Manipulation of omega-3 fatty acids in lamb meat for health conscious consumers

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INTRODUCTION

Meat plays a major role in human diet by contributing quality proteins, essential minerals and trace elements and a range of B vitamins. Apart from its nutritive value, meat has other important characteristics such as colour attractiveness, flavour properties and tenderness which are responsible for the eating quality of meat (Buckley et al., 1995). Lipid composition has been a primary area of consumer concern due to the link between the amount and composition of fat consumed and the development of human diseases, which has led professionals to recommend that people consume diets low in saturated fat, cholesterol and energy (Hargis and Van Elswyk, 1993). As a consequence, health conscious consumers have reduced the consumption of fats from animal products, particularly red meat. However, the consumption of omega-3 polyunsaturated fatty acids (PUFA) has been found to provide protection against heart disease, rheumatoid arthritis, cancer and some auto immune diseases in humans. This has led to the recommendation that human diet should also contain an increased level of omega-3 PUFA (Hargis and Van Elswyk, 1993; Van Oeckel et al., 1996).

Only fish, and to a lesser extent meat, contains a sufficient concentration of omega-3 PUFA to be a satisfactory dietary source of these nutrients. However, for many people meat is the only source of PUFA consumption, because fish consumption is often limited by seasonal availability, affordability or has a lower preference to meat. Increasing the omega-3 content of red meat could make a significant contribution to omega-3 PUFA consumption and provide an excellent alternative food source for those people consuming average amounts of red meat daily. This experiment was undertaken to investigate the potential for increasing omega-3 PUFA in lamb meat and its effect on meat quality through feeding isoenergetic amounts of fish meal (FM), canola meal (CM) and soy meal (SM).

MATERIALS AND METHODS

Animals and diet:

Thirty two 6 mo cross bred wether lambs (mean live weight 32.1kg) were randomly divided into four groups of 8. Lambs were randomly assigned to individual pens and housed indoors for seven weeks. After 7 days adaptation, the groups were assigned to one of the following treatments; 1) basal diet (BAS): 80:20 oaten chaff: lucerne chaff fed *ad libitum*; ii) BAS + isoenergetic amounts of FM (80g DM; 60-65% CP and 9.0-11 MJME/kg); iii) BAS + CM (84g DM; 40% CP and 9.8 MJME/kg); iv) BAS + SM (75g DM; 44% CP and 10.8 MJME/day). Water was freely available.

Sampling and measurements:

Daily feed intake and weekly live weight were measured throughout the experiment. At the end of feeding, half the lambs were fasted overnight and slaughtered at a commercial abattoir and the remaining lambs slaughtered one week later. Hot carcass weight (HCW) was measured at 45 minutes post mortem (PM) and carcasses chilled overnight. Fat depth at GR site was measured at 24h PM by an independent operator using AUSMEAT procedure. Carcasses were then cut into halves and the right sides retained and the longissimus muscle (includes *longissimus thoracis* (LT) and *longissimus lumborum* (LL)) along the midline was dissected out for meat colour, pH and fatty acid measurements. The longissimus muscle was then sliced into chops (1 cm thick), placed on a polystyrene tray, overwrapped with an oxygen permeable PVC wrap to evaluate the differences in surface colour by treatment. At 24h PM samples of LT were taken for total lipid, fatty acid composition and pH determination and stored at -70^{o}C until analysed. For surface colour analyses a* (redness), b* (yellowness) and L* (lightness) were recorded at 24h PM, using a minolta chromameter CR 300 (Minolta Corporation, Japan), calibrated with a white standard plate.

Muscle LT samples (10g) were individually homogenised and the intramuscular fat (IMF) was extracted by the method of Folch et al. (1957) using a chloroform: methanol mixture (2:1 v/v) containing 0.02% butylated hydroxy Toluene. Phospholipid (PL) and neutral lipids were separated by thin layer chromatography (TLC) on silica gel G plates (200X200X0.25 mm) using petroleum ether/diethyl ether/acetic acid 85:15:2 (v/v/v). Area of gel corresponding to PL were scraped off the plate and the lipid extracted. Fatty acid methyl esters were prepared and analysed by gas chromatography using a 50-m X .32-mm BPX70 fused slica capillary column. Fatty acids were identified by comparison of retention times with standard fatty acid methyl ester (FAME) mixtures.

