ARE ß-CAROTENE AND FATTY ACID COMPOSITION RELATED IN CATTLE?

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SUMMARY

Jersey and Limousin non-lactating cows were sampled at two different seasons to determine the ß-carotene concentration and fatty acid profiles of subcutaneous adipose tissue. Results demonstrate significant differences between the Jerseys and Limousins in the concentration of ß-carotene and 14:1, 16:0, 18:1(ω-7) and 18:3(ω-6) fatty acids. Seasonal variations did not affect ß-carotene concentration but had a major effect on most fatty acids and ratios of fatty acid groups. There was no correlation between ß-carotene concentration and individual fatty acids which may indicate that there is no direct effect of ß-carotene on fatty acid metabolism.

Keywords: ß-carotene, fatty acids, cattle, lipid metabolism.

INTRODUCTION

Excessive yellow coloration of adipose tissue in cattle is not desirable on the domestic and overseas beef markets as it can cause downgrading or even rejection of such carcasses (Browne 1993; Hayes *et al.* 1995). ß-Carotene is the main pigment associated with the incidence of the yellow fat colour in cattle (Yang *et al.* 1992; Strachan *et al.* 1993). A correlation between fatty acids in subcutaneous adipose tissue and fat colour in Brahman cattle was reported by Zhou *et al.* (1993). Recently, ß-carotene has been shown to regulate genes associated with lipid and sterol biochemistry (Pal *et al.* 1997). Although the biochemical pathways for fatty acids have been well defined (Brindley 1985), the metabolism of carotenoids in Bovidae is at present unclear. The aim of this study was to investigate the relationship between ß-carotene content and fatty acid composition of adipose tissue in cattle.

MATERIALS AND METHODS

Animals and management. 15 Jersey and 15 Limousin non-lactating cows were used for the study. The cows were a part of the J.S. Davies Cattle Gene Mapping Herd maintained at Martindale, South Australia. They were randomly chosen from 220 animals representing a great number of genotypes from over 70 sire lines in each breed. All cows were under the same management and grazed on the same pastures with some supplement of hay from January to September.

Sample collection and preparation. The same cows were sampled twice, once at the end of the summer (April 1995) when the dry grass and supplemented hay were available, and at the end of winter (November 1995) when green feed was available. Adipose samples were collected from the

area between the 12th and 13th rib using a biopsy technique as described by Malau-Aduli *et al.* (1995).

Chemical analyses. ß-Carotene content in fat samples was analysed by a modified method of Yang *et al.* (1992). Adipose tissue (~0.1 g) was hydrolysed with 1 ml of 20% KOH in methanol at 65^{0}C for 40 min. After the hydrolysis, 3 ml of water was added and ß-carotene extracted twice with 4 ml of diethyl ether. The combined diethyl ether extracts were washed with 5 ml of water and dried under preheated nitrogen. Samples were resuspended in ethanol and the absorbance at 450nm was determined on a spectrophotometer (Shimadzu UV 160A, CO, Kyoto, Japan). By HPLC, the predominant carotenoid (>99%) measured at 450nm was ß-carotene. Fatty acid composition of the triacylglycerol fraction of the adipose tissue was determined as described by Malau-Aduli *et al.* (1995).

Statistical analyses. Least squares analysis of variance was carried out using Proc GLM of SAS (SAS 1989). The model included the fixed effects of breed, season and the interaction between breed and season. Least squares means and differences between means were computed. The residuals from this analysis were used to calculate correlations.

RESULTS AND DISCUSSION

ß-carotene and breed. The mean ß-carotene and fatty acid composition for animals of the two breeds of cattle sampled at two occasions in 1995 are shown in Table 1. The Limousin cows had a significantly lower content of ß-carotene in the adipose tissue than the Jersey cows (1.6 vs 4.9 µg/g fat, respectively). Pitchford *et al.* (1996) have reported similar findings, where Jersey weaners had a higher subjective fat colour score than most other breeds, including Limousin.

ß-carotene and season. ß-carotene concentration in the fat of Jersey and Limousin cows did not vary significantly between the two seasons (3.4 vs 3.1 µg/g fat, respectively). The lack of significant differences could be due to the small alterations in feed composition between seasons. It is most likely the turnover rate of ß-carotene in the adipose tissue is not a rapid process, unlike in other tissues. Blood plasma, for example, reflects dietary carotenoid intake over the recent few weeks, whereas tissue levels indicate longer term intake (Davison *et al.* 1993). This is probably the cause of the low correlation between fat colour and the concentration of ß-carotene in the blood plasma (Hayes *et al.* 1995). Yang *et al.* (1993) reported that after 8 weeks on low carotenoid diets, carotenoid concentration in fat and fat colour were not affected, but the serum ß-carotene concentration fell over 60% in the first two weeks. The slow turnover can account then for the lack of effect of the summer feed on the reduction of ß-carotene in adipose tissue of the Martindale cows.

