CSIRO PUBLISHING

Australian Journal of Agricultural Research

Volume 48, 1997
© CSIRO Australia 1997

A journal for the publication of original contributions towards the understanding of an agricultural system

www.publish.csiro.au/journals/ajar

All enquiries and manuscripts should be directed to
Australian Journal of Agricultural Research
CSIRO PUBLISHING
PO Box 1139 (150 Oxford St)
Collingwood Telephone: 61 3 9662 7628
Vic. 3066 Facsimile: 61 3 9662 7611
Australia Email: jenny.fegent@publish.csiro.au

Published by **CSIRO** PUBLISHING
for CSIRO Australia and
the Australian Academy of Science

Aust. J. Agric. Res., 1997, **48**, 715–22

A comparison of the fatty acid composition of triacylglycerols in adipose tissue from Limousin and Jersey cattle

A. E. O. Malau-Aduli, B. D. Siebert, C. D. K. Bottema, and W. S. Pitchford

Department of Animal Science, University of Adelaide,
Waite Agricultural Research Institute, Glen Osmond, SA 5064, Australia.

Abstract. The fatty acid composition of the triacylglycerol fraction of shoulder fat from Limousin and Jersey yearling heifers, yearling steers, and non-lactating cows was investigated.

Significant breed differences in the degree of fatty acid saturation were apparent between Jersey and Limousin cows, but were not observed in the yearlings. Jersey cows had less saturated fatty acids than the Limousin. Jersey cows showed an increased percentage of monounsaturated fatty acids compared with the Jersey yearlings. In contrast, the level of monounsaturated fatty acids in the Limousin cows was the same as in the Limousin yearlings.

The calculated indices of enzyme activities also differed between the breeds. Jersey cows had higher indices of Δ9-desaturase and elongase activities than Limousin. This was also reflected by differences in the ratios of total unsaturated and polyunsaturated to saturated fatty acids.

Breed differences were also observed in the triacylglycerol fatty acid chain length. In this case, however, yearlings showed significant breed differences that were not detected in the cows. Limousin yearlings had more long chain fatty acids (C16 and C18) than the Jersey yearlings. Limousin yearlings also had a higher elongase activity index than their Jersey counterparts. Thus, breed and age affect the fatty acid composition in these cattle.

Additional keywords: triacylglycerols, fatty acids, Limousin, Jersey, Δ9-desaturase, elongase.

Introduction

Subcutaneous, intramuscular, and intermuscular fat can contribute a significant proportion of fresh beef. Depending on the breed, age, and diet, this fat level could be up to 15% (Parrett *et al*. 1989). Trends in beef merchandising are toward trimming a percentage of these fatty tissues prior to retail sale (Brackebusch *et al*. 1991). Domestic consumer demand for leaner meat cuts has influenced the marketing of lean beef in Australia over the last decade (Lewis *et al*. 1993), largely because fats are implicated in cases of coronary heart disease, obesity, and hypertension (Cliff 1987; Gouldbert 1987).

Beef fat contains 25–30% of the 16-carbon fatty acid palmitate (Marmer *et al*. 1984), which has a hypercholesterolemic effect (Mattson and Grundy 1985). On the other hand, neither of the 18-carbon fatty acids (stearate nor oleate) increases serum cholesterol (Grundy *et al*. 1988). This has prompted attempts to modify the fatty acid composition of beef, increasing the 18-carbon fatty acids at the expense of palmitate.

Fatty acid composition in bovine tissues can be changed by altering diet (Sumida *et al*. 1972; Westerling and Hedrick 1979; Eichorn *et al*. 1986). However, St John *et al*. (1987) reported small changes for palmitate and stearate. They found no significant change in the fatty acid composition of bovine longissimus muscle or subcutaneous adipose tissue when the animals were fed a high oleate rapeseed diet. Another approach to modifying fatty acid composition is selective breeding (St John *et al*. 1991).

Fatty acid profiles in cattle could be manipulated by selecting for individuals or breed types capable of transmitting to their progeny the ability to accumulate adipose tissues with less palmitate and/or more oleate and/or stearate (Huerta-Leidenz *et al*. 1993). There can be no breed improvement without genetic variation. Limousin cattle have been reported to have low levels of intramuscular fat but high meat yield,

10.1071/AR96083 0004-9409/97/050715$05.00

whereas Jersey cattle have low meat yield but high intramuscular fat (Cundiff *et al.* 1988). This large variation makes them ideal models for studying breed differences in fat composition. An attempt to assess genetic variation in fatty acid composition with age based on subcutaneous adipose biopsies is presented in this study.

Sinclair and O'Dea (1987) reported that 'there is paucity of data on the lipid levels and fatty acid composition of meat produced in Australia'. St John *et al.* (1991) reported that 'little is known about the tissue distribution and (or) the biochemical pathways that convert saturated fatty acids to stearate or oleate in the bovine species'. Pyle *et al.* (1977) compared 13 cattle breeds for fatty acid composition and correlations with fatness, but at a single age. Therefore, we evaluated Limousin and Jersey cattle over a range of ages for breed differences in triacylglycerol fatty acid composition.

