FATTY ACID CONTENT AND COMPOSITION OF MUSCLE LIPIDS OF GOAT KIDS FED SUNFLOWER OIL SUPPLEMENTED DIET

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Background

Consumers, becoming more health conscious, are increasingly paying attention to quality aspects of meat, particularly to lean meat. Goat meat is a good source of lean meat due to its very little intramuscular fat content. However, the leanness of goat meat may be a disadvantage in promoting goat meat products, which may have inferior juiciness, palatability, "mouth feel", and tenderness. Therefore, a shift in the partitioning toward deposition of more inter- and intramuscular fat would increase carcass quality as well as consumer acceptance. High concentrate diets enhanced mostly internal fat (Bas *et al*., 1982), but did not influence muscle composition (Muller *et al*., 1985) in goat kids. Using diets rich in 18:2 showed a decrease of the total lipid content and an increase in the amount of phospholipids (PL) in muscles of calves and lambs (Jenkins and Kramer, 1990; Ponnampalam *et al*. 2001). In contrast, in our previous study with kids (Marinova *et al*., 2001), sunflower oil supplemented diet increased the intermuscular fat and total fat content in all meat cuts.

However, not only fat content, but also its fatty acid profile affects the quality of meat. The interest in fatty acids with respect to consumer health lies in the proportions of polyunsaturated (P) and saturated (S) fatty acids, their ratio (P/S), the ratio of n-6/n-3 fatty acids, as well as the content of cholesterol. In addition to the beneficial effects of polyunsaturated fatty acids, the conjugated linoleic acid (CLA) isomers have received much attention for their potential health promoting effects. Vegetable oils as natural sources of the essential linolenic and linoleic acids (being precursors of CLA) are now attracting increased research attention. Feeding calves and lambs diets supplemented with unprotected sources of 18:2, resulted in an increase of muscle PL fraction, but decreased the n-6/n-3 ratio (Jenkins and Kramer, 1990; Ponnampalam *et al*. 2001). Recently it was demonstrated that an unprotected sunflower oil supplemented diet significantly increased CLA content in the triacylglycerol (TG) fraction of various lamb tissues (Peterson at al., 2002). However, no data related to the effect of vegetable oils on the lipid content and composition in goat muscles are available.

Objectives

The object of this study was to examine the effect of dietary enrichment of n-6 fatty acids (sunflower oil) on the content and fatty acid composition of muscle triacylglycerols and structural phospholipids, as well as cholesterol level, in growing goat kids.

Material and methods

Two groups of five male kids (age 3 months) were fed iso-nitrogenous diets for 21 days, as described in a previous paper (Marinova *et al.,* 2001). The diets contained either no added fat (control), or sunflower oil (2.5% of as-fed basis weight of concentrate) (experimental). Samples from *M. longissimus dorsi* (LD)*, M. semimebranosus (*SM) *and M. supraspinalis* (SP) were taken after slaughter at 24h *post mortem*, and lipids were extracted according to the method of Bligh and Dyer (1959). Aliquots of the lipid extracts were submitted to cholesterol and phospholipid assays, using the methods of Sperry and Webb (1950) and Bartlet *et al*.(1959), respectively. Methyl esters of PL and TG isolated by preparative TLC, were obtained using a 0.01% solution of sulfuric acid in dry methanol at 47^{o}C for 14h, as described by Christie (1973). The fatty acid composition of the lipid fraction as well as the content of TG, were analyzed by gas chromatography using triarahidin as an internal standard. The effect of treatment (control ν sunflower oil supplemented group) was subjected to Student's test for determination of significance.

Results and discussion

The intramuscular fat (i.f) content, and the contents of the single lipid fractions distinguished between the three muscles (Table 1). In m.SP, where the total fat content was highest, the concentrations of PL and cholesterol were also higher, but the TG level lower, compared with the other two muscles.

Table 1. Contents of intramuscular fat, phospholipids, triacylglycerols and cholesterol in M. *longissimus dorsi, M. semimembranosus and M. supraspinalis,* of goat kids in response to feeding sunflower oil

Muscles	*M. longissimus dorsi*		*M. semimembranosus*		*M. supraspinalis*	
			Groups[a]			
Items	Control	Experimental	Control	Experimental	Control	Experimental
Internal fat [b]	16.20±10.1	22.50±11.6	15.60±3.60	19.30±4.9	20.10±4.7	25.50±7.7
PL [b]	4.44± 0.51	4.90± 0.89	5.81±0.79	6.30±0.85*	6.08±1.81	6.30±1.08
Cholesterol [b]	0.54± 0.18	0.85± 0.06	0.80±0.15	1.16±0.07*	0.92±0.14	1.21±0.11*
TG [c]	2.15± 0.29	3.33± 0.41	1.44±0.19	3.19±0.62	1.29±0.13	3.79±0.78

[a] Control: no added sunflower oil; experimental : sunflower oil supplemented diet (2.5% of weight of concentrate as fed-basis) ; [b] PL – phospholipids; mg/g fresh tissue; [c] TG – triacylglycerols" µ mol/g fresh tissue; * $P < 0.05$.

