Effect of dietary unsaturated fats on fatty acid composition, flavour, oxidative and colour stability of sheepmeat

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Introduction. It is well established that the amount and composition of fat in the human diet has implications for health. Diets high in saturated fatty acids have been associated with an increased risk of cardiovascular disease (Department of Health, 1994). Substituting dietary saturated fatty acids with polyunsaturated fatty acids (PUFA) can reduce this risk. Longer-chain PUFA of the *n*-3 family, particularly 20:5*n*-3 (EPA) and 22:6*n*-3 (DHA), are considered to be particularly effective at reducing the morbidity of a number of diseases, not only cardiovascular disease.

Meat products can be brought more closely into line with modern nutritional guidelines by modifying the animal's diet although this is more difficult with ruminants in which dietary PUFAs are hydrogenated in the rumen. However, PUFAs in some oilseeds may be naturally "protected" because of the seed coat and fish oil EPA and DHA are possibly more resistant to rumen breakdown than other PUFA (Ashes et al., 1992). There is also the possibility that high levels of PUFAs in meat will increase its susceptibility to oxidative changes such as lipid rancidity and colour deterioration (Wood and Enser, 1997). Changing fat composition and fat oxidation can also affect flavour. This research investigated the associations between dietary fatty acids, their uptake into tissues and the effects on shelf life and flavour in sheep from three different breeds.

Materials and Methods. Seventy two entire ram lambs of three genotypes were used in a completely randomised 3x4 factorial design: SuffolkxLleyn, FrieslandxLleyn and Soay with an initial average live weight of 24, 12 and 26kg respectively, were individually penned and randomly allocated to one of four diets which were offerd *ad libitum*. The diets, based on dried grass, were isonotrogenous, isoenergetic and formulated to provide 50g fat/kg DM. The control fat was megalac, high in saturated fatty acids. The whole linseed diet was high in 18:3*n*-3 (L) and the fish oil diet was high in 20:5*n*-3 (EPA) and 22:6*n*-3 (DHA) (FO). The fourth diet was a mixture of fish oil and linseed (50:50) (LFO) in EPA and DHA. Vitamin E was included in all diets at 200IU/kg. Animals were slaughtered conventionally when they had attained half their mature breed live weight. At 24h post-slaughter, 4x10mm steaks were cut from the hind leg, vacuum packed and half aged for 6 and half for 10 days at 1°C then repacked in a modified atmosphere (O_2:CO_2,75:25) and displayed at 4°C, 1000 Lux illumination for 7 days. *Semimembranosus*(SM), *Gluteobiceps* (GB) and *Semitendinosus* (ST) colour was measured daily using CIELAB L*, a*, b* colour space and lipid oxidation was determined as TBA values (thiobarbituric acid reacting substances) (Vyncke, 1975) at the end of display. The loins (*longissimus*) were removed on the bone, vacuum packed and aged for 10d then frozen. Band sawn loin chops were thawed overnight and used for sensory assessment, after grilling to an internal temperature of 74°C. Samples were rated using 100mm unstructured line scales by a 10 member trained taste panel. Extra loin muscle samples were vacuum packed, frozen and later analysed for vitamin E by HPLC and lipid fatty acid composition by GLC.

Results. Total muscle fatty acid content ranged between 2.4-2.8% of tissue weight with no significant difference between treatments or breeds. There were some differences between breeds in their responses to the diets. Soay on the control diet were significantly different to Friesland and Suffolks which is possibly due to increased PUFA deposition in Soay carcasses and muscle. Figures 1 and 2 show the *n*-3 PUFAs in the SM muscle of Friesland and Soay sheep respectively. The L diet raised the 18:3 level by 2x in both breeds, the basal (C) level being higher in Soay. FO raised EPA by 2-4x and DHA by 3x in both breeds, the control levels again being higher in Soay. In both breeds feeding the L diet, high in 18:3, also increased concentrations of EPA with a smaller effect on DHA. The PUFAs to saturated fatty acids ratios (18:2*n*-6+18:3*n*-3:12:0+14:0+16:0+18:0, P:S) and 18:2*n*-6:18:3*n*-3 fatty acids averaged across breeds were 0.18, 0.23, 0.14, 0.17 and 3.5, 1.4, 2.7, 1.87 for C, L, F and LFO respectively. These results show that the L and FO diets reduced the *n*-6:*n*-3 ratio, which is desirable but did not significantly increase the important P:S ratio. Presumably, although PUFA uptake was increased, significant biohydrogenation of dietary PUFAs also occured leading to even greater uptake and deposition of saturated fatty acids.

