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Digestive utilization of the fat and individual fatty acids of a protected fat rich in PUFAs in goats

M.R. Sanz Sampelayo, J.R. Fernández Navarro, E. Ramos Morales, G. de la Torre Adarve and J. Boza
Unidad de Nutrición Animal, Estación Experimental del Zaidín (CSIC), Profesor Albareda 1, 18008 Granada, Spain

SUMMARY – The apparent fat and fatty acid digestibility was studied in young male Granadina goats fed two diets in which concentrate was supplemented or not with 6% polyunsaturated fatty acids (PUFAs)-rich protected fat. Particularly interesting results were those concerning the hydrogenation of C18 non-saturated fatty acids, obtained in animals fed the non-supplemented diet. This process was considerably less evident in animals fed the supplemented diet. Concerning the C20:5 and C22:6 PUFAs, consumed only by the group fed the supplemented diet, an excellent utilization was obtained in the intestinal tract, especially for the latter.

Key words: PUFAs supplementation, fat digestibility, individual fatty acids digestibility, goats.

RESUME – *"Utilisation digestive, par les caprins, de la graisse et des acides gras individuels d'une graisse protégée et riche en acides gras polyinsaturés". La digestibilité apparente de la matière grasse et des acides gras a été étudiée sur des boucs alimentés avec deux rations. Dans une des rations, le concentré était supplémenté avec 6% de matière grasse protégée riche en acides gras polyinsaturés. Une plus importante hydrogénation des acides gras insaturés de 18 atomes de carbone a été constatée chez les animaux ne recevant pas la source de MGNP par rapport à ceux disposant des MGNP. Concernant les acides gras polyinsaturés, C20:5 et C22:6 (ingérés seulement par le groupe supplémenté), on a constaté que, surtout, le C22:6 était plus efficace au niveau de l'intestin.*

Mots-clés : *Supplémentation avec des PUFAs, digestibilité des matières grasses, digestibilité des acides gras individuels, caprins.*

Introduction

When ruminants are fed diets supplemented with a polyunsaturated fatty acids (PUFAs) rich fat, protected against ruminal degradation, the composition of the different fatty acids in the intestine is greatly affected. Most of the studies carried out dealing with fats digestibility in ruminants have used sheep, calves and cows, but few data are available with regard to goats, an animal species of great interest today, due to the quality of its milk and meat (Haenlein, 1992; Boza and Sanz Sampelayo, 1997). This quality might be further improved by varying the nature and composition of fat included in the diet, as well as by improving its utilization by the animal.

In the non-ruminant animal, fatty acids digestibility decreases as carbonated chain size increases. On the contrary, digestibility increases with the number of double bonds making up the fat (Lessire *et al.*, 1992). These principles are equally applicable to ruminants, although in this case the differences are less important (Ferlay *et al.*, 1993).

Results obtained from experiments in which goats were fed a diet with a concentrate that was supplemented or not with a PUFAs-rich protected fat are presented. The apparent digestibility of fat and of its different fatty acids was determined by means of metabolism assays.

Materials and methods

Two groups of eight uncastrated male Granadina goats, aged 8-12 months were used. The animals were fed a diet made up of a forage, alfalfa hay mixed with cereal straw (500 g/animal/day), and a concentrate (600 g/animal/day). For one of the groups, the concentrate was supplemented with

6% protected fat, of marine origin, with a 35% PUFAs content, especially rich in the n-3 series. Both experimental diets were formulated taking into account the energy requirements of this species (Aguilera *et al.*, 1991). The protected fat was constituted of the calcium salts of its different fatty acids. These compounds were obtained and stabilised following the protocol designed by Boza *et al.* (2000). In the case of the fat-supplemented concentrate, the necessary quantity of this replaced an equal weight of the basic concentrate, except for the mineral-vitamin mixture. The degree of saponification of the protected fat was 84.8%, this quantity being calculated as the fat fraction not extracted without previous acid hydrolysis (Hermansen and Lund, 1990).