Sunflower oil supplementation tended to increase (although to a different extent in different muscles) all lipid fractions. Jenkins and Kramer (1990); Ponnampalam *et al*. (2001) also reported higher PL level after corn or sunflower treatment, but reduced muscle TG levels. Contrary to the negligible changes in PL fractions, the TG concentrations were increased by 55%, 120% and 193%, (Table 1), respectively for m.LD ,m.SM and m.SP.

Table 2. Fatty acid composition (M %) of triacylglycerols from *M. longissimus dorsi, M. semimembranosus and M. supraspinalis* of goat kids in response to feeding sunflower oil

Muscles	*M. longissimus dorsi*		*M. semimembranosus*		*M. supraspinalis*	
			Groups[a]			
Fatty acids	Control	Experimental	Control	Experimental	Control	Experimental
14:0	4.65±1.38	3.12±0.41	2.01±0.74	1.32±0.06	4.90±1.43	4.01±0.33
16:0	25.79±0.68	26.27±0.77	28.48±0.58	26.81±0.34*	26.18±1.37	26.71±0.60
16:1	3.64±0.27	2.56±0.21*	3.32±0.66	2.58±0.12	2.98±0.38	2.56±0.29
17:1	1.18±0.12	0.90±0.12	-	-	-	-
18:0	13.23±0.96	15.62±0.95	15.79±1.26	18.19±1.33	14.72±2.04	16.20±1.21
18:1	48.40±3.25	49.06±0.34	48.24±2.05	46.96±1.38	48.38±2.55	47.78±0.70
18:2	3.11±0.82	2.47±0.13	2.16±0.41	4.14±0.44*	2.84±0.29	2.74±0.30
UFAb	56.33	54.99	53.72	53.68	54.20	53.08

[a] Control: no added sunflower oil; experimental : sunflower oil supplemented diet (2.5% of weight of concentrate as fed-basis) ; [b] UFA - Unsaturated fatty acids; *$P<0.05$.

The increase of fat in kids' muscle after sunflower oil treatment leads to an increase in the relative diameter of larger cells and to a corresponding decrease in that of the smaller cells, most noticeably in SP muscle (Marinova, 2003). Paterson *et al*. (2002) reported that sunflower oil supplementation, as a source of unprotected 18:2, resulted in a significant increase of CLA content in different lamb tissues, and suggested that the biological activity of CLA may be more related to deposition of fat rather than to specific effects on PL alterations. The increased intramuscular fat could have a beneficial effect on the marbling of lean goat meat, although the tendency of getting more cholesterol would have to be considered.

Similarly to other livestock species reared for meat production, the major fatty acids in TG muscle of kids were 16:0, 18:0 and 18:1 (Table 2). The sum of unsaturated fatty acids (UFA) did not differ between the three muscles, although small variations in the proportions of 14:0, 18:0 and 18:2 were observed. In experimental animals, the only significant changes ($p<0.05$) were the reduction in the proportions of 16:1 in LD and 16:0 in SM muscles. The reduction of 16:0 in SM was apparently compensated for by an increase of

18:0 and 18:2 contents. Paterson *et al*. (2002) reported similar changes with sunflower oil in the rib muscle of lambs. Sunflower oil also tended to decrease the proportion of 18:1 in SP muscle, while increasing 18:0 in all three muscles. However, in SM muscle, no increase of 18:2 was observed in the other two muscle TG fractions. It may be speculated that blood flow delivered different amount of 18:2 to different muscles, or, the decreased proportion of 18:2 in LD and SP muscles was due to a conversion of 18:2 to CLA, which substitutes 18:2 in TG molecules, as was suggested by Peterson at al. (2002). Unfortunately we were not able to determine the CLA content.

Table 3. Fatty acid composition (M%) of phospholipids from *M. longissimus dorsi, M. semimembranosus and M. supraspinalis* of goat kids in response to feeding sunflower oil

