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Body and carcass composition, and meat quality of kids fed fish oil supplemented diet

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SUMMARY – Two groups of five animals (age 3 months) each, of local Bulgarian White kids, were fed for 33 days iso-nitrogenous diets, containing either no added fat (control) or fish oil (experimental), added at 2.5% as-fed basis of concentrate. Dietary fish oil did not influence the growth rate, dressing percentage, the weights of body components and carcass cuts, carcass and muscle measurements, but it increased the weights of caul – twice ($P < 0.1$) – and sweetbread and kidney fat (22 and 35%, respectively). The increased dissectable fat was a result mainly of a higher deposition of subcutaneous fat. The thickness of back fat at the last rib (over the loin) was reduced by 53%, but that of fat at the base of the tail was increased by 80%. A slight increase of intermuscular fat in loin and intramuscular fat in *m. longissimus dorsi (m. LD)* was observed. The decrease of water binding capacity (WBC) in *m. LD* ($P < 0.05$) and the tendency of reduction in the other two muscles were accompanied by the same changes in myoglobin content of *m. LD* and *m. semimembranosus*, and colour in *m. supraspinalis* ($P < 0.05$), and an increase of pH in *m. supraspinalis* ($P < 0.01$), compared with the values for the control group. The results of this experiment show that polyunsaturated fatty acid (PUFA) (from fish oil) could have an effect on deposition and distribution of body fat and some physicochemical characteristics of meat.

Key words: Kids, fish oil, carcass, composition, meat, characteristics.

***RESUME –** "Composition corporelle et de la carcasse et qualité de la viande de chevreaux nourris avec des régimes supplémentés avec de l'huile de poisson". Deux lots de cinq chevreaux (âgés de 3 mois) chacun, provenant de chèvres blanches bulgares, ont été soumis pendant 33 jours à des régimes iso-azotés additionnés (expérimental) ou non (témoin) d'huile de poisson à raison de 2,5% du poids brut du concentré. L'apport d'huile de poisson n'a pas affecté la croissance, le rendement, le poids des différentes parties de la carcasse et des composants corporels. En revanche, l'addition d'huile a entraîné une augmentation considérable du poids de la coiffe ($P < 0,1$) et du poids de crépines et gras périrénal (22 et 35%, respectivement). La plus grande quantité de graisse récupérée de la carcasse du lot expérimental est le résultat d'un dépôt de gras sous-cutané. L'épaisseur du gras lombaire au-dessus du filet (la dernière côte) a diminué (53%) mais l'épaisseur à la base de la queue a augmenté (80%). Nous avons constaté un enrichissement en gras intermusculaire dans le filet et en gras intramusculaire dans le* longissimus dorsi (m. LD)*. Par comparaison aux résultats obtenus chez le groupe témoin, la réduction de la capacité de rétention d'eau dans le* m. LD *($P < 0,05$) et dans les deux autres muscles est accompagnée des mêmes changements dans la teneur en myoglobine du* m. longissimus *dorsi et* m. semimembranosus*, la couleur de* m. supraspinalis *($P < 0,05$) et une augmentation de pH dans le* m. supraspinalis *($P < 0,01$). Les résultats de cette expérience montrent que les acides gras polyinsaturés (de l'huile de poisson) affectent le dépôt et la répartition des graisses corporelles et certaines caractéristiques physico-chimiques de la viande.*

***Mots-clés :** Chevreaux, huile de poisson, carcasse, composition, viande, caractéristiques.*

Introduction

Beneficial effects of C20 and C22 long chain *n*-3 fatty acids on human health are attracting increased research attention. Numerous investigations with lamb, calf, beef and cattle, but not with goats, showed that diets supplemented with fish meal or fish oil influenced the fatty acid composition of meat lipids, by increasing the levels of *n*-3 polyunsatureted fatty acids (PUFA) (Jenkins and Kramer, 1990; Mandell *et al.*, 1997; Ponnampalan *et al.*, 2001; Scollan *et al.*, 2001; Wachira *et al.*, 2002). In experiments with sheep and beef cattle it has been reported that fish oil or fish meal supplemented diets influenced the back fat thickness, the percentage of subcutaneous, inter- and intramuscular adipose tissue, although the results were controversial (Mandell *et al.*, 1997; Ponnampalan *et al.*, 2001; Scollan *et al.*, 2001; Wachira *et al.*, 2002). However, no data are available concerning the effects of marine products on the composition and quality of the single cut, which determine to a great extent the commercial view of meat and consumer acceptability. No data for comparison are available for kids as well.