Materials and methods

Animals and management

The animals used in this study were part of the parental generation of the J. S. Davies Cattle Gene Mapping Resource Herd held at Martindale, a property located about 150 km north of Adelaide, SA. They included 78 Jersey and Limousin non-lactating, non-pregnant cows, yearling heifers, and steers, in total (Table 1). Limousin cows, heifers, and steers were heavier than their Jersey counterparts. Limousin cows were also, on average, slightly older than the Jersey cows, but the heifers and steers were the same age (yearlings). They were all pasture-fed with some supplementary oaten hay and silage constituting a major dietary source during the summer. They were all maintained under the same routine management such that all animals had equal access to pasture, hay, and silage. Cows were sampled in January and yearling heifers and steers sampled in April 1994.

Table 1. Numbers of cattle sampled and average liveweight (kg) and age (months) (± s.e.)

Breed	No.	Liveweight	Age (range)
		Cows	
Jersey	30	356±7	39±3 (20–68)
Limousin	24	536±8	51±4 (29–96)
		Yearling heifers	
Jersey	7	142±24	12
Limousin	7	236±14	12
		Yearling steers	
Jersey	5	233±15	12
Limousin	5	291±24	12

Sample collection using biopsy technique

The animals were restrained in a crush and the hair around the shoulder muscle (M. triceps brachii) clipped. A local anaesthetic was injected at the sampling site before 3 g of subcutaneous fat was taken. Antibiotics were administered to prevent secondary infection. The fat samples were snap-frozen in liquid nitrogen, flushed with N_2 gas, transported to the laboratory, and stored at -20°C until the samples were analysed for fatty acid composition. After surgery, the animals were checked daily during the time the wounds healed.

Laboratory procedures

Total lipid extraction

Approximately 0·1 g of the subcutaneous fat sample was frozen in liquid nitrogen, placed in a mortar, and pulverised with a pestle into finely ground powder. Total lipids were extracted by using chloroform–methanol (2 : 1 v/v), containing butylated hydroxy toluene (BHT) crystals as an anti-oxidant (Christie 1989).

Triacylglycerol and phospholipid separation

The extracted lipids were separated into classes by thin layer chromatography (TLC) using 100 μL of the lipid extract reconstituted in hexane. The extract was spotted on silica gel G plates (200 by 200 by 0·25 mm) with a micropipette. The TLC plate was developed in an acetone/petroleum ether (1 : 3 v/v) solvent system in a tank containing a few crystals of BHT to prevent oxidation. Triacylglycerols and free fatty acids migrated while phospholipids remained at the origin. The areas corresponding to the triacylglycerols were scraped off the plate and transferred to clean screw-capped test tubes for methylation.

Methylation

Methylation was carried out by a base-catalysed transesterification procedure (Siebert *et al.* 1996).

Fatty acid analysis

Fatty acid concentration was determined by gas chromatography as described by Christie (1989), using a Hewlett Packard Model 5890A Series II gas chromatograph. Details of this instrument's calibration have been described by Siebert *et al.* (1996). Identification of sample fatty acids was made by comparing the relative retention times of FAME peaks from samples with those of standards. These were calculated as normalised area percentages of fatty acid.

Degree of saturation

Fatty acids were classified into saturated (SFA, no double bonds), monounsaturated (MUFA, one double bond), and polyunsaturated (PUFA, 2 or more double bonds) and computed as follows:

$$\text{SFA} = 14{:}0+16{:}0+17{:}0+18{:}0$$

$$\text{MUFA} = 14{:}1\Delta^{9}+16{:}1\Delta^{9}+17{:}1\Delta^{9}+18{:}1\Delta^{9}+18{:}1\Delta^{11}$$

$$\text{PUFA} = 18{:}2\Delta^{9,12}+18{:}3\Delta^{9,12,15}+18{:}3\Delta^{6,9,12}+18{:}4\Delta^{6,9,12,15}$$

Chain length

The summation of individual fatty acids on the basis of carbon chain length was carried out as follows:

$$\text{Total C14} = 14{:}0+14{:}1\Delta^{9}$$

$$\text{Total C16} = 16{:}0+16{:}1\Delta^{9}$$

$$\text{Total C17} = 17{:}0+17{:}1\Delta^{9}$$

$$\text{Total C18} = 18{:}0+18{:}1\Delta^{9}+18{:}1\Delta^{11}+18{:}2\Delta^{9,12}+18{:}3\Delta^{6,9,12}+18{:}3\Delta^{9,12,15}+18{:}4\Delta^{6,9,12,15}$$

Statistical analyses

All data were analysed by least squares analysis of variance using PROC GLM Type 1 Sums of Squares (SAS 1989). The model for the cow data included the fixed effects of breed, the

