The quality of beef from steers fed supplements of *n*-3 polyunsaturated fatty acids

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Introduction. Ruminant meat and meat products have become increasingly targeted in recent years as main contributors to excess saturated fat in the diet. The fatty acid composition of human dietary fat has been linked to cardiovascular and other life style diseases (Department of Health, 1994). Clinical research has demonstrated that the long chain polyunsaturated fatty acids (PUFA) of fish oil (20:5*n*-3, eicosapentaenoic acid and 22:6*n*-3, decosahexaenoic acid) are effective in reducing the risk of coronary heart disease as they are antithrombotic (Barlow *et al.,* 1990). Current recommendations are that the ratio of the PUFA to saturated fatty acids should be around 0.45 and intakes of *n*-3 PUFA should be increased relative to *n*-6 to bring the ratio below 4.0 (Department of Health, 1994). However, lean ruminant meat, particularly from animals reared on a forage-based system, can make a valuable contribution to *n*-3 PUFA in the human diet (Enser *et al.,* 1996). Enhancing the levels of these fatty acids would help to make the product more attractive to consumers and thus combat its negative image. However, increasing PUFA can compromise oxidative stability, resulting in undesirable flavour and colour changes, especially in processed meat (Monahan, 1995).

This study examined the effect of feeding differing sources of PUFA in the diet on the fatty acid composition, eating quality, colour and oxidative stability of steaked and minced beef.

Material and Methods. Thirty two Charolais-cross steers were divided into four treatment groups and fed *ad libitum* on grass silage and one of four concentrates (forage:concentrates 60:40 on a DM basis). Concentrates were based on barley, molassed sugar beet and one of four fat sources: Megalac (palm oil, 16:0, C), lightly bruised whole linseed (18:3*n*-3, L), fish oil (20:5*n*-3 and 22:6*n*-3, FO) and linseed plus fish oil in equal amounts (LFO). The diets all contained vitamin E at 345 IU/kg concentrate. Animals were reared at IGER and transferred to the University of Bristol where they were conventionally slaughtered and chilled. At 48 h post-mortem *Longissimus thoracic et lumborum* (LTL) was removed from each animal and aged 10 days in vacuum pack at 1°C. This was then cut into steaks and over-wrapped (OW) in oxygen permeable film and displayed at 4°C under 1000 Lux illumination. Colour was measured daily with a Minolta Chromameter to obtain CIELAB L*, a*, b* colour space values. On days 4, 8 and 11 of display OW steak samples were measured for lipid oxidation by the thiobarbituric acid (TBA) test (Tarladgis et al., 1960). Sensory assessment was performed on 10 day aged steaks grilled to an internal temperature of 74°C which were rated, using 100mm unstructured line scales, from nil to extreme, for beef flavour intensity, fatty/greasy, blood, livery, metallic, bitter, sweet, rancid, fishy, acidic, cardboard, vegetable and hedonic overall liking.

Three forequarter muscles: *Triceps brachii*, *Infraspinatus* and*Supraspinatus*, were also removed at 48h post-mortem, trimmed of excess fat, demembraned and then vacuum packed and stored overnight at 1°C. Muscles were minced and shaped into 200g burgers and packed in modified atmosphere (MAP) (O_2:CO_2, 75:25) and displayed (4°C, 1000 Lux). Colour was measured daily. After 3 and 10 days of display, MAP samples were taken and placed in a vacuum bag, cooked at 80°C to 78°C centre temperature and then stored at 1°C for 24h before measuring lipid oxidation by the TBA test. Extra steak and mince samples were vacuum packed, frozen and later analysed for vitamin E by HPLC and lipid fatty acid composition by GLC.

Results. Fatty acid analysis (Table 1) showed that supplementation with linseed doubled the concentration of 18:3*n*-3 in total lipid and phospholipids. There was also a significant increase in 20:5*n*-3 in both fractions but not in 22:6. Feeding the two *n*-3 PUFAS in fish oil doubled thier concentration in both lipid fractions and basal levels were higher in phospholipids. There was an indication that the LFO diet enhanced 22:6 synthesis. Saturated fatty acid concentrations also increased when the *n*-3 PUFA were fed, presumably because of increased ruminal biohydrogenation.

