THE COMPOSITION AND OXIDATIVE STABILITY OF LIPIDS IN LONGISSIMUS MUSCLE FROM GRAZING CATTLE SUPPLEMENTED WITH SUNFLOWER OIL OR LINSEED OIL

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Background

Manipulation of ruminant ration composition has been employed to enhance the concentrations of conjugated linoleic acid (CLA) and omega-3 polyunsaturated fatty acids (PUFA) in milk and meat. Compared with conventional indoor rations, consumption of grass, rich in n-3 PUFA, led to an improvement in the fatty acid profile of beef, by increasing PUFA and CLA concentrations, decreasing the n-6:n-3 PUFA ratio and decreasing the saturated fatty acid concentration (French et al., 2000). Enrichment of concentrate rations with plant oils, such as linseed oil or sunflower oil, also resulted in an increase in the concentration of CLA in bovine muscle (Enser et al., 1999, Noci et al., 2002). No information is available on the efficacy of such supplementation strategies for grazing beef cattle.

Strategies that improve the fatty acid composition must not impair other quality characteristics of beef. Appearance, specifically colour, is an important quality attribute influencing the consumer's decision to purchase. Increasing the PUFA concentration *per se* and/or increasing the concentration of longer carbon chain PUFA, predispose lipids to oxidation (Rey et al., 2001). Lipid oxidation is believed to be linked to muscle pigment oxidation and consequently to colour stability (O'Grady et al., 2001).

Objectives

The first objective of this study was to investigate the effect of plant oil supplementation of grazing cattle on the fatty acid profile of muscle, in particular the n-3 PUFA and CLA concentrations. The second objective was to determine the effect of alterations in the fatty acid composition on colour and lipid stability of beef.

Materials and methods

Forty-five Charolais crossbred heifers (mean initial bodyweight = 330 kg, s.d. 39.90) were blocked by initial bodyweight and, within block, randomly assigned to one of three dietary treatments (n = 15): unsupplemented grazing (GO); restricted grazing plus 2 kg/head/day of linseed oil-enriched meal (LO) or restricted grazing plus 2 kg/head/day of sunflower oil-enriched meal (SO). Concentrate and grass allowances were monitored at three-week intervals during a 5-month experimental period to achieve similar carcass weights across the treatments. Animals were slaughtered at a commercial facility, carcasses were chilled for 48 h at 4^{o}C, and the *M. Longissimus dorsi* (LD) was excised from each carcass. Intramuscular fat was extracted from muscle samples using chloroform and methanol (2:1 v/v), methylated at 50^{o}C for 20 minutes in alkaline and then acidic conditions and the fatty acid methyl esters obtained were analysed by gas chromatography (Supelcowax 100 m CP-Sil 88, Varian 3800). Vitamin E concentrations were measured as described by O'Sullivan et al. (2003).

Samples of LD collected 48h *post mortem* were vacuum packaged and stored at 4^{o}C for a further 24h prior to analysis. Samples were cut into steaks (25.4 mm thickness) and placed in retail display trays. Trays were over-wrapped with oxygen permeable film for aerobic storage or flushed with 80% O_2: 20% CO_2 for storage under modified atmosphere conditions. All samples were stored for up to 10 days at 4^{o}C under simulated retailed display conditions (616 lux fluorescent lighting). Colour measurements were made at 2 day intervals using a Cr-300 Chromameter (Minolta Co. Ltd., Japan) set on the CIE colour scale and reported as the 'a' redness value. Lipid oxidation was measured by the distillation method of Tarladgis et al. (1960) as modified by Ke et al. (1977) and results were expressed as 2-thiobarbituric acid reactive

substances (TBARS) in mg malondialdehyde/kg muscle. The data were analysed as a randomized block design using Genstat 6.0.

Results and discussion

Fatty acid data are summarised in Table 1. In general, the fatty acid composition of GO-fed cattle was similar to that previously reported by French et al. (2000). Compared to GO, SO-fed cattle had a higher concentration of C18:1 trans-11, C18:2, cis 9, trans-11 CLA, C20:4, total PUFA and n-6 PUFA but a lower concentration of C12:0, C18:3 and C22:5 and higher P:S and n-6:n-3 PUFA ratios. Compared to GO, LO-fed cattle had a higher concentration of C18:1 trans-11, cis 9, trans-11 CLA and n-3 PUFA and n-6:n-3 ratio but a lower concentration of C12:0, C20:4, C22:5 and C22:6. Compared to LO, SO-fed cattle had a higher concentration of C18:1 trans-11, C18:2, cis 9, trans 11 CLA, C20:4, C22:6 and n-6 PUFA, a lower concentration of C18:3 and a higher n-6:n-3 ratio.

