EFFECTS OF DIETARY LINSEED OIL ON FATTY ACID COMPOSITION OF LAMB MEAT

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Background

Fatty acids are involved in various "technological" aspects of meat quality. Since they have very different melting points, variation in fatty acid composition has an important effect on firmness and softness of the fat in meat. Moreover, interest in meat fatty acid composition stems from the need to find ways to produce healthier meat, which has a higher ratio of polyunsaturated (PUFA) to saturated (SFA) fatty acids and a more favourable balance between ω-6 and ω-3 PUFA (Wood *et al.,* 2003).

The differences in the physiological effects on humans of ω-6 and ω-3 PUFA were unknown until 1980. Nowadays, evidence from epidemiological, clinical and biochemical studies demonstrates that ω-3 PUFA exert a protective effect against some common cancers such as breast, colon and perhaps prostate (Rose and Connolly, 1999), reduce some types of cardiovascular disease, improve rheumatoid arthritis and inflammatory bowel diseases and minimize episodes of rejection (Alexander, 1998).

Nutritionists have focused on the type of PUFA and the balance in the diet between ω-3 PUFA formed from α-linolenic acid (C18:3) and ω-6 PUFA formed from linoleic acid (C18:2) (Williams, 2000). The ratio of ω-6/ω-3 PUFA is considered a risk factor in cancers and coronary heart disease, especially in the formation of blood clots leading to a heart attack (Enser, 2001).

Some international agencies (British Nutrition Foundation, 1992; Department of Health, 1994) concerned with human health have considered the benefits of dietary long chain ω-3 PUFA, establishing a ω-6/ω-3 ratio of less than 4 to improve human health status. Consequently, there have been many attempts to manipulate feeds in order to increase the ω-3 fatty acid content in rabbits (Lopez-Bote *et al*., 1997), poultry (Chanmugam *et al.,* 1992), pigs (Enser *et al.,* 2000; D'Arrigo *et al.,* 2002a, 2002b) and ruminants (Ponnampalam *et al.,* 2002a, 2002b).

Ruminant meats are a relatively good source of ω-3 PUFA, due to the presence of C18:3 in grass. In Mediterranean areas where grazing lands are scarce and on farms where livestock is reared in sheds, it is possible to increase ω-3 PUFA content of ruminant meats by feeding animals on grain-based diets including whole linseed.

Objectives

The present study observed the effects on the fatty acid composition of lamb meat when linseed oil was used in feed.

Materials and methods

Twenty male Gentile di Puglia lambs were weaned at the age of 45 days and immediately divided into two homogeneous groups of 10. Control group lambs were fed on hay and commercial concentrated feed containing soybean oil (30 g kg^{-1}); experimental group lambs on hay and commercial concentrated feed containing linseed oil (30 g kg^{-1}). Energy, protein and fibre contents of both diets were the same.

Lambs were slaughtered at 100 days. The carcasses were refrigerated at 4°C for 24 hours. *Longissimus lumborum* (Ll) muscles were taken from right half-carcasses. Representative sub-samples were taken from Ll muscles and divided into two pieces. One piece was cooked in a ventilated electric oven at 180°C until an internal endpoint temperature of 75°C was reached in the geometric centre of the meat cut. The

temperature was recorded by a thermocouple (Hanna Instruments) inserted into the meat sample placed at the centre of the wire rack (ASPA, 1996).

Raw and cooked meat samples were homogenized in a grinder to perform chemical analysis (ASPA, 1996). Lipids were extracted from both raw and cooked samples according to the method suggested by Folch *et al*. (1957) using a chloroform/methanol 2:1 (v/v) solution. Fatty acids were methylated using a BF_3/methanol solution (12% v/v) and analysed by gas chromatography (Chromopack CP 9000) using a 60 m silicated glass column with a 0.25 mm internal diameter and 0.2 μm film thickness.

The atherogenicity and thrombogenicity indexes (Ulbricht and Southgate, 1991) and the PCL/PCE (plasma cholesterol lowering/plasma cholesterol elevating) ratio (Reiser and Shorland, 1990) were also calculated.
Analysis of variance was carried out on the data using the GLM procedure of SAS. The model considered diet, cooking and their interaction as main effects. Means were compared using Student's t test (SAS, 1999/2000).