Statistical analysis:

Data were analysed using the Minitab Statistical Package. General Linear Model (ANOVA) was used to test for significance of treatment effects and to calculate least significant difference values between the treatment means at the $P< 0.05$, $P< 0.01$ and $P< 0.001$ levels.

RESULTS

The effect of supplementing the diet with FM, CM and SM on colour, pH, lipid content and fatty acid composition are presented in Table 1. Muscle LT pH determined at 24h PM showed no differences among treatments and ranged from 5.70 to 5.77. Surface colour measurements of displayed longissimus muscle slices at 24h PM had similar a*, b* and L* values for all treatments. There was no significant differences observed for IMF content between BAS and supplemented lambs. When adjusted to initial live weight, lambs fed FM had larger ($P< 0.01$) HCW than the other treatment groups; HCW was 17.9, 20.1, 18.8 and 18.6 for BAS, FM, CM and SM, respectively. Total saturated fatty acid (SFA) concentration in the PL of muscle LT was significantly ($P< 0.05$) higher, and total PUFA concentration tended ($P< 0.1$) to be higher in SM fed lambs compared with the other treatments. Meat from all lambs had similar concentrations ($P> 0.1$) of omega-3 PUFA, but omega-6 PUFA was significantly higher ($P< 0.06$) in SM lambs compared with BAS, FM and CM. However, meat from FM fed lambs had a significantly ($P< 0.001$) greater ratio of omega-3 to omega-6 than the other treatments. Composition of PL in muscle LT samples showed a two-fold increase ($P< 0.01$) in docosahexaenoic acid (DHA, C 22:6n-3) for FM treatment compared with all other treatments. FM and SM fed lambs tended to have greater level of eicosapentaenoic acid (EPA, $P< 0.09$) in PL of LT samples than the CM and BAS lambs. C18:0, C18:1, C18:2, C18:3 and C20:4 in PL of muscle LT (Table 2) were similar for BAS, FM and CM lambs.

DISCUSSION

Feeding isoenergetic amounts of FM, CM and SM did not influence muscle pH in the LT measured at 24h PM compared with BAS lambs; values ranged from 5.70 to 5.77 for all treatments and were within the normally accepted range of 5.4-5.8 for domestic stock (Warner, 1988; Powell et al., 1996; Woodford et al., 1996). Measurements of a*, b* and L* values for surface colour of fresh meat (LT) was also not influenced by nutrition. Even though the lambs fed FM were larger and leaner, IMF content of LT muscle was not significantly changed by treatments, indicating that meat from these carcasses would have been of acceptable eating quality (juiciness, flavour and palatability) (Wood 1990).

Supplementary feeding had no significant effect on total SFA in muscle PL of LT with the exception of feeding SM. Lough et al. (1992) found no differences in the SFA content in longissimus muscle from lambs fed 6% whole canola seed and 4.9% deoiled soy lecithin and canola seed soy lecithin diet containing 70% forage and 30% concentrate. The increase in total SFA content with SM feeding was due to a significant increase ($P< 0.05$) in stearic acid (C18:0) and a tendency for increased palmitic acid (C16:0) levels in PL, which are the major saturated fatty acid composition of meat. In the present study, the tendency for increased level of linoleic acid ($P< 0.09$), linolenic acid ($P< 0.1$) and arachidonic acid ($P< 0.08$) with SM feeding only showed a tendency for increased level of PUFA content in PL of LT muscle than the other

treatments. Lough et al. (1992) found that, feeding lambs with soy lecithin increased ($P< 0.01$) the proportion of PUFA, but found no change in oleic acid concentration in lean tissue when compared to a basal roughage diet or roughage diet containing 6% canola seed or 6% canola seed plus 4.8% soy lecithin. The tendency for increased level of C18 carbon and C20:4 fatty acids in PL of meat from SM fed lambs compared with other treatments may be due to the effect of PL in SM, which was reported to be important in the emulsification of lipids and may escape the rumen and influence the absorption of fatty acids in small intestine (Lough et al., 1992).The reason for the slight increase ($P< 0.07$) in omega-6 PUFA with SM feeding compared to that on BAS, FM and CM diets was due to the slight increase in linoleic and arachidonic acid.