It is of importance, for goat meat production, to test if the potential possibilities of fish fatty acids for influencing lipid metabolism could have an effect on deposition and distribution of body fat. The objective of this study was to study the effects of fish oil on growth rate, carcass composition and meat quality of growing kids.

Material and methods

The experiment was carried out with weaned (3 months of age) male kids of local Bulgarian White goat breed, gradually switched (over a 14 days period) to a diet with an ingredient composition, described in a previous paper (Marinova *et al.*, 2001). Then, kids were separated into 2 groups, control and experimental, of 5 animals each. The concentrate of daily diet of the experimental animals was gradually supplemented with fish oil, starting with a level of 0.5% (of concentrate wet weight) to a level of 2.5% at the end of the first week. After the adjustment period, the animals received 2.5% fish oil supplemented diet (prepared fresh every day) for 33 days. Kids from both groups were offered their daily ration of concentrate and hay (600 and 960 g, respectively for each animal) in two equal meals. The daily dry matter, fat and energy intake for the control and experimental groups, were: 1.463 (kg/per animal, for both groups), 31.03 and 46.03 (g/per animal, respectively), and 12.7 and 13.2 (MJ/per animal, respectively). Water was available *ad libitum.* Representative concentrate (no added oil) and hay samples were subjected to routine proximate analyses and lipid extraction (AOAC, 1995). The animals were weighed at the beginning and at the end of the treatment period.

All the kids were slaughtered between 09:00 and 10:00 h, without fasting. The slaughter and post-slaughter handling, as well as the measurements of the physicochemical characteristics of the meat were made as it was described in our previous paper (Marinova *et al.*, 2001). The effect of treatment (control vs fish oil supplemented group) was subjected to Student's test for determination of significance.

Results and discussion

The fish oil supplementation did not induce significant changes (Table 1) in the average daily weight gain (90.33 for the control and 82.42 g/animal, for the experimental group). Similar results were reported for other ruminants, fed fish oil or fish meal (Jenkins and Kramer, 1990; Mandell *et al.*, 1997; Scollan *et al.*, 2001). Wachira *et al.* (2002) showed breeds dependent decrease of daily weight gain in sheep, fed fish oil. Lipid rich in *n*-3 PUFA supplementation could influence feed intake, the data being controversial (Wonsil *et al.*, 1994; Mandell *et al.*, 1997; Ponnampalam *et al.*, 2001; Scollan *et al.*, 2001; Wachira *et al.*, 2002). No comparisons are possible with our experiment, where the animals received a controlled daily diet, fully utilised. It could be suggested, that the fish oil supplementation of 2.5% in concentrate, corresponding to 1% for the whole daily amount of food, offered to kids, may have been too low to substantially affect the conditions of fermentation and digestion in the rumen, feed intake and, hence, animal performance (Wonsil *et al.*, 1994).

After visual evaluation of the fatness score, the animal carcasses in both groups were of second quality, in category "B" using the EUROP classification system for lambs (EEC Regulations No. 2137/92 and No. 461/93). In beef cattle and lambs, receiving fish oil for a long period, the carcass conformation score and fat score, respectively, were higher (Scollan *et al.*, 2001; Wachira *et al.*, 2002), or did not change when using fish meal (Mandell *et al.*, 1997).