Table 2. Tests of significance for factors fitted for least squares analysis

Abbreviations of traits explained in Table 3

Trait	Cow data			Yearling data		
	Breed	Age	Breed×age	Sex	Breed	Sex×breed
14:0	**	n.s.	*	n.s.	n.s.	n.s.
14:1Δ^9	*	**	n.s.	n.s.	n.s.	n.s.
16:0	**	n.s.	**	n.s.	n.s.	n.s.
16:1Δ^9	*	**	**	n.s.	n.s.	n.s.
17:0	*	n.s.	**	n.s.	n.s.	n.s.
17:1Δ^9	n.s.	**	n.s.	**	**	*
18:0	*	**	*	n.s.	n.s.	n.s.
18:1Δ^9	**	n.s.	n.s.	n.s.	n.s.	n.s.
18:1Δ^{11}	**	n.s.	n.s.	n.s.	n.s.	n.s.
18:2$\Delta^{9,12}$	*	n.s.	*	n.s.	n.s.	n.s.
18:3$\Delta^{9,12,15}$	*	n.s.	n.s.	n.s.	n.s.	n.s.
18:3$\Delta^{6,9,12}$	*	**	n.s.	n.s.	n.s.	n.s.
18:4$\Delta^{6,9,12,15}$	**	*	n.s.	n.s.	n.s.	n.s.
SFA	**	**	n.s.	n.s.	n.s.	n.s.
MUFA	**	**	*	n.s.	n.s.	n.s.
PUFA	*	n.s.	n.s.	n.s.	n.s.	*
USRatio	**	**	n.s.	n.s.	n.s.	n.s.
PSRatio	*	n.s.	n.s.	n.s.	n.s.	n.s.
Total C14	n.s.	**	*	n.s.	*	n.s.
Total C16	n.s.	**	**	n.s.	*	n.s.
Total C17	n.s.	*	**	n.s.	*	n.s.
Total C18	n.s.	**	**	n.s.	*	n.s.
RC16	**	**	*	n.s.	n.s.	n.s.
RC18	**	**	**	n.s.	n.s.	n.s.
USI	**	**	**	n.s.	n.s.	n.s.
Δ9-desaturase(16)	**	**	*	n.s.	n.s.	n.s.
Δ9-desaturase(18)	**	**	*	n.s.	n.s.	n.s.
Elongase	**	**	**	n.s.	*	*

*$P < 0{\cdot}05$; **$P < 0{\cdot}01$; n.s., not significant.

partial regression on age, and the interaction between age and breed (Table 2). Initial analysis included weight as a covariate, but this was dropped from the model because it was not a significant source of variation. Breed and age effects were partially confounded since Limousin cows were on average 11 months older than Jersey cows. However, a large range within each breed was evident in ages (Table 1); hence, breed and age were only partially confounded. The model used for the yearling data included the fixed effects of sex and breed, and the 2-way interaction between sex and breed. Significance was defined as $P < 0{\cdot}05$.

Results

Individual fatty acids (C14–C18) from the triacylglycerol fraction of shoulder subcutaneous adipose tissue were measured in purebred Jersey and Limousin yearlings and dry cows. The tests of significance used to analyse fatty acid data for cows and yearlings are shown in Table 2.

Cow data

For cows, breed was a highly significant source of variation in all of the traits except 17:1Δ^9, total C14, C16, C17, and C18 fatty acids (Table 2). Percentages of 14:1Δ^9, 16:1Δ^9, 17:0, 18:1Δ^9, 18:1Δ^{11}, 18:2$\Delta^{9,12}$, 18:3$\Delta^{6,9,12}$, and 18:4$\Delta^{6,9,12,15}$ fatty acids in Jersey were higher than those of Limousin cows (Table 3). On the other hand, percentages of 14:0 and 18:0 were lower in Jersey cows than in Limousin (Table 3). Oleate (18:1Δ^9) was the most abundant of all the fatty acids, totalling 41·6 and 38·8% in Jersey and Limousin cows, respectively.

In general, as animals aged, their fat became less saturated. Specifically, percentages of 14:1Δ^9, 16:1Δ^9, 17:1Δ^9, 18:3$\Delta^{6,9,12}$, 18:4$\Delta^{6,9,12,15}$, and total monounsaturated fatty acids (MUFA), and the ratio of total monounsaturated to total saturated fatty acids, increased with age. In contrast, 18:0 and total saturated fatty acids (SFA) decreased with increasing age (Fig. 1). The respective regression equations on age for the Jersey and Limousin were

$$\text{SFA} = 51{\cdot}5 - 0{\cdot}093\text{age}$$

and

$$\text{SFA} = 56{\cdot}5 - 0{\cdot}066\text{age} \quad (R^2 = 0{\cdot}40)$$

with the standard error of the difference in intercepts being 2·0 and slopes being 0·041. The effect of age was different in the 2 breeds as portrayed by significant breed×age interaction for the indi-