Table 1. Fatty acid and Vitamin E concentrations in *M. Longissimus dorsi* from grazing cattle, either unsupplemented (GO) or supplemented with sunflower oil (SO) or linseed oil (LO)

Fatty acids (mg/100 g muscle)	GO	SO	LO	s.e.d.	Significance[1]
C12:0	1.52b	0.88a	0.88a	0.157	***
C14:0	53.36	47.77	49.81	6.926	NS
C16:0	542.2	520.1	525.6	69.23	NS
C18:0	435.6	431.6	406.1	56.45	NS
C18:1 cis-9	843.0	847.1	780.1	125.3	NS
C18:1 trans-11	76.63^{a}	227.0^{c}	157.8^{b}	24.60	***
C18:2n6 cis	58.80^{a}	78.39^{b}	62.50^{a}	4.816	***
CLA c9,t11	18.37^{a}	47.43^{c}	32.00^{b}	5.976	***
CLA t10, c12	1.73	0.93	1.51	0.479	NS
C18:3n3	34.34^{b}	22.14^{a}	31.72^{b}	2.929	***
C20:4n6	11.75^{a}	12.47^{c}	9.57^{b}	0.803	***
C20:5n3	7.63	6.40	6.40	0.561	0.06
C22:5n3	12.69^{b}	10.40^{a}	9.69^{a}	0.688	***
C22:6n3	2.71^{b}	2.34^{b}	1.65^{a}	0.269	**
SFA[2]	1089	1058	1037	134.5	NS
MUFA[2]	1032	1186	1037	143.3	NS
PUFA[2]	158.0^{a}	203.0^{b}	181.1^{ab}	14.93	*
P:S Ratio	0.15^{a}	0.21^{b}	0.18^{ab}	0.015	**
n-6 PUFA[2]	86.92^{a}	106.5^{c}	92.51^{c}	6.405	***
n-3 PUFA[2]	59.49	48.18	55.03	4.725	0.07
n-6:n-3 Ratio	1.46^{a}	2.24^{c}	1.72^{b}	0.096	***
Total fatty acids	2513	2688	2513	329.1	NS
Vitamin E (ug/g)	2.70^{a}	3.16^{b}	1.99^{c}	0.224	**

[1]NS = not significant; *,** and *** = P<0.05, P<0.01 and P<0.001, respectively; [2]SFA=total saturated fatty acids; MUFA = total monounsaturated fatty acids; PUFA = total polyunsaturated fatty acids; n-6 PUFA = sum of C18:2, C18:3n-6, C20:2, C20:3n-6, C20:4 and C22:2; n-3 PUFA = sum of C18:3n-3, C20:3n-3, C20:5, C22:5 and C22:6.

Vitamin E concentration was lowest in LO-fed cattle and highest in SO-fed cattle (Table 1). Since similar amounts were supplied by the concentrates this suggests greater metabolism and a possible greater requirement for Vitamin E in the diet that supplied the greatest amount of n-3 PUFA.

There was no effect of diet on colour stability of beef (Table 2). Muscle lipids tended to be more susceptible to oxidation in MAP (higher TBARS) than in aerobic packaging with muscle from SO-fed animals more stable than LO-fed animals (Table 2). Muscles from LO-fed animals had lower lipid stability compared to GO-fed animals on day 2 and 6 of display in MAP.

Table 2. Surface redness ('a' value) and lipid oxidation (TBARS) in *M. longissimus dorsi* from grazing cattle either unsupplemented (GO) or supplemented with sunflower oil (SO) or linseed oil (LO) stored in aerobic or in modified atmosphere packs (MAP).

		Storage Time (days)					
	Packaging	0	2	4	6	8	10
Redness							
GO	Aerobic	17.99	13.46	9.36	8.10	8.83	8.74
SO	Aerobic	17.79	12.78	10.11	8.63	9.15	9.13
LO	Aerobic	18.53	13.23	9.87	7.61	7.97	8.79
s.e.d.		1.067	0.900	0.639	0.528	0.551	0.607
Significance[1]		NS	NS	NS	NS	NS	NS
GO	MAP	17.99	17.33	14.84	13.03	10.20	9.09
SO	MAP	17.79	17.45	15.41	12.56	10.63	8.52
LO	MAP	18.53	18.30	16.56	14.60	10.81	9.50
s.e.d.		1.067	0.703	0.960	1.351	0.973	1.004
Significance[1]		NS	NS	NS	NS	NS	NS
Lipid oxidation							
GO	Aerobic	0.83	0.82	0.46^{b}	0.39^{a}	0.65^{b}	0.86^{b}
SO	Aerobic	0.37	0.37	0.26^{a}	0.28^{a}	0.31^{a}	0.41^{a}
LO	Aerobic	0.52	0.67	0.27^{a}	0.62^{b}	0.63^{b}	1.01^{b}
s.e.d.		0.200	0.258	0.088	0.065	0.135	0.169
Significance[1]		NS	NS	*	**	*	**
GO	MAP	0.83	0.77^{a}	1.27^{b}	0.97^{a}	3.14	4.83^{b}
SO	MAP	0.37	0.58^{a}	0.53^{a}	0.80^{a}	2.37	3.05^{a}
LO	MAP	0.52	1.16^{b}	0.93^{b}	1.82^{b}	3.48	4.82^{b}
s.e.d.		0.200	0.122	0.215	0.430	0.571	0.654
Significance[1]		NS	**	**	*	NS	*

[1]NS = not significant, * and ** = P<0.05 and P<0.01, respectively. Within packaging type and day, means with a common superscript do not differ significantly.

Conclusions

Supplementing grazing animals with plant oil-enriched concentrates resulted in a further beneficial effect on the fatty acid composition of muscle compared to grazing alone. Sunflower oil was more effective than linseed oil in increasing the concentration of CLA and TVA, but had a negative effect on the n-6:n-3 PUFA ratio. Linseed oil had a less pronounced effect on the CLA concentration than sunflower oil, but it also had a less negative effect on the n-6:n-3 PUFA ratio. While linseed oil supplementation caused a transient increase in lipid oxidation, this was not reflected in a loss in colour stability.

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