Incorporation of lipid into the diet did not influence significantly the dressing percentage or the weight of internal organs, but there was an increase (Table 1) of the weights of caul – twice ($P < 0.1$) – and the weights of sweetbread and perirenal fat (22% and 35%, respectively). In rats using fish oil reduced or prevented excessive growth of abdominal adipose tissue (Fickova *et al.*, 1998) were observed. No data for comparison, however, were available for ruminants.

The back fat (over the loin) was reduced (54%) and the fat at the base of tail increased (80%) suggesting a trend of uneven distribution of subcutaneous fat after fish oil supplementation. Wachira *et al.* (2002) also observed a decrease of subcutaneous fat over the loin in a breed of sheep with high proportion of lean. It could be suggested that in goats producing more lean than other ruminants, fish oil appeared to have the same effect. It is not clear, however, why fish oil tended to increase fat thickness at the base of tail. Ponnampalam *et al.* (2001) and Scollan *et al.* (2001), however, did not find changes in the fat thickness at the 12th rib neither in lambs nor cattle.

Table 1. Live weight and slaughter data: weights of single cuts and their percentages of half carcass weight and relative percentages of dissectable lean, fat and bone in each cut, and chemical composition of half carcass of kids in response to feed fish oil

Items[†]	Groups						Significance level
	Control			Experimental			
	Mean	SEM	%	Mean	SEM	%	
Average daily gain (g)	90.33	0.016		82.42	0.021		NS
Cold carcass weight (kg)	7.631	0.990		8.546	0.834		NS
Dressing percentage (%)	50.34	1.321		47.58	0.733		NS
Weight caul (kg)	0.083	0.029		0.189	0.061		**
Weight sweetbread (kg)	0.131	0.018		0.184	0.019		NS
Weight kidney fats (kg)	0.089	0.038		0.138	0.042		NS
Thickness of subcutaneous fat (mm)							
Before the last rib	1.40	0.849		0.65	0.417		NS
At the base of tail	1.75	0.688		3.16	0.582		NS
Length of *m. LD* (cm)	22.78	1.410		23.86	1.038		NS
m. LD, cross-sectional area (cm^2)	7.40	1.550		7.56	1.360		NS
Weight of *m. LD* (kg)	0.090	0.023		0.112	0.025		NS
Weight of *m. SM* (kg)	0.104	0.022		0.126	0.014		NS
Weight of *m. SP* (kg)	0.045	0.004		0.060	0.006		NS
Half carcass (kg)	3.534	0.502	100	4.031	0.422	100	NS
Meat	2.178	0.324	61.53	2.459	0.312	60.88	NS
Bone	1.078	0.123	30.40	1.252	0.100	31.00	NS
Subcutaneous fat	0.145	0.025	4.09	0.188	0.034	4.65	NS
Intermuscular fat	0.141	0.065	3.98	0.140	0.024	3.47	NS
Neck (kg)	0.283	0.064	7.99	0.281	0.025	6.96	NS
Meat	0.169	0.041	4.77	0.139	0.022	3.44	NS
Bone	0.093	0.022	2.63	0.113	0.003	2.80	NS
Subcutaneous fat	0.014	0.007	0.40	0.015	0.009	0.37	NS
Intermuscular fat	0.007	0.002	0.20	0.014	0.006	0.35	*
Leg (kg)	1.076	0.150	30.40	1.239	0.108	30.68	NS
Meat	0.708	0.111	20.00	0.809	0.075	20.03	NS
Bone	0.326	0.029	9.21	0.377	0.030	9.33	NS
Subcutaneous fat	0.016	0.004	0.45	0.031	0.010	0.77	NS
Intermuscular fat	0.026	0.013	0.75	0.022	0.001	0.54	NS
Shoulder (kg)	1.491	0.238	42.12	1.798	0.230	44.51	NS
Meat	0.898	0.117	25.27	1.066	0.172	26.39	NS
Bone	0.448	0.066	12.66	0.566	0.062	14.01	NS
Subcutaneous fat	0.056	0.030	1.58	0.085	0.029	2.10	NS
Intermuscular fat	0.089	0.041	2.51	0.081	0.027	2.01	NS
Loin (kg)	0.335	0.052	9.46	0.328	0.040	8.47	NS
Meat	0.208	0.038	5.88	0.230	0.040	5.69	NS
Bone	0.089	0.020	2.51	0.088	0.012	2.18	NS
Subcutaneous fat	0.028	0.004	0.79	0.010	0.003	0.25	NS
Intermuscular fat	0.010	0.008	0.28	0.014	0.006	0.35	NS
Breast (kg)	0.355	0.033	10.03	0.379	0.028	9.38	NS
Meat	0.196	0.028	5.51	0.215	0.021	5.52	NS
Bone	0.120	0.012	3.40	0.108	0.008	2.57	NS
Subcutaneous fat	0.031	0.008	0.88	0.047	0.007	1.16	NS
Intermuscular fat	0.009	0.004	0.25	0.009	0.001	0.22	NS
Chemical composition of carcass							
Moisture (%)	71.57	2.437		69.87	1.806		NS
Protein (%)	20.22	0.120		20.96	0.189		NS
Fats (%)	7.71	2.110		8.66	1.864		NS
Ash (%)	0.96	0.051		0.97	0.075		NS