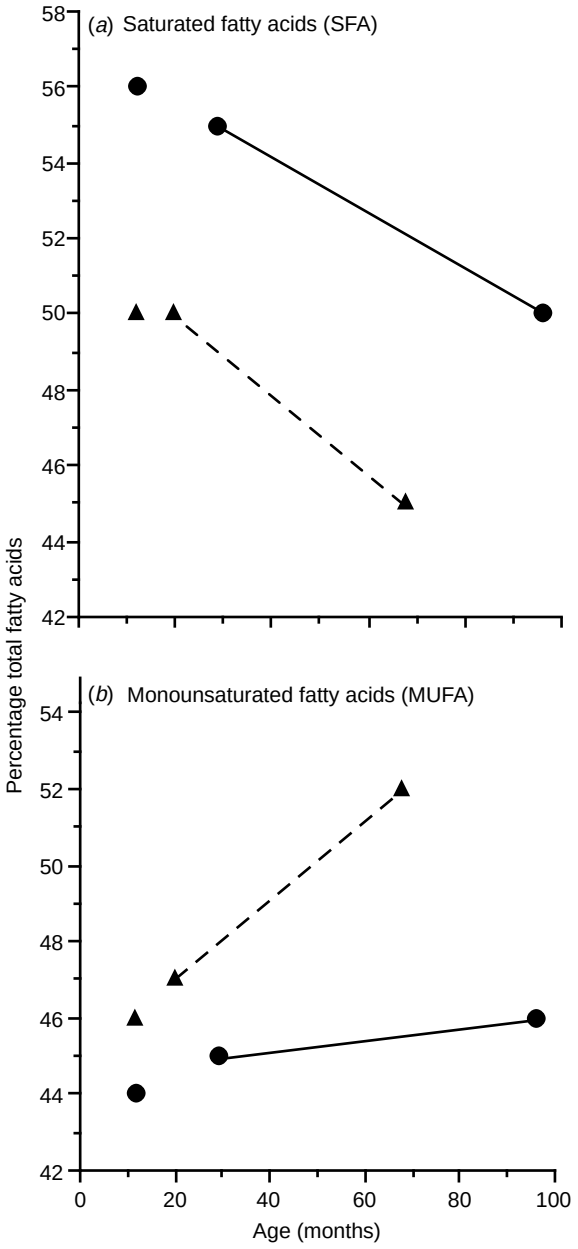

Fig. 1. Relationship between proportion of fatty acids and age. The regression equations are: SFA = 51·5−0·093age and 56·5−0·066age ($R^2 = 0·40$) and MUFA = 44·5+0·113age and 43·8+0·025 ($R^2 = 0·27$) for Jersey and Limousin, respectively. Unjoined data points represent predicted yearling figures and the joined points are cow data at the minimum and maximum age ranges. ●, Limousin; ▲, Jersey.

vidual fatty acids 14:0, 16:0, 16:1Δ^9, 17:0, 18:0, and 18:2$\Delta^{9,12}$. Moreover, the interaction was significant for MUFA, and total C14, C16, C17, and C18 fatty acids. In the Jersey, MUFA level increased with age, but in the Limousin, it remained almost constant (Fig. 1). The respective regression equations on age for the Jersey and Limousin were

$$\text{MUFA} = 44·5 + 0·113\text{age}$$

and

$$\text{MUFA} = 43·8 + 0·025\text{age} \quad (R^2 = 0·27)$$

with the standard error of the difference in intercepts being 2·2 and slopes being 0·045.

Yearling data

In the yearling data, almost all of the differences due to sex and sex×breed interactions were not significant (Table 2). Sex was a significant source of variation for 17:1Δ^9 only. Sex×breed interaction significantly affected 17:1Δ^9, PUFA, and the elongase enzyme activity index. Hence, least squares means for steers and heifers were pooled together and computed on the basis of breed as shown in Table 3.

Breed differences were significant for 17:1Δ^9, in which Limousin yearlings had 1·2% and Jersey had 0·9% (Table 3). Oleate (18:1Δ^9) was also the most abundant fatty acid in the yearlings, the percentages being 32·1 and 34·6% in the Jersey and Limousin, respectively.

Observation of the cow and yearling data revealed an interesting trend in which the percentages of myristate (14:0) and palmitate (16:0) were higher in yearlings than cows. However, oleate (18:1Δ^9) was higher in cows than in yearlings. The essential fatty acids linoleate (18:2$\Delta^{9,12}$) and linolenate (18:3$\Delta^{9,12,15}$) did not present a well-defined pattern, except that in the cows, Jersey had 1·3% more linoleate and 1·0% less linolenate than Limousin.

Degree of saturation

Breed differences were large for degree of saturation in the cows. Limousin cows had higher percentages of SFA (52·9%) than Jersey (47·5%) (Table 3). In contrast, Jersey cows exhibited higher levels of MUFA (49·3 *v.* 45·3%) and PUFA (3·2 *v.* 1·8%) than Limousin cows (Table 3). Breed differences in the degree of saturation in the yearlings were not significant (Table 2).

As expected from the results with individual fatty acids, all ratios reflecting differences in the degree of saturation were higher in Jersey cows than in Limousin (Table 3). Jersey cows had significantly higher ratios of total unsaturated to saturated fatty acids and total polyunsaturated to saturated fatty acids than Limousin. Jersey cows also had much higher ratios of the conversion of palmitate to palmitoleate, stearate to oleate, and stearate to palmitoleate and oleate than Limousin. Again, breed differences were not apparent when the animals were yearlings.

