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SUMMARY – The addition of protected polyunsaturated fatty acids (PUFAs) in the concentrate as a way to improve the quality of goat meat with respect to fat composition have been evaluated. Groups of kid goats were milk-fed under natural rearing from birth until 45 days of age, then slaughtered on day 46. The mothers were fed a diet in which the concentrate fraction was supplemented or not with a PUFAs-rich protected fat; the supplement was provided either during lactation alone or during both gestation and lactation. The kid goats fed by mothers given the fat-supplemented diet showed adipose deposits in the leg cut (cover, intermuscular and intramuscular fat) with higher concentrations of PUFAs, especially of C18:4, C20:5, C22:5 and C22:6, but lower quantities of C18:0. The duration of the supplementation did not produce significant changes in the fat composition, although in some cases there was a tendency towards a greater difference in the case of animals fed by mothers given the supplemented diet during both gestation and lactation.

Key words: Goat, gestation, lactation, PUFAs supplementation, kid goats, composition of adipose deposits.

RESUME – *"Composition du tissu adipeux chez les chevreaux en réponse à l'ingestion maternelle d'acides gras protégés riches en PUFAs". L'objectif de ce travail était d'améliorer la qualité de la carcasse des chevreaux, notamment la composition du gras. Des groupes de chevreaux ont été maintenus auprès de leurs mères sous un régime de lactation naturelle jusqu'à leur abattage. Le concentré distribué aux mères comprenait ou non des matières grasses protégées (MGP), riches en acides gras polyinsaturés. Ce concentré a été distribué soit pendant la lactation, soit pendant la gestation et la lactation. Les chevreaux issus de mères qui recevaient un concentré enrichi en MGP avaient des dépôts adipeux (graisse de couverture, intermusculaire et intramusculaire) avec de plus grandes concentrations d'acides gras polyinsaturés, notamment C18:4, C20:5, C22:5 et C22:6, et aussi des concentrations inférieures de C18:0. La durée de la supplémentation (période de lactation vs période de gestation-lactation) n'a pas beaucoup affecté cette composition.*

Mots-clés : *Chèvres, gestation, lactation, supplémentation en acides gras polyinsaturés, chevreaux, composition des dépôts adipeux.*

Introduction

The use of protected fats in ruminant nutrition is a way to increase the energy density of the diets provided, especially at certain moments during the reproductive cycle (Jenkins and Palmquist, 1984; Baldi *et al.*, 1992). Recently, and with the aim of changing the fat composition either in the milk or in the meat of these animals to make it healthier for consumption, various protected fats high in polyunsaturated fatty acids (PUFAs) have been evaluated. These compounds pass subsequently into the milk or are deposited in the carcass of the animals (Ashes *et al.*, 1992; Franklin *et al.*, 1999; Sanz Sampelayo *et al.*, 2000).

Today, goat milk and the meat of kid goats are considered high-quality foods, because of their specific composition, compared to that of other ruminant species (Haenlein, 1992). Goat meat is also characterised by low levels of fat content (Morand-Fehr *et al.*, 1985; Sanz Sampelayo *et al.*, 1987), which makes it particularly valuable in the light of the negative connotations associated with the consumption of animal fats. The relationship between the consumption of saturated fat and the incidence of cardiovascular disease seems evident (Ney, 1991).

The composition of goat milk is improved by the addition of a PUFAs-rich fat, protected against the ruminal metabolism, to the goat's diet. In this case, milk fat is high in such fatty acids (Sanz Sampelayo *et al.*, 2000). It seems logical that changing the composition of the goat milk would also change that of the different adipose deposits in the animal consuming this milk. Studies carried out

with kid goats fed by their mothers show that if, during the mothers' lactation their diet is supplemented with a PUFA-rich protected fat, the growth of the young animals is stimulated. However, the development of the different fat deposits is unaffected (Sanz Sampelayo *et al.*, 2002). Addition of PUFAs in animal diets has other beneficial effects, such as improved reproductive efficiency (Burke *et al.*, 1997; Staples *et al.*, 1998). It appears to be logical to assume that some additional effect might occur on the composition of fat deposits in kid goats when their mothers' diet is supplemented with PUFAs, not only during lactation but also during the gestation period. Consequently, this paper presents results concerning the fatty acid composition of the different adipose deposits in kid goats whose mothers were fed a diet with a concentrate fraction that was supplemented or not with a PUFAs-rich protected fat; which was administered either only during lactation or during both gestation and lactation periods.