Fatty acids and breed. The fatty acid composition of the Jersey and Limousin cows studied was comparable to that reported in other breeds (Siebert *et al.* 1996). Oleic acid (18:1 ω-9) was the major fatty acid and accounted for ~40% of the total fatty acids in the triacylglycerol fraction in both breeds (Table 1). Palmitic acid (16:0) was the major saturated fatty acid and accounted for

~30% of the total (Table 1). Significant differences between the cows of the different breeds were observed in the percentage of myristoleic acid (14:1) (1.5 vs 2.0%, respectively P<0.01), vaccenic acid (18:1,ω-7) (3.1 vs 4.1%, respectively P<0.01), palmitic acid (16:0) (29.5 vs 28.4%, respectively, P<0.01), and α–linolenic acid (18:3,ω-3) (0.6 vs 0.8%, respectively, P<0.05) (Table 1).

Fatty acids and season. Season had a large effect on the fatty acid composition in the animals studied (Table 2). Palmitic acid (16:0) did not differ significantly between seasons. However, a highly significant breed by season interaction (P<0.01) was found with palmitic acid (16:0). The Jerseys had a higher percentage of palmitic acid in April than in November (30.3±0.52% vs 28.6±0.52%, respectively), whereas the Limousins were the opposite (27.3±0.52% vs 29.4±0.52%, respectively).

The difference in oleic acid (18:1 ω-9) was almost significant. There was a significant breed by season interaction (P<0.05) for oleic acid. The Jerseys had a lower oleic acid concentration in April than in November (39.9±0.83 vs 40.4±0.83%, respectively). Although the difference in oleic acid was not significant in the Jerseys, the Limousins had more oleic acid in April than in November (42.4±0.83 vs 38.8±0.83%, respectively) and the difference was highly significant (P<0.01).

Table 1. Means for ß-carotene concentration (µg/g fat) and fatty acid composition (standardised % of total fat) in the triacylglycerol fraction of adipose tissue in 15 Jersey and 15 Limousin cows

	Breed			
Component	Jersey	Limousin	S.E.	Significance
ß-carotene	4.9	1.6	0.37	P<0.001
14:0	4.1	4.0	0.16	ns
14:1	1.5	2.0	0.13	P<0.01
16:0	29.5	28.4	0.36	P<0.05
16:1	7.5	6.8	0.35	ns
18:0	10.9	10.4	0.58	ns
18:1 (ω-9)	40.2	40.6	0.59	ns
18:1 (ω-7)	3.1	4.1	0.26	P<0.01
18:3 (ω-3)	0.6	0.8	0.05	P<0.05
PUFA	2.2	2.4	0.13	ns
MFA/SFA	1.18	1.23	0.04	ns
PUFA/SFA	0.05	0.06	0.003	ns

ns-not significant, MFA = monounsaturated fatty acids (14:1 + 16:1 + 18:1,ω-9 + 18:1,ω-7), PUFA = polyunsaturated fatty acids (18:2,ω-6 + 18:3,ω-3 + 18:3,ω-6), SFA = saturated fatty acids (14:0 + 16:0 + 18:0).

Table 2. Seasonal differences in ß-carotene concentration (µg/g fat) and fatty acid composition (standardised % of total fat) between 15 Jersey and 15 Limousin cows

	Season			
Component	Dry (April)	Green (November)	SE	Significance
ß-carotene	3.4	3.1	0.37	ns
14:0	3.7	4.5	0.16	P<0.01
14:1	1.2	2.3	0.13	P<0.001
16:0	28.8	29.0	0.36	ns
16:1	6.3	8.1	0.35	P<0.001
18:0	13.1	8.2	0.58	P<0.001
18:1 (ω-9)	41.2	39.6	0.59	ns
18:1 (ω-7)	2.9	4.4	0.26	P<0.001
PUFA	1.8	2.8	0.13	P<0.001
MFA/SFA	1.13	1.28	0.04	P<0.01
PUFA/SFA	0.04	0.07	0.003	P<0.001

Definitions as for Table 1.

ß-carotene and fatty acid correlations. No direct correlation between ß-carotene concentration and fatty acid profiles in adipose tissue was found in either breed. This data contradicts that of Zhou *et al.* (1993) who examined the ß-carotene concentration in subcutaneous fat sampled from the rump region of Brahman cross carcasses. They reported positive correlations between total carotenoid concentration and *cis* MFA/SFA ratio and total *cis*-MFA, and negative relationships between total carotenoid concentration with SFA and the *trans*-fatty acid C18:1*t*. The concentration of total carotenoid, however, was much lower (0.7 µg/g fat) than the levels reported herein.

The results highlight possible breed, breed sampling or environmental differences between the studies. ß-Carotene is known to be a vitamin A precursor, to act as a strong antioxidant (Britton 1995), and to influence many metabolic processes by gene regulation (Pal *et al.* 1997). The difference in results obtained in this study versus previous work may indicate that ß-carotene has various degrees of influence on metabolic function in different breeds.

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