Muscles	*M. longissimus dorsi*		*M. semimembranosus*		*M. supraspinalis*	
			Groups[a]			
Fatty acids	Control	Experimental	Control	Experimental	Control	Experimental
14:0	0.85±0.04	0.96±0.42	0.11±0.01	0.53±0.03**	0.90±0.28	1.25±0.27
15:0	0.42±0.12	0.52±0.09	-	-	0.24±0.02	0.39±0.15
16:0	22.03±0.64	23.15±1.39	20.57±0.50	19.74±0.23	18.55±1.06	19.04±1.00
16:1 7	0.72±0.13	1.35±0.18*	1.00±0.20	1.54±0.22	0.70±0.07	1.17±0.14*
16:1 9	1.00±0.24	0.78±0.13	1.18±0.19	0.78±0.08	0.84±0.14	1.00±0.13
17:0	1.48±0.29	1.08±0.06	0.88±0.12	0.91±0.10	1.14±0.23	1.08±0.19
17:1	0.87±0.09	0.83±0.15	1.01±0.16	0.82±0.10	0.84±0.18	0.57±0.11
18:0	17.05±0.95	17.53±1.12	17.31±0.63	18.13±0.40	16.50±0.84	15.95±0.51
18:1	30.62±2.18	29.04±3.01	31.71±2.57	28.86±1.97	30.88±1.91	31.95±1.92
18:2	13.83±1.38	13.52±1.75	14.93±2.13	17.41±0.95	17.96±1.05	18.32±1.59
18:3	1.84±0.19	1.80±0.30	2.26±0.40	1.92±0.17	2.27±0.49	1.74±0.16
20:3	0.60±0.03	0.67±0.13	0.45±0.02	0.72±0.07*	0.52±0.07	0.44±0.04
20:4	7.75±0.62	7.28±1.49	8.21±1.40	7.81±0.35	7.79±0.54	6.60±0.49
20:5	0.94±0.16	1.49±0.48	0.38±0.20	0.83±0.30	0.87±0.42	0.50±0.21
PUFA[b]	24.95	24.76	26.23	28.69	29.41	27.60
P/S[c]	0.60	0.57	0.67	0.73	0.79	0.73
n-6/n-3	7.98	6.53	8.94	9.43	8.37	11.32

[a] Control: no added sunflower oil; experimental : sunflower oil supplemented diet (2.5% of concentrate as fed-basis) ; [b] polyunsaturated fatty acids; [c] P/S – polyunsaturated/saturated ratio; *P<0.05.

FA profiles of PL in the three muscles of goat kids reflected the metabolic type of muscles (Table 3). The highest proportion of 16:0, and the lowest proportion of 18:2 were found in LD, whereas no differences in the content of 18:1 were observed between muscles. The linoleic acid concentration in the three muscles was higher than that reported for muscle PL of goats of different breeds and ages (Banskalieva *et al*., 2000). The SP muscle being oxidative type had a higher level of PL (Table 1), as well as a higher proportion (29.6%) of polyunsaturated fatty acids (PUFA) than the LD and SM muscles of oxidative-glycolytic type (24.95% and 26.23%, respectively). The n-6/n-3 ratios in the LD, SM and SP were 7.98, 8.94 and 8.74, respectively, ie. higher than the minimum of 4.0 officially recommended. High n-6/n-3 ratio with great variation (4.38 to 19.62) caused by differences in age, breed, muscles, diet, etc. have also been reported earlier in goats (Banskalieva, *et al*., 2000). The P/S ratios of 0.60, 0.67 and 0.79 of LD, SM and SP, respectively, were somewhat comparable to the recommended beneficial value of 0.7, indicating that as a meat producing species, goats have a rather optimal P/S ratio.

The sunflower oil treatment had no significant effect on the major fatty acids (16:0,18:0 and 18:1) in muscle PL fractions of kids. The relative proportion of 18:2 tended to increase in SM and SP resulting in a slight elevation in the total content of polyunsaturated FA in SM, but not in the other two muscles. However, an opposite tendency ie., decrease was observed in the proportions of 18:3n-3, 20:2n-6 and 20:4n-6. The increased P/S ratio reflects the net effect in the sum of polyunsaturated FA of a muscle. Despite the slightly diminished P/S ratios in LD and SP, they remained close to the recommended beneficial value of 0.7. The tendency of 20:4 to decrease may suggest that the activity of Δ6-desaturase (participating in conversion of 18:2 to 20:4) is affected, or some amount of 18:2 was converted to CLA (Peterson at al. (2002). Although small, the variations in the amount of n-6 fatty acids were compensated by a slightly increased incorporation

of some n-3 fatty acids in the PL fraction. As a result, the n-6/n-3 ratios tended to decrease in LD and SM, but not in SP muscle.

Conclusions

The results of this study show that the P/S ratio in PL fractions of the muscle of goat kids was comparable to the recommended beneficial value set for this ratio. However, the higher proportions of n-6 fatty acids resulted in the higher n-6/n-3 ratio compared to other species. Sunflower oil supplementation increased mostly TG fractions, which may have a positive effect on the marbling of goat meat. Only in the SM muscle of the treated kids, was a tendency of increased incorporation of 18:2 into the TG and PL fractions observed. Using an unprotected source of 18:2 did not change the P/S ratios in muscle PL fractions, but increased the value of n-6/n-3 ratio in SP, whereas in the other two muscles (LD and SM) an opposite tendency was observed.

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