Results averaged over breeds for lipid oxidation are shown in Figure 3. The SM muscle was the least stable as indicated by the TBA results with the ST and GB being similar. The FO diet increased the oxidative breakdown of fatty acids (higher TBA values) compared with the other diets with few differences between the other diets. In all muscles, TBA values were lower for the L than the C diet and samples aged for 10 days had higher TBA values than those aged for 6 days.

Colour brightness (saturation) declined as display time increased in all 3 breeds. In Suffolks and Soays (but not in Frieslands) the decline was faster in the FO samples (Figure 4), suggesting increased myoglobin oxidation in these more unsaturated samples. Colour measurement results showed that the SM muscle is the least stable in colour as well as in lipid stability, with GB and ST showing similar deterioration in colour over the six day display period.

There were some clear effects of diets on flavour descriptors (Table 1) although for others the trends were non significant because of a breed effect. Overall the animals fed FO had low lamb flavour, high fatty/greasy and high fishy scores compared with the other groups. Soays produced meat which had low lamb flavour and higher abnormal flavour, livery, metallic and bitter scores compared with the other two breeds. Suffolks tended to have the best flavour and overall liking scores.

Conclusions. Each fat source increased the level of its particular PUFA in muscle, i.e. L increased 18:3 and FO EPA and DHA with LFO intermediate between these two. Feeding L also increased EPA and DHA deposition presumably via synthesis from 18:3. PUFA supplements did not increase the P:S ratio in muscle. There were no significant deleterious effects of feeding L on meat quality. However, feeding FO increased lipid oxidation during retail display and tended to increase colour deterioration. There was also some indication of poorer flavour.

There was a marked breed effect on many of the results with Soays responding less to PUFA supplementation and having unusual flavour characteristics.

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Table 1. Eating quality attributes of lamb loin chops as affected by diet and breed

Attributes	Control	Linseed	Fish oil	Linseed+Fish oil	sig.	Suffolk	Soay	Friesland	sig.
Toughness	32.7	32.9	26.4	29.0	ns	32.9[b]	25.7[a]	32.1[b]	*
Juiciness	28.5[a]	28.5[a]	33.4[b]	32.9[b]	***	32.7[b]	29.0[a]	30.7[b]	**
Lamb Flavour	19.9[a]	23.8[b]	20.7[a]	22.1[ab]	*	24.8[b]	18.8[a]	21.3[a]	***
Abnormal Lamb Flavour	36.1	32.3	38.7	33.9	ns	30.4[a]	38.7[b]	36.6[b]	*
Fatty/Greasy	21.2[a]	23.6[ab]	28.2[c]	25.4[b]	***	24.6[ab]	23.1[a]	26.0[b]	*
Livery	17.5	15.2	15.4	16.4	ns	12.6[a]	23.4[b]	12.4[a]	***
Sweet	11.2	10.2	11.0	9.5	ns	11.4	9.6	10.3	ns
Acidic	8.7	7.9	8.1	7.8	ns	7.5	8.8	8.1	ns
Metallic	12.4[b]	11.4[ab]	12.5[b]	9.1[a]	*	9.7[a]	13.3[b]	11.1[ab]	**
Bitter	13.7	12.5	10.7	13.1	ns	10.2[a]	15.2[b]	12.1[a]	***
Stale	13.3	12.2	15.1	12.1	ns	12.0	12.8	14.8	ns
Rancid	12.5	10.8	14.8	10.8	ns	10.4	12.2	14.0	ns
Vegetable	7.2	8.0	7.5	7.2	ns	8.3[b]	8.0[b]	6.1[a]	*
Grassy	0.8	0.9	0.9	0.9	ns	1.2	0.5	0.9	ns
Fishy	1.6[a]	3.0[ab]	3.8[b]	2.1[a]	*	2.6	2.0	3.3	ns
Ammonia	3.9	4.7	4.1	3.2	ns	3.5	5.2	3.2	ns
Soapy	11.1	7.8	8.7	8.3	ns	7.7	9.1	10.1	ns
Overall liking	16.3	20.4	15.6	18.3	ns	19.5	15.8	17.6	ns