Table 3. Least squares means (±s.e.) of fatty acids in the triacylglycerols component of cattle fat (% total fatty acids)

Fatty acid numbers in superscripts depict the positions of the double bond. SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids

Fatty acid	Cows			Yearlings		
	Jersey	Limousin	Sign.	Jersey	Limousin	Sign.
14:0	3·8±0·1	4·6±0·1	*	6·2±0·6	5·0±0·7	
14:1Δ^9	1·3±0·1	1·0±0·1	*	1·7±0·2	1·3±0·3	
16:0	28·2±0·3	30·2±0·4	**	32·5±1·0	30·2±1·3	
16:1Δ^9	5·5±0·2	4·5±0·3	*	5·7±0·6	4·6±0·8	
17:0	1·2±0·1	1·0±0·1	*	1·2±0·2	1·6±0·3	*
17:1Δ^9	0·9±0·1	1·0±0·1		0·9±0·1	1·2±0·1	
18:0	14·3±0·5	17·1±0·6	*	17·2±3·6	19·1±4·7	
18:1Δ^9	39·5±1·5	37·5±1·3	*	32·1±3·6	34·6±4·6	
18:1Δ^{11}	2·1±0·1	1·3±0·1	**	0·2±0·1	0·2±0·2	
18:2$\Delta^{9,12}$	1·7±0·4	0·4±0·4	**	1·0±0·1	1·2±0·1	
18:3$\Delta^{9,12,15}$	0·7±0·1	1·0±0·3		0·5±0·1	0·4±0·1	
18:3$\Delta^{6,9,12}$	0·4±0·1	0·2±0·1	*	0·2±0·1	0·2±0·1	
18:4$\Delta^{6,9,12,15}$	0·4±0·0	0·2±0·0	**	0·6±0·1	0·4±0·2	
SFA	47·5±0·6	52·9±0·7	**	57·1±4·2	55·9±5·4	
MUFA	49·3±0·6	45·3±0·7	**	40·6±4·2	41·9±5·4	
PUFA	3·2±0·5	1·8±0·6	**	2·3±0·2	2·2±0·3	
Δ9-desat(16)[A]	16·8±0·7	12·5±0·7	**	15·1±1·6	13·1±2·1	
Δ9-desat(18)[B]	73·5±0·8	68·4±0·9	**	63·3±7·5	63·5±9·7	
Total C14[C]	5·1±0·2	5·4±0·2		7·9±0·7	6·3±0·9	*
Total C16[DG]	34·0±0·9	35·7±0·9		38·2±1·0	34·8±1·4	*
Total C17[EG]	2·1±0·1	1·7±0·4		2·2±0·2	2·6±0·1	*
Total C18[FG]	58·8±1·5	57·2±1·3		51·7±1·4	56·3±1·8	*
Elongase	60·9±0·4	58·9±0·5	*	55·2±1·3	60·0±1·7	*

Test for differences between breeds $*P < 0{\cdot}05$, $**P < 0{\cdot}01$.

[A] Δ9-desaturase(16) = index of desaturase enzyme activity in C16 fatty acids = 100(16:1Δ^9/16:0+16:1Δ^9.

[B] Δ9-desaturase(18) = index of desaturase enzyme activity in C18 fatty acids = 100 (18:1Δ^9/18:0+18:1Δ^9).

[C] Total C14 = 14:0+14:1Δ^9.

[D] Total C16 = 16:0+16:1Δ^9.

[E] Total C17 = 17:0+17:1Δ^9.

[F] Total C18 = 18:0+18:1Δ^9+18:1Δ^{11}+18:2$\Delta^{9,12}$+18:3$\Delta^{9,12,15}$+18:3$\Delta^{6,9,12}$+18:4$\Delta^{6,9,12,15}$.

[G] Index of elongase enzyme activity in the chain-lenthening of C16–C18 fatty acids = 100(18:0+18:1Δ^9/16:0+16:1Δ^9+18:0+18:1Δ^9).

In order to define better the involvement of specific enzymes in the fatty acid composition, indices of enzyme activities were calculated. The 2 key enzyme activities analysed were the Δ9-desaturase and elongase. The Δ9-desaturase inserts a double bond at the ninth carbon atom of the fatty acid chain. Therefore, the Δ9-desaturase is responsible for the conversion of saturated to monounsaturated fatty acids. The elongase adds 2 carbon units to the fatty acid chain and thus converts C16 to C18.

Calculated enzyme activity indices paralleled the fatty acid ratios. Large breed differences existed in the calculated indices of Δ9-desaturase enzyme activities (Table 3). It was also evident that the Δ9-desaturase enzyme activity index was far greater for C18 fatty acids than for C16 fatty acids. Jersey cows exhibited higher indices than Limousin (16·8 *v.* 12·5% for 16-carbon chain fatty acids and 73·5 *v.* 68·4% for 18-carbon fatty acids, respectively).

Observation of the cow and yearling data showed that Δ9-desaturase indices were higher in Jersey cows than in yearlings. In the Limousin, they did not increase with age to the same extent. The difference was more pronounced in Δ9-desaturase enzyme activity index for C18 fatty acids than any other fatty acid.