Results and discussion

Feed containing linseed oil did not modify the chemical composition of raw and cooked meat when compared to feed containing soybean oil, as found also for 75-day-old lambs (Caputi Jambrenghi *et al*., 2004a). Regardless of diet, cooking lowered the moisture content of meat and increased the levels of protein, ash and N-free extract (P<0.01), without any alteration to the ether extract content (Table 1).

Table 1. Chemical composition of raw and cooked meat (% wet matter)

	Control group		Experimental group		SED	Significance of main effects	
	Raw	Cooked	Raw	Cooked	(DF = 36)	Diet	Cooking
N (samples)	10	10	10	10			
Moisture	75.13^{M}	65.98^{N}	74.99^{M}	65.74^{N}	2.494	ns	**
Protein	19.14^{N}	26.79^{M}	18.84^{N}	26.55^{M}	1.158	ns	**
Ether extract	3.49	3.43	3.94	4.12	1.464	ns	ns
Ash	1.06^{N}	1.70^{M}	1.10^{N}	1.67^{M}	0.142	ns	**
N-free extract	1.18^{N}	2.10^{M}	1.12^{N}	1.92^{M}	0.243	ns	**

Differences between raw and cooked meat within each group: M, N: P<0.01
Significance of main effects: **: P<0.01; ns: not significant

Feed containing linseed oil brought about an increase in the C18:3 ω-3 content of the raw (1.54 *vs* 0.86; P<0.01) and cooked meat (1.12 *vs* 0.42; P<0.01), thus confirming the results obtained with 75-day-old lambs (Caputi Jambrenghi *et al*., 2004b), and in the C22:6 ω-3 level of the cooked meat (0.14 *vs* 0.01; P<0.01) (Table 2).

It also increased total PUFA in the cooked meat (7.24 *vs* 5.96; P<0.01), total ω-3 in the raw (2.12 *vs* 1.64; P<0.01) and cooked meat (1.94 *vs* 0.86; P<0.01), and lowered the ω-6/ω-3 ratio of the cooked meat (2.88 *vs* 6.34; P<0.01) bringing it to below 4, as recommended by the Human Nutrition Society (Carnovale and Marletta, 1997).

On the cooked meat, feed containing linseed oil raised the PUFA/SFA ratio (0.15 *vs* 0.13; P<0.01), bringing it closer to the 0.45 level recommended by the Department of Health (1994), as well as lowered the thrombogenicity index (1.43 *vs* 1.55; P<0.01).

Cooking reduced the level of C18:3 ω-3 (P<0.01) in meat produced with either feed. However, cooking increased the level of C22:6 ω-3 in the experimental group meat (0.14 *vs* 0.06; P<0.01), unlike the control group meat where the level was lowered (0.01 *vs* 0.14; P<0.01).

Cooking had a positive effect on meat produced with the linseed oil feed regarding total SFA (47.62 *vs* 49.68; P<0.01), total MUFA (45.14 *vs* 42.36; P<0.01), total UFA (52.38 *vs* 50.32; P<0.01), the UFA/SFA ratio (1.10 *vs* 1.01; P<0.01), the thrombogenicity index (1.43 *vs* 1.54; P<0.01). Cooking had a negative

effect on meat produced with the soybean oil feed regarding total PUFA (5.96 *vs* 7.66; P<0.01), total ω-3 (0.86 *vs* 1.64; P<0.01), the ω-6/ω-3 (6.34 *vs* 3.83; P<0.01) and PUFA/SFA ratios (0.13 *vs* 0.16; P<0.01).

Conclusions

The use of linseed oil in the production of 100-day-old lambs does not modify the chemical composition of the meat. It improves, however, the dietary characteristics, especially in cooked meat, increasing the C18:3 ω-3, C22:6 ω-3 and total ω-3 contents and improving the ω-6/ω-3 and PUFA/SFA ratios and the thrombogenicity index.