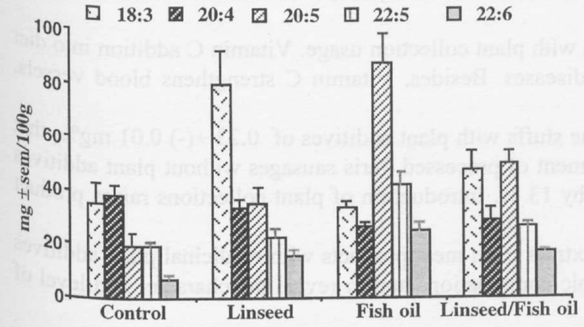

Figure 1. Content of selected PUFA in the SM of Friesland lambs fed different dietary fat

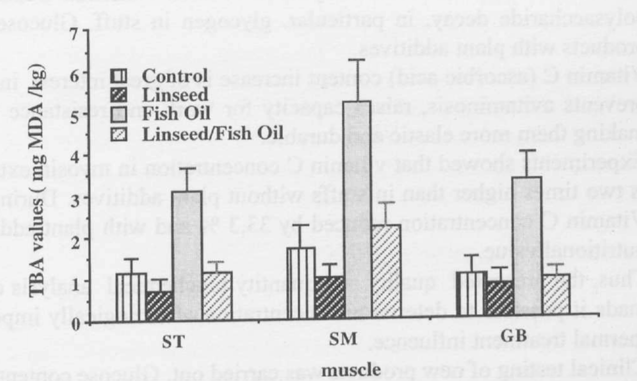

Figure 3. Mean TBA values across three breeds of sheep in ST, SM and GB muscles after 6d storage and 6d illuminated display

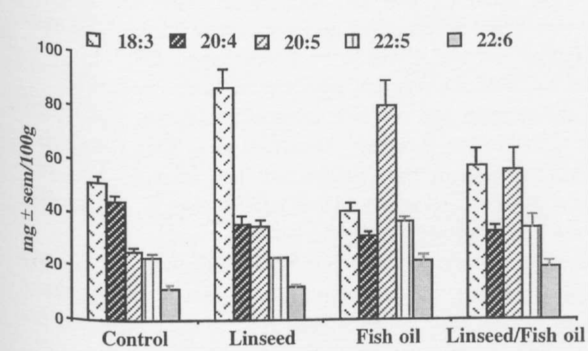

Figure 2. Content of selected PUFA in the SM of Soay lambs fed different dietary fat

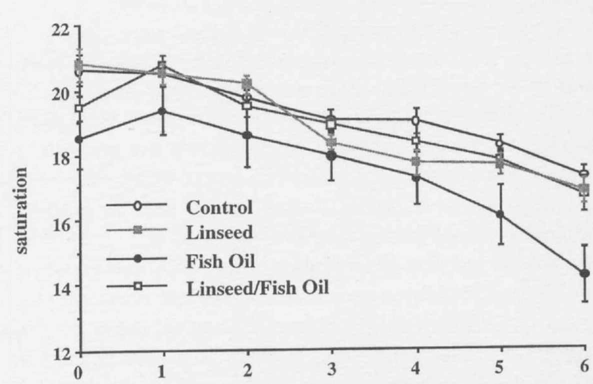

Figure 4. The effect of diet and display time on the colour saturation of Soay 10d aged SM muscle