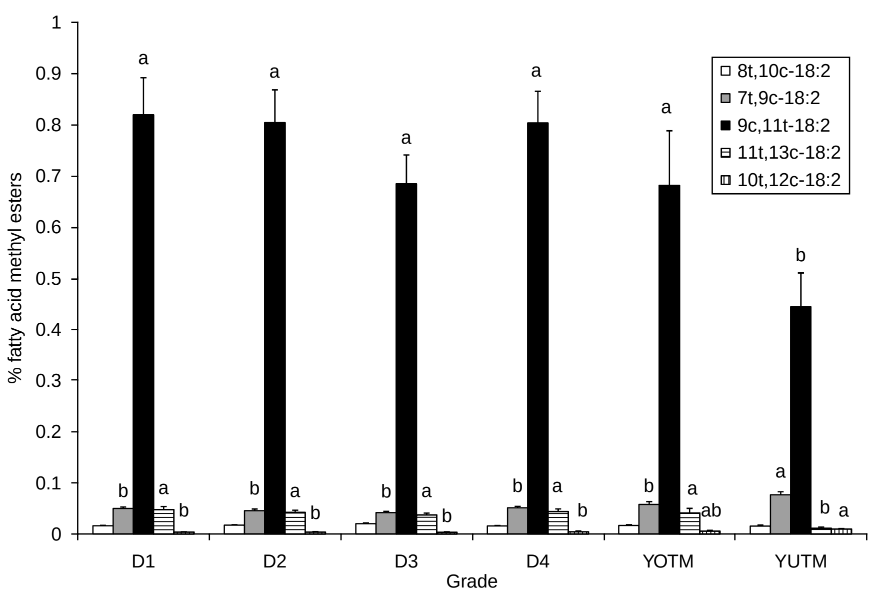


**Fig. 2.** Beef adipose tissue conjugated linoleic acid (CLA) composition. Bars and vertical lines represent mean ± SEM: $n = 18$ for youthful under 30 mo of age (YUTM) youthful over 30 mo of age (YOTM), and $n = 21$ for Canadian D grades 1 to 4. For each isomer, bars not sharing the same letter designation are significantly different ($P < 0.05$).

marketing provided regulator clearance can be obtained to take advantage of these enrichments and strategies can be developed to deal with high levels of variation in fatty acid concentrations. Levels of beneficial fatty acids, however, need to be considered within the context of the complete fatty acid profile of ruminant meat, and it would be important to demonstrate their health advantages in beef despite its relatively high proportion of saturated fatty acids. This would be consistent with the finding that whole beef lipids have been shown to have a protective effect against cancer (Scimeca 1999) including inhibiting the growth of human cancer cells (De la Torre et al. 2006). The precise effects of vaccenic and rumenic acids in humans and their effective concentrations are not, however, known and an exhaustive discussion of their potential health benefits in animal models and humans is beyond the scope of the present article. There are certainly indications that their consumption may be beneficial given consuming milk fat reduces cardiovascular risk factors in humans (Warensjo et al. 2004), improves blood lipid profiles (Tricon et al. 2006; Tholstrup et al. 2006), is associated with reduced risk of breast cancer (Knekt et al. 1996; Aro et al. 2000) and reduces the risk of colorectal cancer (Larsson et al. 2005). However, the results are not consistent with some studies reporting mixed or limited effects (Desroches et al. 2005; Chardigny et al. 2008; Motard-Belanger et al. 2008). Additional supportive research to demonstrate the linkage between consumption of proposed beneficial fatty acids in ruminant products and their effects on human health is, therefore, likely necessary to justify and enable claims for their enrichment.

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