DO BREED AND SEASON AFFECT β-CAROTENE AND THE FATTY ACID COMPOSITION OF MUSCLE PHOSPHOLIPID IN BEEF?

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ABSTRACT

The purpose of this study was to determine the relationship between ß-carotene concentration and fatty acid profiles in meat of cattle sampled in two seasons. Jersey and Limousin cows were chosen for the experiment. Muscle samples from the *Longissimus dorsi* were collected, and the ß-carotene concentration and fatty acid composition of the phospholipid fraction determined. Results demonstrated that, compared to Limousin, Jersey had a higher concentration of ß-carotene, C16:1, C18:1(ω-9) and total monounsaturated fatty acids, and a lower concentration of the C18:2, C20:4, C24:1, and total polyunsaturated fatty acids. The ß-carotene concentration and most of the fatty acid profiles were influenced by season. Observed breed by season interactions in C18:2, C18-3(ω-3), C20:4, and C24:1 fatty acids demonstrated that there are different seasonal influences in these two breeds. Significant residual correlations between ß-carotene concentration and C16:1, C18:0, C20:4, and C24:1 fatty acids may indicate a direct metabolic relationship between these components. Since it is known that ß-carotene can protect fatty acids against oxidation and influence sterol metabolism, the observed relationship may influence membrane function, meat fat colour, meat colour or possibly the storage of meat.

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

INTRODUCTION

The average Westerner consumes about 150 g of triacylglycerides and 4-8 g of phospholipids per day, with two thirds of the fatty acids derived from animal sources (Rizek *et al* 1974). It is known that these fatty acids have an impact on human health (Bonanome and Grundy 1988), and there has been great interest in livestock metabolism of fatty acids and other nutrients, such as carotenoids, which may affect fatty acid composition. Carotenoids are a group of hydrocarbons which are precursors for vitamin A. They also act as natural antioxidants, and can regulate genes associated with lipid and sterol biochemistry (Pal *et al* 1997). ß-Carotene is one of the main carotenoids present in cattle and can cause yellow colouration of fat tissue (Zhou *et al* 1993). The metabolism of ß-carotene in Bovidae at present has not been well defined. There are reports on the possible relationship between fatty acids and ß-carotene in the adipose tissue (Zhou *et al* 1993, Kruk *et al* 1997). However, a relationship between ß-carotene content with fatty acids in meat has not been demonstrated. The aim of this study was to investigate the relationship between ß-carotene content and phospholipid fatty acid composition in the muscle tissue of two breeds of cattle in two different seasons.

MATERIAL AND METHODS

Animals and management. 15 Jersey and 15 Limousin non-lactating cows, part of the J.S. Davies Gene Mapping Herd maintained at Martindale in South Australia, were randomly chosen for the experiment. The cows represented over 140 sire lines and were under the same management. They grazed on the same pastures with some supplement of hay from January to September.

Sample collection and preparation. Meat biopsy samples from the area between the 12th and 13th rib (Malau-Aduli *et al* 1995) were collected twice, once at the end of the summer (April 1995) when dry grass and supplemented hay were available and once at the end of winter (November 1995) where pastures were rich in green grass. The meat samples were divided into 1 g sub-samples, immediately frozen in liquid N_2, and stored under nitrogen gas at -20°C until required for analysis.

Chemical analyses. ß-Carotene concentration in meat was analysed by hydrolysing 1-1.5 g of meat in 2 ml of 20% KOH in methanol for 40 min at 65°C. Samples were extracted with 5 ml and then 3 ml of hexane. The combined hexane extracts were washed with 5 ml of water and evaporated to dryness under preheated nitrogen. The residue was redissolved in ethanol and the absorbance at 450 nm was determined spectrophotometrically (Shimadzu UV 160A, CO, Kyoto, Japan). Fatty acid composition of the phospholipid fraction of the meat was determined as described by Malau-Aduli *et al* (1995).