The animals were gradually accustomed to consuming the fat-supplemented concentrate, by replacing an increasing proportion of the standard concentrate with the fat-supplement concentrate. After this process, which lasted about 10 days, the animals were fed the experimental diets for a further 15 days period. After this period, they were held in individual metabolism cages for 7 days, the first 2 of which comprised the adaptation phase, and the following 5, the main phase during which trials were performed. During this latter period, at 09:00 h each day, the refusals of the previous day's diet and total faeces were individually collected and quantified. Subsequently, the animals were given their daily diet, with water being available *ad libitum*. The animals were weighed on arrival at the laboratory, and at the beginning and end of the metabolism trials. On the basis of the data obtained, the fat intake and apparent digestibility, as well as that of the different fatty acids making up the fat were determined. Coefficients of apparent digestibility were calculated from the total fat intake, that of the different fatty acids and the corresponding faecal flow. The diets and fecal fat content was determined by extraction with petroleum ether, after HCl hydrolysis. To establish the fatty acid profile of dietary fat in food refusals and faeces, the corresponding methyl esters were separated by gas chromatography. The results obtained were statistically analysed by the corresponding analysis of the variance, following the general linear model (Steel and Torrie, 1984).

Results and discussion

The average dry matter daily intakes were 800.5 and 775.5 g/animal for animals fed fat-supplemented and non-supplemented concentrates, respectively. The difference between these values was not statistically significant ($P > 0.05$). Table 1 shows data corresponding to the total intake, faecal flow and apparent digestibility either of total fat and different fatty acids, illustrating differences between groups.

As expected, the fat digestibility was statistically greater ($P < 0.05$) for animals fed diet-supplemented than for control group (Shell *et al.*, 1978). Fatty acids detected in the faeces of ruminants not only represent faecal fraction of dietary origin, undigested or absorbed, but they may also be of other origins, such as those having been synthesized in the rumen, or derived from bacterial cells or from one or more endogenous sources (Bock *et al.*, 1991). Therefore, the apparent digestibility of the different fatty acids in a source of fat represents net disappearance of these fatty acids in the total intestinal tract. From the latter values it is possible to identify certain changes undergone by consumed fatty acids and, in consequence, the nature of the absorbed fat in relation to that consumed. In the present study, irrespective of the values included in Table 1, we observed how certain fatty acids which the intake was zero or practically so, namely C4:0, C10:0, C12:0, C15:0 and C17:0, appeared in the faeces of both groups of animals. This fact suggests that those fatty acids were synthesized in the rumen or from endogenous origin.

The apparent digestibility of saturated fatty acids C14:0, C16:0, C18:0 and C20:0, corresponding to the animals fed fat-supplemented diet, presented values significantly higher ($P < 0.05$) than those of the control group. For the former group, the digestibility of these acids was always positive, and normal values were registered, while for the control group (with the exception of C16:0 acid) the digestibility was negative, and faecal flows higher than the quantities consumed in each case were detected. The high percentage of saturated fatty acids, generally detected in ruminant faeces as stated by Shell *et al.* (1978), could be derived from the dietary fat hydrogenation, in the rumen or in the large intestine; from endogenous excretion; or from the selective absorption of mono or polyunsaturated fatty acids.

From these observations, and taking into account that faecal flow values of C14:0, C16:0 and C20:0 acids did not differ greatly between the two groups of animals, it might be assumed that the endogenous origin of these flows, or their production by the hydrogenation of others, would affect

Table 1. Intake (g/day), faecal flow (g/day) and total digestive tract apparent digestibility (%) of total fat and individual fatty acids

	Treatment†		SE	Level of significance
	1	2		
Fat				
Intake	53.6	26.7	3.04	***
Faecal flow	9.9	8.6	2.00	NS
Digestibility	81.5	67.8	6.26	**
C14:0				
Intake	1.18	0.10	0.02	***
Faecal flow	0.40	0.30	0.06	***
Digestibility	66.1	–200.0	24.30	***
C16:0				
Intake	10.94	4.77	0.17	***
Faecal flow	3.46	2.49	0.17	**
Digestibility	68.4	47.8	2.67	***
C16:1				
Intake	1.61	0.28	0.02	***
Faecal flow	0.22	0.06	0.01	***
Digestibility	86.3	78.6	2.64	NS
C18:0				
Intake	2.76	1.03	0.04	***
Faecal flow	1.04	2.87	0.35	*
Digestibility	62.3	–178.6	32.33	**
C18:1				
Intake	14.96	7.70	0.27	***
Faecal flow	1.47	0.91	0.09	**
Digestibility	90.2	88.2	0.78	NS
C18:2				
Intake	14.16	11.09	0.31	***
Faecal flow	0.56	0.32	0.03	**
Digestibility	96.0	97.1	1.28	*
C18:3				
Intake	2.32	1.51	0.24	***
Faecal flow	0.24	0.10	0.01	***
Digestibility	89.7	93.4	0.37	***
C20:0				
Intake	0.31	0.14	0.01	***
Faecal flow	0.24	0.17	0.01	*
Digestibility	22.6	–21.4	9.25	**
C20:1				
Intake	0.81	0.12	0.01	***
Faecal flow	0	0	0	NS
Digestibility	100.0	100.0	0	NS
C20:5				
Intake	1.15	0	0.06	***
Faecal flow	0	0	0	NS
Digestibility	100.0	–	–	–
C22:0				
Intake	0.67	0	0.02	***
Faecal flow	0	0	0	NS
Digestibility	100.0	–	–	–
C22:6				
Intake	2.70	0	0.06	***
Faecal flow	0	0	0	NS
Digestibility	100.0	–	–	–