The steaks and mince samples from animals fed the FO diet had significantly higher TBA values than those fed the other fat sources (Figures 1 and 2) and greater colour deterioration (Figures 3 and 4). The vitamin E concentrations in steak samples from FO and LFO supplemented animals were significantly lower ($p<0.05$) than in the controls but not significantly lower than in animals fed L (2.89, 2.94, 3.73 & 3.36 mg/kg for F, LFO, C and L respectively). Samples of mince from fish oil supplemented animals had significantly ($p<0.05$) lower vitamin E concentrations than control animals (5.34 & 6.49 mg/kg respectively).

Of the flavour descriptors, only rancid and fishy showed significance differences with meat from steers fed FO having higher scores. However, overall scores were low and overall liking was similar for C and FO supplemented animals although steaks from L fed animals were preferred.

Conclusion. Linseed not only enhanced the levels of 18:3*n*-3 in muscle, but also stimulated chain elongation, resulting in increased 20:5*n*-3 from 18:3*n*-3. FO increased the C_{20} PUFA, 20:5*n*-3 and 22:6*n*-3 and the concentrations and proportions of these fatty acids are similar to those quoted by Mandell *et al.,* (1997). The colour and oxidative stability of steaks and mince from steers fed FO was decreased but L had no deleterious effects. There was evidence that high long chain PUFA levels led to vitamin E depletion through increased oxidation.

Feeding additional 18:3 to steers improved the overall liking of LTL steaks. However, further studies are needed to define the interrelationships between sensory flavour score and the fatty acids of specific lipid classes. The P:S ratios in supplemented cattle were lower than those recommended, and lower than reported for typical retail beef in the UK (Enser *et al.*, 1996). This suggests that greater 'protection' of PUFA sources is required than that provided here. In contrast, the *n*-6 :*n*-3 ratio was beneficially closer to the recommended value for man.

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Table 1. Fatty acid composition of total fat in LTL muscle and of phospholipids in minced forequarter muscle from steers fed diets containing different fat sources (n=8).

Fatty acid	LTL Steak total lipid						Mince phospholipid					
	Control	Linseed	Fish oil	Mixture	s.e.m	P<	Control	Linseed	Fish Oil	Mixture	s.e.m	P<
	(mg/100g muscle)						(mg/100g muscle)					
12:0 lauric	3.20	3.79	3.70	4.36	0.56	NS	0.2	0.2	0.3	0.2	0.05	NS
14:0 myristic	121	152	173	169	24.0	NS	2.5	2.6	5.3	2.9	0.9	0.01
16:0 palmitic	1029	1089	1305	1171	145.7	NS	84.7	71.2	98.9	72.5	6.6	0.001
16:1 *cis*	129	162	176	165	20.5	NS	14.2	12.3	16.9	12.9	1.3	0.01
18:0 stearic	528	581	543	490	73.5	NS	62.6	62.1	61.7	55.8	2.6	NS
18:1 *trans*	63	147	184	173	23.5	0.01	3.4	8.1	13.9	10.1	1.3	0.001
18:1 *n*-9 oleic	1209	1471	1260	1225	197.3	NS	134	122	115	109	9.1	NS
18:1 *n*-7 vaccenic	35	42	46	36	5.4	NS	9.3	10.0	14.5	11.9	0.9	0.001
18:2*n*-6 linoleic	81	78	66	64	6.5	NS	68.9	57.7	45.4	50.4	4.3	0.001
18:3*n*-3 α-linolenic	22	43	26	30	4.0	0.01	10.9	22.8	13.0	16.4	1.5	0.001
20:3*n*-6	7.8	5.9	4.9	4.2	0.4	0.001	10.1	7.0	6.4	6.0	0.7	0.001
20:4*n*-6 arachidonic	23	21	14	17	1.1	0.001	34.4	26.6	18.4	22.1	1.9	0.001
20:5*n*-3 eicosapentaenoic	11	16	23	15	1.3	0.001	14.2	19.0	30.3	21.8	2.2	0.001
22:5*n*-3 docosapentaenoic	20	21	24	21	1.5	NS	28.1	28.0	33.4	28.7	1.8	NS
22:6*n*-3 docosahexaenoic	2.2	2.4	4.6	4.9	0.4	0.001	4.2	4.3	7.9	8.9	0.7	0.001
Total fatty acids	3529	4222	4292	3973	524.0	NS	583	559	682	544	31.7	NS
P:S	0.061	0.067	0.045	0.051								
n-6 / *n*-3	2.03	1.27	1.09	1.20								