Chain length

When the fatty acids were classified on the basis of carbon chain length (Table 3), 18-carbon fatty acids (C18) were the most abundant, accounting for over 50% of the total fatty acids, and C17 fatty acids were the least common of those measured (about 2%). There were no breed differences in percentages of C14, C16, C17, and C18 fatty acids in cows (Table 3). However, Jersey yearlings had higher percentages of C14 and C16 and lower percentages of C17 and C18 fatty acids than Limousin. Observation of the cow and yearling data showed that the percentages of C14 and C16 were lower and C18 was higher in Jersey cows than in the Jersey yearlings. Unlike the Jersey, no differences were observed between cows and yearlings in the Limousin.

In cows, Jersey had a higher elongase enzyme activity index than Limousin (60·9 *v.* 58·9%), whereas in

yearlings, Jersey had lower activity (56·4 *v.* 60·9%) (Table 3). Note that the calculated index of elongase enzyme activity did not change with increasing maturity in the Limousin, whereas in the Jersey, there was an increase from 56·4% in yearlings to 62·1% in cows.

Discussion

Breed differences in most of the triacylglycerol fatty acids in Jersey and Limousin yearlings were not detected. However, in the cows, differences were observed in all but one fatty acid (Table 2). Our data indicate that fatty acid composition in the Jersey changes as the animals age. The decrease in myristate (14:0), palmitate (16:0), and stearate (18:0), and the concomitant increase in oleate (18:1Δ^9) observed between yearlings and mature dry cows, seem to suggest that more and more saturated fatty acids are converted into unsaturated fatty acids. Leat (1975) showed that the saturation of depot fats of Jersey cattle increased up to 1 year *post partum* and then decreased with age. He concluded that the saturated fatty acids deposited in adipose tissue during the first year of life were progressively diluted with fatty acids of higher unsaturation. This is supported by our data (Fig. 1) showing that the proportion of saturated fats in both Jersey and Limousin breeds decreases with age. In addition, our yearling data showed that the percentages of 14:0, 16:0, and 18:0 were higher in yearlings than in cows. It may also be possible that differences observed between the cows and yearlings could have been due to climatic and pasture differences in January and April when they were sampled.

Degree of saturation

In highly fattened crossbred cattle, Siebert *et al.* (1996) found no significant difference in the saturated (mean 44%) and monounsaturated (mean 54%) fatty acids in adipose tissue between the Jersey×Hereford and European×Hereford cattle. In contrast, Huerta-Leidenz *et al.* (1993) observed highly significant breed differences in the percentages of saturated and unsaturated fatty acids in subcutaneous adipose tissues from purebred Brahman and Hereford cows. They reported that subcutaneous adipose tissue from Hereford cows was higher in total saturated fatty acids (38·8 *v.* 34·5%) and lower in monounsaturated (59·5 *v.* 63·4%) and polyunsaturated (1·8 *v.* 2·4%) than that from Brahman cows. Leat (1977) reported similarly marked differences between Angus and Friesian breeds of cattle. Our data show that even larger differences exist between Jersey and Limousin cows (Table 3). The magnitudes were 5·4% less saturated, 4·0% more monounsaturated, and 1·4% more polyunsaturated fatty acids in the Jersey than in the Limousin.

The ratio of unsaturated to saturated fatty acids is often expressed as an index of unsaturation. For instance, 16:1Δ^9/16:0 and 18:1Δ^9/18:0 represent ratios of the conversion of palmitate to palmitoleate and stearate to oleate, respectively. Leat (1977) went a step further to calculate ratios of 16:1Δ^9+18:1Δ^9/18:0 as an index of unsaturation. Using this index, Huerta-Leidenz *et al.* (1993) observed that Brahman cows had higher indices of unsaturation than Herefords. Leat (1977) also observed that in hay-fed cattle, the 16:1Δ^9/18:0 ratio of subcutaneous fat biopsies remained low until 12 months of age, and then increased in the period 12–24 months of age.

Enzyme activities

Δ9-desaturase

The process of the conversion of saturated to unsaturated fatty acids is catalysed by enzymes (Gurr and Harwood 1991). A flaw associated with the ratios of Leat (1977) is that they do not quantify the activity of the enzymes involved in the conversion. An alternative is to express the quantity of product of a reaction as a percentage of the substrate that was available to be converted. Thus, instead of being unitless, such an index can be expressed as a percentage. An example is the activity of Δ9-desaturase in C16 fatty acids, Δ9-desaturase(16):

$$\Delta 9\text{-desaturase}(16) = 100\left(\frac{16:1\Delta^9}{16:0 + 16:1\Delta^9}\right)$$

This index calculates the proportion of palmitate (16:0) that is converted to palmitoleate (16:1Δ^9) when a double bond is inserted at the ninth carbon atom from the methyl end of the fatty acid chain by Δ9-desaturase enzyme.