Statistical analyses. Least squares analysis of variance was carried out using Proc GLM (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 between the concentration of ß-carotene and various fatty acids.

Table 1. Means for ß-carotene concentration (µg/g meat) and fatty acid composition (standardised % of total fat) in the phospholipid fraction of the *Longissimus dorsi* in 15 Jersey and 15 Limousin cows.

Component	A Breed				B Season			
	Jerseys	Limousins	SE	Sign.	April	November	SE	Sign.
ß-carotene	0.47	0.26	0.02	***	0.27	0.46	0.02	***
14:0	1.6	1.4	0.22	ns	0.4	2.6	0.22	***
16:0	20.8	20.2	0.73	ns	18.5	22.5	0.73	***
16:1	3.9	2.9	0.20	***	2.7	4.1	0.20	***
18:0	10.4	10.8	0.37	ns	11.2	10.0	0.37	*
18:1 (ω-9)	31.6	26.5	1.02	***	26.7	31.4	1.0	***
18:1 (ω-7)	2.6	2.0	0.29	ns	1.6	3.0	0.29	**
18:2	4.7	7.5	0.32	***	8.2	3.9	0.32	***
18:3 (ω-6)	1.5	1.5	0.30	ns	0.2	2.9	0.3	***
20:3 (ω-6)	1.0	1.3	0.21	ns	1.5	0.8	0.21	*
20:4	4.1	5.7	0.39	**	7.3	2.5	0.39	***
20:5	2.2	2.8	0.27	ns	3.1	1.8	0.27	**
24:0	2.4	2.9	0.31	ns	3.7	1.6	0.31	***
24:1	0.2	0.7	0.14	**	0.1	0.8	0.14	***
MUFA	41.4	33.7	1.14	***	33.5	41.5	1.14	***
PUFA	16.5	22.5	1.36	**	22.6	16.4	1.4	**

Note: ***P<0.001, **P<0.01, *P<0.05, ns-not significance, MUFA=monounsaturated fatty acids [16:1 + 18:1(ω-9) + 18:1(ω-7) + 20:1 + 24:1], PUFA=polyunsaturated fatty acids [18:2 + 18:3(ω-6) + 20:3(ω-6) + 20:4 + 20:5 + 22:5 + 22:6]. All fatty acids are expressed as a proportion of total fatty acids. Because minor fatty acids (17:0, 20:0, 20:1, 22:0, 22:5, 22:6) are not included in the Table so their proportions do not equal 100%.

RESULTS

ß-Carotene, breed and season. The Jersey cows had higher concentrations of ß-carotene than the Limousin cows (0.47 µg/g meat vs 0.26 µg/g meat respectively, Table 1A). There was a higher concentration of ß-carotene in the muscle of the Jersey cows in both seasons, even though there was a highly significant difference between the seasons. In April, the concentration of ß-carotene was lower than in November (0.27 µg/g meat vs 0.46 µg/g meat respectively, Table 1B). The lack of breed by season interaction indicates that both breeds were affected in a similar manner.

Table 2. Correlations between ß-carotene content in the *Longissimus dorsi* and phospholipid fatty acid composition in 15 Jersey and 15 Limousin cows.

Fatty acids	Correlation with ß-carotene concentration	Significance
16:1	- 0.27	*
18:0	0.29	*
20:4	- 0.25	*
24:1	- 0.35	**

Note: definitions as for Table 1.

Table 3. Breed by season interactions between phospholipid fatty acids from Jersey and Limousin cows sampled in April and November.

Fatty acid	Season	Jerseys	Limousins	Sign.	Season	Jerseys	Limousins	Sign.
18:2	A	6.3 ± 0.46	10.1 ± 0.46	***	N	3.1 ± 0.46	4.8 ± 0.46	**
18:3(ω-3)	A	0.9 ± 0.33	2.2 ± 0.33	**	N	1.6 ± 0.33	1.5 ± 0.33	ns
20:4	A	5.8 ± 0.55	8.9± 0.55	***	N	2.5 ± 0.55	2.5 ± 0.55	ns
24:1	A	0.15 ± 0.20	0.0 ± 0.20	ns	N	0.16 ± 0.20	1.4 ± 0.20	***
PUFA	A	17.5 ± 1.92	27.6 ± 1.92	***	N	15.3 ± 1.92	17.4 ± 1.92	ns

Note. A - April, N -November, other definitions as for Table 1.