Table 2. Fatty acid composition of raw and cooked meat (% total fatty acids)

	Control group		Experimental group		SED	Significance of main effects	
	Raw	Cooked	Raw	Cooked	(DF = 36)	Diet	Cooking
N (samples)	10	10	10	10			
C10:0	0.30	0.28	0.32	0.34	0.102	ns	ns
C12:0	0.46	0.38	0.34	0.48	0.164	ns	ns
C14:0	4.52	4.22	4.14	4.54	0.679	ns	ns
C16:0	24.16^{BN}	25.16^{aM}	25.36^{AM}	24.44^{bN}	0.760	ns	ns
C16:1	1.88^{N}	2.78^{AM}	1.54^{n}	1.98^{Bm}	0.412	**	**
C18:0	16.98^{M}	15.14^{N}	17.78^{M}	15.96^{N}	0.950	**	**
C18:1 ω-9 trans	6.06^{A}	6.48^{A}	5.12^{B}	5.18^{B}	0.633	**	ns
C18:1 ω-9 cis	33.08^{N}	34.66^{M}	33.44^{N}	35.08^{M}	1.025	ns	**
C18:2 ω-6 cis	4.92^{M}	4.18^{N}	4.54^{M}	3.70^{N}	0.586	*	**
C18:3 ω-6	0.26^{M}	0.12^{BN}	0.26^{n}	0.36^{Am}	0.112	**	ns
C18:3 ω-3	0.86^{BM}	0.42^{BN}	1.54^{AM}	1.12^{AN}	0.231	**	**
C20:1 ω-9	0.64^{am}	0.40^{n}	0.36^{b}	0.44	0.253	ns	ns
C18:2 conj cis	0.08	0.08^{B}	0.16	0.26^{A}	0.120	**	ns
C18:2 conj trans	0.12	0.06^{B}	0.04^{N}	0.26^{AM}	0.160	ns	ns
C20:3 ω-6	0.34^{B}	0.26	0.54^{A}	0.40	0.182	**	ns
C20:3 ω-3	0.06	0.02^{B}	0.01^{N}	0.22^{AM}	0.112	*	**
C20:4 ω-6	0.06	0.08	0.04	0.06	0.068	ns	ns
C20:5 ω-3	0.42^{M}	0.20^{N}	0.32^{M}	0.14^{N}	0.126	*	**
C22:5 ω-3	0.04	0.10	0.01^{N}	0.14^{M}	0.089	ns	**
C22:6 ω-3	0.14^{AM}	0.01^{BN}	0.06^{BN}	0.14^{AM}	0.065	ns	ns
Other acids	3.08^{N}	3.58^{M}	3.04	3.26	0.422	ns	**
Total SFA	48.18^{Bm}	47.06^{n}	49.68^{AM}	47.62^{N}	1.259	*	**
Total MUFA	44.16^{AN}	46.98^{AM}	42.36^{BN}	45.14^{BM}	0.998	**	**
Total PUFA	7.66^{M}	5.96^{BN}	7.96	7.24^{A}	0.948	**	**
Total UFA	51.82^{An}	52.94^{m}	50.32^{BN}	52.38^{M}	1.259	**	**
Total ω-6	6.02^{m}	5.10^{n}	5.84	5.30	0.956	ns	*
Total ω-3	1.64^{BM}	0.86^{BN}	2.12^{A}	1.94^{A}	0.304	**	**
ω-6/ω-3	3.83^{N}	6.34^{AM}	2.78	2.88^{B}	1.438	**	**
UFA/SFA	1.08^{An}	1.13^{m}	1.01^{BN}	1.10^{M}	0.055	**	**
PUFA/SFA	0.16^{M}	0.13^{BN}	0.16	0.15^{A}	0.022	ns	**
Atherogenicity index	0.82	0.80	0.84	0.82	0.076	ns	ns
Thrombogenicity index	1.51	1.55^{A}	1.54^{M}	1.43^{BN}	0.076	ns	ns
PCL/PCE	1.02	0.99	0.98	1.01	0.073	ns	ns

Differences between diets: A, B: P<0.01; a, b: P<0.05
Differences between raw and cooked meat within each group: M, N: P<0.01; m, n: P<0.05
Significance of main effects: *: P<0.05; **: P<0.01; ns: not significant

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