Similarly, index of Δ9-desaturase enzyme activity in C18 fatty acids, Δ9-desaturase(18) would be:

$$\Delta 9\text{-desaturase}(18) = 100\left(\frac{18:1\Delta^9}{18:0 + 18:1\Delta^9}\right)$$

This index therefore calculates the proportion of stearate (18:0) that is converted to oleate (18:1Δ^9) when a double bond is inserted by Δ9-desaturase enzyme. Linoleate (18:2$\Delta^{9,12}$) and linolenate (18:3$\Delta^{9,12,15}$) are excluded from this equation because both are essential fatty acids that cannot be synthesised by the animals. Transvaccenate (18:1Δ^{11}) was also excluded because it is produced from linoleate by biohydrogenation in the rumen. Similarly, octadecatetraenoate (18:4$\Delta^{6,9,12,15}$) was also excluded because it is converted from alpha-linolenate (18:3$\Delta^{6,9,12}$) since they both belong to the n-3 series of polyunsaturated fatty acids.

Elongase

Fatty acids can be elongated by a microsomal system which uses acetyl-coA as the unit for 2 carbon addition (Cook 1985). In general, the mitochondrial system elongates fatty acids in the range C10–C14, whereas the microsomal system uses C16 and longer acids (Gunstone *et al.* 1986). Elongation of fatty acids (≥C16) is carried out by the microsomal fatty acid elongase. Therefore, an index of elongase enzyme activity (EA) in the chain lengthening of C16 to C18 fatty acids is:

$$\mathrm{EA} = 100\left(\frac{18:0+18:1\Delta^9}{16:0+16:1\Delta^9+18:0+18:1\Delta^9}\right)$$

This index uses all of the non-essential C18 fatty acids as a proportion of both C16 and C18 fatty acids expressed as a percentage. It should be borne in mind that the basic assumption associated with the desaturase and elongase enzyme indices is that there is no fat mobilisation occurring in the animals due to weight loss. Experiments to measure directly the enzyme activities to validate these indices are currently on-going in our laboratory.

Smith *et al.* (1984) in their investigation of the interrelationships among age, fat deposition, and lipid metabolism in growing cattle reported that fatty acid synthesis and several lipogenic enzyme activities increased with age. Our data indicated that there was a general increase in the indices of enzyme activities as animals aged, and the increase was most pronounced in Δ9-desaturase activity on C18 fatty acids. The proportion of unsaturated fatty acids increased with age. Fatty acid percentages across the appropriate range of cow ages (see Table 1) within the 2 breeds were predicted from the fitted regression equations as shown in Fig. 1. Limousin triacylglycerol was more saturated than in the Jersey. More interesting is the fact that there was the same trend of decreasing levels of SFA in the 2 breeds with increasing age. Note that the yearling values are as expected based on the age trends for cows.

The regression of MUFA on age showed that Jersey cows contained more MUFA than the Limousin (Fig. 1). For Limousin cows, the MUFA percentage remained almost constant with increasing age. In contrast, MUFA increased with age in the Jersey. This observation further reinforces the point that a major breed difference exists between the Jersey and Limousin.

Leat (1977) reported marked differences in growth rate, fat content, and fatty acid chain length between Angus and Friesian steers and heifers. However, at 2 years of age, results indicated no breed differences in their fat compositions and chain lengths. The lower percentages of C14 and C16 in cows than in yearlings observed in the Jersey breed imply that the process of chain lengthening by the successive addition of 2 carbon units increases with age. This was partly reflected by an increase in the percentage of C18 as well as elongase enzyme activity index, and this increase was more pronounced in the Jersey than in the Limousin breed.

Finally, it should be noted that the differences observed in the dry cows in the percentages of the PUFA linoleate ($18{:}2\Delta^{9,12}$) and linolenate ($18{:}3\Delta^{9,12,15}$) are of dietary origin since both are essential fatty acids that cannot be synthesised by the animals. Feed consumption per unit weight or absorption differences (as well as utilisation rates) between the Limousin and Jersey cows, therefore, seem to be the source of variation, and since both breeds were on the same pasture, this reflects genetic differences.

Conclusion

In conclusion, this study has clearly demonstrated that the fatty acid composition of the triacylglycerols of subcutaneous shoulder fat in Jersey and Limousin cows differed. The Limousin cows had a greater proportion of saturated fatty acids than Jersey cows. Yearling calves did not exhibit breed differences in the degree of saturation but did have differences in chain length. Since the cattle groups used in the study were fed on pasture only and were under the same management conditions, our results suggest a strong genetic basis for the differences in triacylglycerol fatty acid composition of Limousin and Jersey cattle.

Acknowledgments

This study was funded by the J. S. Davies Bequest Fund to the University of Adelaide, the South Australian Cattle Compensation Trust Fund, and the Australian Development Cooperation Scholarship from AusAID for A. E. O. Malau-Aduli.

References

Brackebusch, S. A., McKeith, F. K., Carr, T. R., and McLaren, D. G. (1991). Relationship between longissimus composition and the composition of other major muscles of the beef carcass. *Journal of Animal Science* **69**, 631–40.

Christie, W. W. (1989). 'Gas Chromatography and Lipids.' (The Oily Press: Oxford, UK.)

Cliff, R. W. (1987). Coronary heart disease: animal fat on trial. *Pathology* **19**, 325.

Cook, H. W. (1985). *In* 'Biochemistry of Lipids and Membranes'. (Eds D. E. Vance and J. E. Vance.) (Benjamin/Cummings Pub. Co.: California.)