P:S $(18:2n\text{-}6 + 18:3n\text{-}3) : (12:0 + 14:0 + 16:0 + 18:0)$

n-6 / n-3 $\dfrac{18:2n\text{-}6 + 20:3n\text{-}6 + 20:4n\text{-}6}{18:3n\text{-}3 + 20:5n\text{-}3 + 22:5n\text{-}3 + 22:6n\text{-}3}$

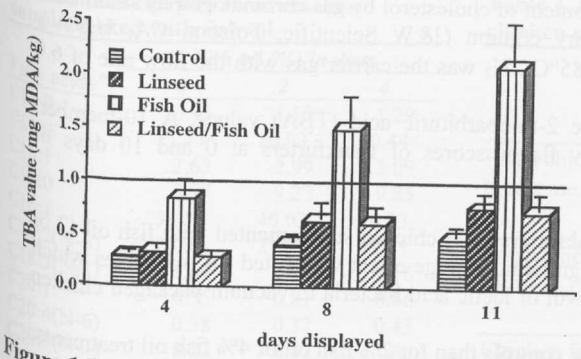

Figure 1 The effect of time displayed upon mean TBA value of overwrapped beef steaks from animals fed different fat sources

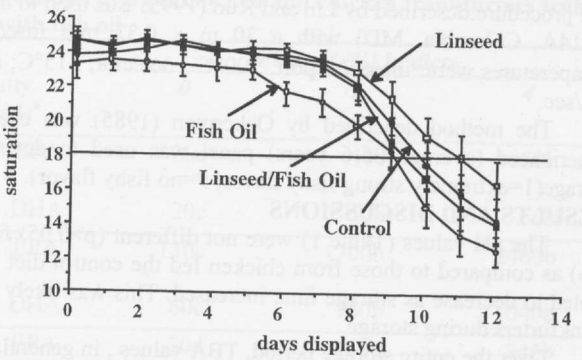

Figure 3. The effect of time displayed upon mean saturation of overwrapped beef steaks from animals fed different fat sources

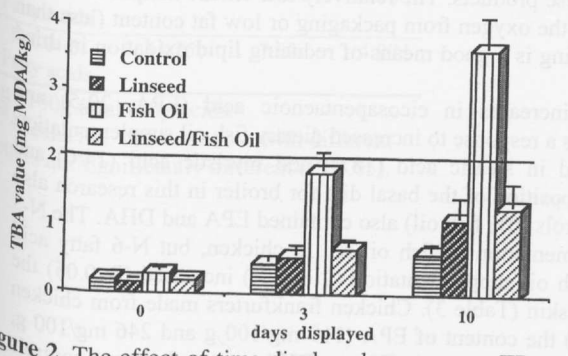

Figure 2. The effect of time displayed upon mean TBA value of cooked MAP mince from animals fed different fat sources

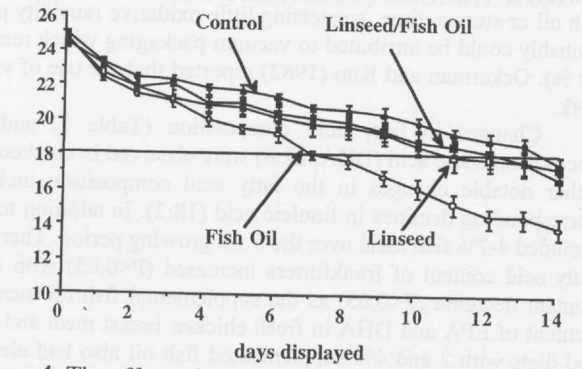

Figure 4. The effect of time displayed upon mean saturation of MAP minced beef from animals fed different fat sources