Materials and methods

Three groups of Malagueña goats were kept under semi-extensive breeding conditions, and received indoors a concentrate without (Group 1) or with (Group 2) a protected fat (PF) source. Animals in the third group (Group 3) were given the PF-concentrate along with gestation and lactation periods. The concentrate contained 5% fat protected against the ruminant metabolism (calcium salts), a fat of marine origin rich in PUFAs (27.09%). Of the kid goats born in each group, six were chosen randomly; and their mothers from birth until 45 days of age, being slaughtered on day 46. For this purpose, the animals were first anaesthetised and then killed by section of the jugular vein in the neck. After slaughter, the skin, feet, all internal organs and the heat were removed. The carcass was split into two sides. The leg was separated from the left side of the carcass, obtaining by dissection, all of the cover fat, the intermuscular fat and the muscle. The muscle was dried by lyophilization and the intramuscular fat obtained by extraction, using a chloroform-methanol mixture (2:1, v/v). The fat content of the milk and the fatty acid composition of the milk fat produced by the animals fed the two diets (fat-supplemented and non fat-supplemented) were measured throughout the rearing period. The fatty acid composition of the cover, intermuscular and intramuscular fat was also determined. The fat content of the milk samples was measured by Gerber's method, and the fatty acid profile of the different samples of milk and the fat deposits was determined by gas chromatography. The model accounted for variations caused by the type of feed given to the goats. The results were submitted to an ANOVA in accordance with the general linear model procedure.

Results and discussion

The aim of this study was to analyse the possibility of obtaining improved goat meat from young animals, the special quality of this meat being determined by the nature of the various adipose deposits. This would be affected by the diet provided to the kid goats' mothers either during lactation alone, or during lactation and the previous gestation. Fat content of the milk from the goats given the supplemented concentrate (45.9 and 44.0 g/kg for Groups 2 and 3, respectively) was higher than that of the non-supplemented animals (39.6 g/kg), although no significant differences were detected between these values ($P > 0.05$). On the other hand, the quantity of PUFAs detected in the milk fat was significantly higher in the samples corresponding to the diet-supplemented animals (3.75, 6.64 and 6.09% for Groups 1, 2 and 3, respectively). With respect to the fatty acid profile of the different adipose deposits in the kid goats (Table 1), in general higher PUFAs levels were recorded in the cover fat and in the intermuscular fat in the animals fed by females given the fat-supplemented diet, both during lactation and during gestation followed by lactation ($P < 0.05$). However, no significant differences were found between these latter two situations ($P > 0.05$). For intramuscular fat, the values for PUFAs concentration corresponding to the kid goats in Group 3 were higher ($P < 0.05$) than for those in Group 1. There was also no significant effect ($P > 0.05$) noted between the kid goats of Groups 1 and 2 or between those of Groups 2 and 3. With respect to the individual fatty acids, certain changes were observed in the composition of the different adipose deposits, affecting more or less equally the composition of the cover fat and of the inter and intramuscular fat. For the kid goats in the fat-supplemented group, both during lactation alone and during gestation followed by lactation, higher quantities of C16:0 were obtained ($P < 0.05$), and considerably lower quantities of C18:0 ($P < 0.05$). With respect to the PUFAs C18:4, C20:5, C22:5 and C22:6, the levels detected for the same animals, in their different fat deposits, were generally higher ($P < 0.05$). Finally, the levels of C18:2 detected for the three groups of kid goats, whether in the non-supplemented group or in the group whose the diet was supplemented during lactation or during gestation followed by lactation, were increasing. With

respect to the intramuscular fat, a significant difference ($P < 0.05$) was only found between the value for the Group 3 animals and those of Groups 1 and 2. This result is related to the levels of this acid detected in the fat of the corresponding milk that was, 3.43, 2.78 and 4.37%, for Groups 1, 2 and 3, respectively.