Cundiff, L. V., Dikeman, M. E., Koch, R. M., Crouse, J. D., and Gregory, K. E. (1988). Breeding for lean beef. Beef Research Progress Report No. 3, USDA, pp. 3–7.

Eichorn, J. M., Coleman, L. J., Wakayama, E. J., Blomquist, G. J., Bailey, C. M., and Jenkins, T.G. (1986). Effects of breed type and restricted versus *ad libitum* feeding on fatty acid composition and cholesterol content of muscle and adipose tissue from mature bovine females. *Journal of Animal Science* **63**, 781.

Gouldbert, U. (1987). High risk versus public health strategies in primary prevention of coronary heart disease. *American Journal of Clinical Nutrition* **45**, 1185.

Grundy, S. M., Florentin, L., Nix, D., and Whelan, M. F. (1988). Comparison of monounsaturated fatty acids and carbohydrates for reducing raised levels of plasma cholesterol in man. *American Journal of Clinical Nutrition* **47**, 965.

Gunstone, F. D., Harwood, J. L., and Padley, F. B. (1986). 'The Lipid Handbook.' (Chapman and Hall: London.)

Gurr, M. I., and Harwood, J. L. (1991). 'Lipid Biochemistry: An Introduction.' (Chapman and Hall: London.)

Huerta-Leidenz, N. O., Cross, H. R., Savell, J. W., Lunt, D. K., Baker, J. F., Pelton, L. S., and Smith, S. B. (1993). Comparison of the fatty acid composition of subcutaneous adipose tissue from mature Brahman and Hereford cows. *Journal of Animal Science* **71**, 625–30.

Leat, W. M. F. (1975). Fatty acid composition of adipose tissue of Jersey cattle during growth and development. *Journal of Agricultural Science* (Cambridge) **85**, 551.

Leat, W. M. F. (1977). Depot fatty acids of Aberdeen Angus and Friesian cattle reared on hay and barley diets. *Journal of Agricultural Science* (Cambridge) **89**, 575.

Lewis, J. L., Sadler, M. F., and Buick, D. R. (1993). Estimation of the nutritional value of retail fat-trimmed beef cuts from new gross composition data. *Food Australia* **45**, 13–17.

Marmer, W. N., Maxwell, R. J., and Williams, J. E. (1984). Effects of dietary regimen and tissue site on bovine fatty acid profile. *Journal of Animal Science* **59**, 109.

Mattson, F. H., and Grundy, S. M. (1985). Comparison of dietary saturated, monounsaturated and polyunsaturated fatty acids on plasma lipids and lipoproteins in man. *Journal of Lipid Research* **26**, 194.

Parrett, D. F., Bechtel, P. J., Romans, J. R., and McKeith, F. K. (1989). Composition of beef subprimal cuts. *Journal of Food and Comparative Analysis* **2**, 79.

Pyle, C. A., Bass, J. J., Duganzich, D. M., and Payne, E. (1977). The fatty acid composition of the subcutaneous brisket fat from steers obtained from Angus cows mated to 13 different beef breeds. *Journal of Agricultural Science* (Cambridge) **89**, 571–4.

SAS Institute, Inc. (1989). 'SAS User's Guide: Statistics.' Version 6. (SAS Institute, Inc.: Cary, NC.)

Siebert, B. D., Deland, M. P., and Pitchford, W. S. (1996). Breed differences in the fatty acid composition of subcutaneous and intramuscular lipid of early and late maturing grain-finished cattle. *Australian Journal of Agricultural Research* **47**, 943–52.

Sinclair, A. J., and O'Dea, K. (1987). The lipid levels and fatty acid compositions of the lean portions of Australian beef and lamb. *Food Technology in Australia* **39**, 228–31.

Smith, S. B., Prior, R. L., Ferrel, C. L., and Mersmann, H. J. (1984). Interrelationships among diet, age, fat deposition and lipid metabolism in growing steers. *Journal of Nutrition* **114**, 153–62.

St John, L. C., Lunt, D. K., and Smith, S. B. (1991). Fatty acid elongation and desaturation enzyme activity of bovine liver and subcutaneous adipose tissue microsome. *Journal of Animal Science* **69**, 1064–73.

St John, L. C., Young, C. R., Knabe, D. A., Thompson, L. D., Schelling, G. T., Grundy, S. M., and Smith, S. B. (1987). Fatty acid profiles and sensory and carcass traits of tissues from steers and swine fed an elevated monounsaturated fat diet. *Journal of Animal Science* **64**, 1441.

Sumida, D. M., Vogt, D. W., Cobb, E. H., Iwanaga, I. I., and Reimer, D. (1972). Effect of breed type and feeding regime on fatty acid composition of certain bovine tissues. *Journal of Animal Science* **35**, 1058.

Westerling, D. B., and Hedrick, H. B. (1979). Fatty acid composition of bovine lipids as influenced by diet, sex and anatomical location and relationship to sensory characteristics. *Journal of Animal Science* **48**, 1343.

Manuscript submitted 8 July 1996, accepted 28 February 1997