[†]*m. LD = m. longissimus dorsi; m. SM = m. semimembranosus; m. SP = m. supraspinalis.*
*P < 0.05; **P < 0.01; NS = non-significant (P > 0.05).

No significant differences were found in cold carcass weight, length of *m. longissimus dorsi,* cross-sectional area, as well as in the weights of the three muscles (*m. LD, m. SM, m. SP*) between the control and experimental groups (Table 1). Calculated as a percentage of the half carcass weight, however, a trend for increasing weights of *m. LD*, *m. SM* and *m. SP* was observed, together with a higher relative proportion of meat in the loin, probably as a result of a positive effect fish oil on muscle development (Ponnampalam *et al*., 2001; Scollan *et al*., 2001).

The relative proportion of fat or meat in the carcass did not change, although the total amount of fat in the whole carcass right side tended to increase, by 5%, compared to the control animals (Table 1). Data for the half carcass reflect the changes in the five cuts. Quantities and percentages of total fat content were slightly increased in leg, breast and shoulder, mainly as a result of changes in subcutaneous fat. The lower amount of subcutaneous fat in the loin (Table 1) corresponded to the reduced fat thickness at the 12th rib and to a limited increase of intermuscular fat in the same cut. No significant changes in the weights (as a percentage of the half carcass weight) of neck, loin and breast were observed in experimental animals as well. No data for comparison of the effects of fish oil supplementation on the proportions and composition of single cuts of carcass were available.

After fish oil supplementation the relative proportion of fat was slightly increased in *m. LD* (Table 2). However, Ponnampalam *et al*. (2001) found a decrease of intramuscular fat in *m*. *l. thoracis*, in heavy lambs, and Jenkins and Kramer (1990) observed a reduction of muscle triacylglycerols in preruminant calves. In animals fed fish oil a significant decrease of water binding capacity (WBC) in *m. LD* ($P < 0.05$) and only a tendency in the other two muscles was observed, accompanied by the same changes of myoglobin content of *m. LD* and *m. SM*, and color in *m. SP* ($P < 0.05$). Fish oil supplementation affected pH value, recorded 24 h post-mortem as this value was higher in *m. SP* ($P < 0.05$), compared to the control animals, as well as compared to *m. LD* and *m. SM*. The higher pH could indicate a darker red color of shoulder cuts, but pH data (Table 2) are in the range of the normal pH values for this kind of animals and the changes of some physicochemical characteristics are not enough to influence the commercial view and quality of goat meat.