Table 1. Fatty acid composition of the different fat deposit of the kids

	Treatment†			RSD††	Level of significance
	1	2	3		
Cover fat					
C10:0	0.33[a]	0.39[a,b]	0.51[b]	0.13	*
C12:0	0.91	0.89	1.00	0.25	NS
C14:0	8.39	8.31	8.74	1.01	NS
C14:1	0.53[a]	0.37[b]	0.36[b]	0.12	*
C16:0	25.46[a]	29.17[c]	27.29[b]	1.24	***
C16:1	3.39	3.57	3.54	0.32	NS
C18:0	11.54[a]	8.59[b]	9.80[a,b]	2.22	*
C18:1	43.37	40.84	40.07	3.11	NS
C18:2	3.83	3.88	4.37	0.59	NS
C18:3	0.32	0.25	0.30	0.08	NS
C18:4	1.18[a]	2.64[b]	2.31[b]	0.44	***
C20:1	0.24[a]	0.55[a,b]	0.94[b]	0.35	**
C20:4	0.17[a]	0.12[b]	0.13[b]	0.03	*
C20:5	0.05[a]	0.09[a]	0.17[b]	0.03	***
C22:5	0.12[a]	0.21[b]	0.28[c]	0.05	***
C22:6	0.04[a]	0.14[b]	0.20[b]	0.07	***
PUFAs	5.71[a]	7.32[b]	7.76[b]	0.67	***
Intermuscular fat					
C10:0	0.39[a]	0.33[a]	0.61[b]	0.11	***
C12:0	1.03	0.92	1.16	0.22	NS
C14:0	8.82	8.50	9.30	0.81	NS
C14:1	0.34	0.34	0.31	0.06	NS
C16:0	26.15[a]	29.24[b]	27.35[b]	0.96	***
C16:1	3.19[a]	3.78[b]	3.58[b]	0.31	*
C18:0	11.30[a]	8.26[b]	9.86[b]	1.37	**
C18:1	43.29[a]	40.74[a,b]	39.30[b]	2.34	**
C18:2	3.58	3.81	4.61	0.46	**
C18:3	0.29	0.25	0.28	0.03	NS
C18:4	1.01[a]	2.56[b]	2.07[b]	0.44	***
C20:1	0.30[a]	0.52[a,b]	0.86[b]	0.28	**
C20:4	0.15[a,b]	0.17[b]	0.13[a]	0.02	*
C20:5	0.00[a]	0.13[b]	0.16[c]	0.02	***
C22:5	0.14[a]	0.27[b]	0.26[b]	0.03	***
C22:6	0.00[a]	0.20[b]	0.16[b]	0.04	***
PUFAs	5.17[a]	7.38[b]	7.66[b]	0.53	***
Intramuscular fat					
C12:0	0.44	0.42	0.43	0.08	NS
C14:0	5.05[a]	5.43[a]	3.95[b]	0.51	***
C14:1	0.87	1.01	0.53	0.48	NS
C16:0	21.64[a]	23.86[b]	22.29[a,b]	1.32	*
C16:1	2.27	2.45	2.45	0.44	NS
C18:0	12.80[a]	9.68[b]	9.95[b]	1.35	***
C18:1	38.59	34.93	35.77	3.39	NS
C18:2	10.39[a]	10.68[a]	13.25[b]	1.82	*
C18:3	0.55	0.58	0.62	0.13	NS
C18:4	0.65[a]	1.80[b]	1.64[b]	0.38	***
C20:1	0.42[a]	0.80[a,b]	1.33[b]	0.75	*
C20:4	4.34	4.01	3.56	0.84	NS
C20:5	0.44[a]	1.56[b]	1.74[b]	0.21	***
C22:5	1.19[a]	1.63[b]	1.46[b]	0.25	*
C22:6	0.38[a]	1.19[b]	1.03[b]	0.19	***
PUFAs	17.93[a]	21.43[a,b]	23.29[b]	3.01	**

†Treatments 1-3: goats not supplemented (1), supplemented during lactation (2) and during gestation plus lactation (3) with a protected fat rich in PUFAs.
††Residual standard deviation.
[a,b,c]Different superscripts between columns mean significantly different values.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; NS: not significant ($P > 0.05$).

Franklin *et al.* (1999) claimed that the fatty acid profile of adipose deposits and that of the milk fat of ruminants may be altered in a positive way by supplementing the animal's diet with an unsaturated fat suitably protected against the ruminant metabolism. Our results confirm the above conclusion, and reveal that when a PF, high in PUFAs is included in the diet of lactating goats, it improved milk-fat composition, but an additional effect occurred with regard to changes of the composition of the meat of the young kids. We also noted that when the protected fat is provided to goats during gestation to influence reproductive efficiency, and during lactation to modify the composition of the corresponding milk fat, the effects achieved on the composition of the different fat deposits in the corresponding kid goats were similar to those observed on the kid goats for which their mothers were supplemented only during lactation. Although the total quantities of PUFAs in the different fat deposits were somewhat higher in the first case, the differences measured were not statistically significant.

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