Fatty acids, breed and season. The composition of phospholipid fatty acids (Table 1) in the meat of the Jersey and the Limousin cows was in the range of that reported in other studies (Malau-Aduli *et al* 1995, Siebert *et al* 1996) (Table 1). The most abundant fatty acid was oleic acid (18:1, ω-9) which accounted for about 30% of the total phospholipid fatty acids. This was followed by palmitic acid (16:0) at 20% of the total, and stearic acid (18:0) at 10% of the total phospholipid fatty acids.

Large breed differences between the Jersey and the Limousin cows were observed in the concentration of monounsaturated fatty acids (41.4 vs 33.7% of total, respectively). There was a higher concentration in the Jersey cows of oleic acid (18:1 ω-9) (31.6 vs 26.5 %, respectively), and palmitoleic acid (16:1), (3.9 vs 2.9 %, respectively) and a lower concentration of nervonic acid (24:1) (0.15 vs 0.71 %, respectively).

The polyunsaturated fatty acids (PUFAs) also differed between these two breeds (16.5% of total in Jerseys vs 22.5% of total in Limousins). The two major PUFAs, linoleic acid (18:2) and arachidonic acid (20:4), appeared in higher concentrations in the Limousin cows (4.7 % of total in the Jerseys vs 7.5 % of total in the Limousins, and 4.1% of total in Jerseys vs 5.7 % of total in the Limousins, respectively).

Season had a large effect on the composition of all fatty acids measured (Table 1B). All monounsaturated fatty acids appeared at a higher concentration in November (41.5%) than in April (33.5%). The saturated fatty acids 14:0 and 16:0 similarily were higher in November than in April. However, the 18:0 and 24:0 fatty acids were the reverse of this pattern.

Fatty acids and breed by season interaction. Season had an impact not only on all fatty acids studied, but also influenced the two breeds differently. Significant breed by season interactions were observed in the percentage of PUFAs. The Limousin cows had a higher percentage of PUFAs in April than the Jersey cows (27.6% vs 17.5%, respectively, $P<0.001$) (Table 3). However, there was not significance difference between the two breeds for the PUFAs in November.

DISCUSSION

Jersey and Limousin cattle are diverse in a number of traits (Pitchford *et al* 1996).They differ in fatty acid and ß-carotene composition in the adipose tissue (Kruk *et al* 1997). Our study has shown that Jersey cows had a higher content of ß-carotene in the *Longissimus dorsi* in both seasons. This suggests breed differences in absorption and/or deposition of ß-carotene in the Jersey and Limousin meat. An alternative explanation could be that there are differences in intramuscular fat content. We have found that in young, grain fed animals, the Jersey has a higher intramuscular fat content than Limousin (unpublished data).

The breed and seasonal changes in ß-carotene content and fatty acid profiles of meat phospholipids in cattle have shown that there is a metabolic interplay between these components in this tissue. This interplay might be expected since ß-carotene as an antioxidant should protect the unsaturated fatty acids in the cell membranes. However, the correlations between ß-carotene and 16:1, 20:4, 24:1 were negative.

A high concentration of ß-carotene causes yellow colouration of subcutaneous fat. This is considered to be undesirable by the consumers. There were no significant differences in the concentration of ß-carotene in the adipose tissue between seasons (Kruk *et al* 1997). The observed seasonal differences in the concentration of ß-carotene in meat suggest that changes occur more quickly in the muscle than compared to adipose tissue. The excessive amount of this pigment in the meat of cattle associated with high marbling scores can cause downgrading of such carcasses and a significant loss for the meat industry.

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