CM supplementation failed to increase the omega-3 PUFA level of meat, even though the level of C18:1, C18:2 and C18:3 were higher in CM than FM and SM. This may have been due to insufficient amounts of CM escaping ruminal reduction and fatty acid saturation to result in a significant increase in lipid absorption in the small intestine. The reason for increased levels of EPA and DHA in PL of meat from FM fed lambs compared with other treatments was not clear. It may be due to: i) increased levels of these fatty acids in FM which have escaped from ruminal degradation; ii) lack of specific enzymes to saturate long chain PUFA to other C18 carbon fatty acids in the rumen; iii) or there may be a competition for the deposition sites by the long chain PUFA present in FM. Further research is needed to investigate the mechanism involved. Even though SM treatment was similar to FM treatment in terms of concentrations of EPA and DHA in PL of their meat, the ratio of omega-3/total PUFA in meat was significantly ($P< 0.001$) higher with FM feeding than with BAS, CM and SM.

CONCLUSION

Feeding FM and SM had beneficial effects on boosting the omega-3 fatty acid profile of muscle phospholipid without affecting the pH and colour of meat measured at 24h post mortem. By judicious selection of supplementary feeds for sheep, higher levels of essential omega-3 PUFA can be incorporated in the lamb meat, which can meet the modern requirement for human nutrition. However, further investigation is needed to study the digestion, absorption and metabolism of long chain PUFA in different oil based ruminant diets and the subsequent effect on the fatty acid composition and sensory characteristics of meat.

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Table 1: Effect of isoenergetic amounts of fish meal, canola meal and soybean meal supplements fed to growing lambs on pH, surface colour, total lipid content and fatty acid composition of longissimus muscle at 24h post mortem.

	BAS	FM	CM	SM	SEM	Significance
Muscle pH	5.70	5.77	5.74	5.71	0.04	NS
Surface colour L*-value	40.9	41.1	41.0	40.0	0.78	NS
Surface colour a*-value	10.59	10.94	11.08	10.99	0.61	NS
IMF content (%)	4.1	3.5	4.0	4.1	0.26	NS
Total SFA #	146	139	135	195	15.2	*
Total PUFA#	150	143	138	194	16.5	0.1
omega-3 PUFA#	52	61	47	65	5.3	0.1
omega-6 PUFA#	98	82	91	129	11.4	0.07
omega-3/ omega-6	0.35	0.43	0.34	0.34	0.01	***

#values were expressed in mg of fatty acids in muscle phospholipid of 100 g meat and means are the average of 6 observations.
Significance *$P< 0.05$, ***$P< 0.001$, NS = not significant
Means of pH, surface colour and intramuscular fat content are the average of 8 observations.

Table 2: Level of individual fatty acids in phospholipid of longissimus muscle from growing lambs fed isoenergetic amounts of fish meal, canola meal and soybean meal

	BAS	FM	CM	SM	SEM	Probability
Palmitic acid	63.4	66.3	56.7	87.3	8.1	NS
Stearic acid	59.1	51.6	58.2	87.4	8.0	*
Oleic acid	110	105	93	156	16.3	0.09
Linoleic acid	61	50	56	77	7.0	0.09
Linolenic acid	13	11	11	15	1.4	0.1
Arachidonic acid	25	23	19	36	4.2	0.08
EPA	17	20	14	21	1.8	0.08
DHA	6.8	12.6	4.9	7.9	1.7	***

Values were expressed in mg of fatty acids in muscle phospholipid of 100 g meat.
Significance *$P< 0.05$, ***$P< 0.001$, NS = not significant.
Means are the average of six observations.