†Treatement 1-2: Goats supplemented and not supplemented with a protected fat rich in PUFAs, respectively.
*P < 0.05; **P < 0.01; ***P < 0.001; NS: Not significant.

animals in the fat-supplemented group and in the control group equally, with differing coefficients of digestibility resulting from the different intakes. Specifically, with regard to C18:0 acid, Bock *et al.* (1991) reported high concentrations of this acid in faeces and speculated that they could be of endogenous or bacterial origin, or be due to dietary C18:1, C18:2 and C18:3 acids hydrogenation. Ashes *et al.* (1992) stated that this process could become widespread. Given the value of the faecal flow of this acid, recorded in the control group, in comparison with the one in the fat-supplemented group, it is logical to assume that in addition to the endogenous or bacterial origin of part of this faecal flow, another fraction would be derived from the hydrogenation of an equal number of atoms of carbon of unsaturated fatty acids.

Concerning fat-supplemented group, and although hydrogenation of the C18 unsaturated fatty acids could take place, its effect according to the corresponding value for the faecal flow of C18:0, must be smaller than that on the control group. The latter might be due to the fat protection against ruminal metabolism.

Apparent digestibility of C18:1 acid showed no significant differences ($P > 0.05$) between the experimental groups, while digestibility of C18:2 and C18:3 acids, was higher ($P < 0.05$) for the non-supplemented group. If, as indicated above, hydrogenation of unsaturated fatty acids of 18 atoms of carbon took place in the control group to a greater extent than in the supplemented group, this would reflect a situation in which apparent digestibility coefficients of hydrogenised fatty acids were overstated. Thus, true differences between groups concerning these coefficients might be different from those recorded. Nevertheless, it should be noted that mono and polyunsaturated fatty acids digestibility is normally high (Ferlay *et al.*, 1993). In relation to the digestibility estimated for fatty acids of 18 atoms of carbon, it is also necessary to consider that, with respect to the post-ruminal digestibility another fact could also alter the characteristics of consumed fatty acids, namely the desaturation activity of the intestinal epithelium, by which saturated fatty acids are converted into monounsaturated ones. Especially important is the conversion of C18:0 into C18:1, a process that in the opinion of Grummer (1991) is of lesser degree and opposite nature to that of ruminal hydrogenation. According to Grummer (1991), and taking into account the digestibility coefficients estimated in the present study for C18:0 and C18:1 acids, it does not seem logical to assume that the above-mentioned desaturation process could become significant with respect to that of hydrogenation.

Concerning C20:0 and C20:1 fatty acids, it might be deduced from the corresponding faecal flows and coefficients of digestibility that part of the dietary C20:1 might, in both cases, have been hydrogenated. This fact would account for the low or even negative coefficient detected for C20:0 as well as the high degree of digestibility of C20:1 detected in the two groups. Finally, the fatty acids C20:5 and C22:6, which together with C22:0 were consumed only by the fat-supplemented group of animals, presented no faecal flows. Consequently, the coefficients of apparent digestibility for these were equal to 100. With respect to the C20:5 and given that the faecal flow of the saturated fatty acid with an equal number of atoms of carbon, C20:0, part of this fatty acid may be assumed to have been hydrogenated, that would lead to an overstatement of the corresponding coefficient of digestibility. However, if we consider C22:6, and taking into account that the faecal flow of C22:0 is also non-existent, it does not seem logical to assume that in this case a significant degree of hydrogenation of the latter took place, and that consequently the calculated coefficient of digestibility was overstated. With regard to these two PUFAs some authors have showed the impossibility of these fatty acids being hydrogenated to any significant degree in the rumen, due to the lack of specific enzymes or esterification factors (Ashes *et al.*, 1992).

The results obtained reflect a digestive efficient utilisation of the different fatty acids of the fat in the supplemented diet consumed by the goat. Moreover, the variations observed between the fat in the two diets would be due to the fact that the PUFAs-rich diet was adequately protected against the ruminal metabolism and stabilised by means of various antioxidant substances.

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