Table 2. Physicochemical characteristics of *m. longissimus dorsi, m. semimembranosus* and *m.supraspinalis* of kids in response to feeding fish oil

Items	Groups				Significance level
	Control		Experimental		
	Mean	SEM	Mean	SEM	
m. longissimus dorsi					
pH (24 h)	5.43	0.072	5.58	0.021	NS
Moisture (%)	76.85	0.345	76.58	0.645	NS
WBC (%)	38.72	1.046	34.22	1.150	*
Colour (525 nm)	22.93	1.381	22.98	0.802	NS
Myoglobin (mg/g)	2.36	0.296	2.07	0.241	NS
Fats (%)	1.59	0.179	1.99	0.262	NS
Protein (%)	21.28	0.390	21.45	0.542	NS
Ash (%)	0.98	0.049	1.13	0.035	*
m. semimembranosus					
pH (24 h)	5.41	0.046	5.49	0.092	NS
Moisture (%)	76.24	0.462	76.61	0.418	NS
WBC (%)	38.92	1.437	37.33	1.103	NS
Colour (525 nm)	22.83	1.193	21.78	0.708	NS
Myoglobin (mg/g)	2.75	0.336	2.61	0.219	NS
Fats (%)	1.95	0.420	1.82	0.332	NS
Protein (%)	21.43	0.432	20.91	0.311	NS
Ash (%)	1.00	0.029	1.09	0.049	NS
m. supraspinalis					
pH (24 h)	5.59	0.070	5.83	0.029	**
Moisture (%)	77.77	0.216	77.20	0.258	NS
WBC (%)	34.08	0.913	30.87	1.678	NS
Colour (525 nm)	24.07	0.760	22.12	0.462	*
Myoglobin (mg/g)	2.64	0.223	2.63	0.056	NS
Fats (%)	2.00	0.195	2.09	0.309	NS
Protein (%)	20.41	0.255	20.11	0.216	NS
Ash (%)	1.04	0.035	1.04	0.054	NS

*P < 0.05; **P < 0.01; NS = non-significant (P > 0.05).

In the current experiment, it could be expected that the higher daily fat intake (15 g of added fish oil, rich in *n*-3 fatty acids) rather than the increased energy (0.51 MJ) affected distribution of body fat. In all cases, however, the added fat enhanced the flow of fish PUFA which can change fatty acid composition of cell membrane lipids and modify the course of several processes in these cells (Fickova *et al.*, 1998). It is quite attractive to suggest that the highest blood flow rate (and, hence, nutrient supply) to the internal adipose tissues, compared with subcutaneous and intramuscular (Gregory *et al.*, 1986) increased the effect of fish fatty acids and allows for the elevated deposition of internal fat in animals fed fish oil. The effect of fish oil, however, may be limited or increased by the different stage of fat depots development and specific peculiarities of lipid metabolism in the different anatomical locations (Eguinoa *et al.*, 2003). The observed tendencies for a different deposition of subcutaneous fat in some locations, and a slight increase of inter- and intramuscular fat in others (Tables 1 and 2), probably as a result of a greater capacity for fatty acid synthesis or of a different rate of lipolysis in adipocytes from carcass and abdominal depots, may be a compensatory mechanism for a changed nutrient supply in carcass depots (Eguinoa *et al.*, 2003).

The reasons for differences of lipid deposition after fish oil supplementation, therefore, are not still clear. There not the biochemical mechanisms, related with the changed lipid metabolism and not much data are available to explain such a situation. The observed changes in our experiment with kids, as well as the results of experiments with other ruminants, undoubtedly depend on the experimental design. From the fragmentary experiments with fish oil available not a common conception of the amount of fat and duration of treatment, age and stage of development of ruminants, where the type of diet and structure of fish oil is of importance as well can be obtained. Further investigations are needed on this aspect.

Conclusions

The results of this preliminary study show that the dietary fish oil did not influence significantly the animals growth rate or body components and carcass composition. The changed deposition and distribution of body fat suggest that PUFA (from fish oil) could be, to some extent, a repartitioning factor for carcass fat in goats and could have a favorable effect on carcass fatness score and on the quality of goat meat taste.

The changes of some of the physicochemical characteristics are not enough to influence the quality of kid meat, but fish oil supplementation however could be disadvantageous because of its tolerate effect on the elevation of internal fat depots in goats.

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