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The effect of animal fat on sheep's diet digestibility, degradability and rumen fermentation process

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ABSTRACT

The effect of replacement of maize grain by animal fat in a diet with high level of acid detergent fibre (27%) on diet digestibility, rumen fermentation and energy content of the diet was evaluated. Six fistulated wether sheep were used in a 2 x 2 Latin square experimental design in three replicates. Forage : concentrate ratio in the diets was 47.7 : 52.3 and animal fat contributed to concentrates by 7%, replacing maize on a weight basis. Digestibility of ether extract was increased ($P<0.001$) by 13.1% for the diet with fat compared to the diet without fat, while digestibility coefficients of the other nutrients were unaffected. The energy content of the diet with fat increased by 3.4% ($P<0.05$). The inclusion of animal fat to sheep diet increased significantly the molar proportion of propionate ($P<0.05$) by 10.7% and the crude protein degradability ($P<0.001$) by 4%, and decreased the molar proportion of butyrate by 6.1% ($P<0.05$), the acetate to propionate ratio ($P<0.01$) by 13.2%, and the protozoa counts by 32% ($P<0.001$).

The results showed that animal fat can replace cereal grains in sheep diets up to the level of 5% without any problem on rumen fermentation process.

KEY WORDS: animal fat, sheep, digestibility, degradability, fermentation

INTRODUCTION

Different sources of fat are used in ruminant nutrition to increase diet's energy content, to replace a proportion of cereal grains, or to alter the fatty acids profile of milk fat (Palmquist and Conrad, 1978; Palmquist, 1984; Grummer, 1991). The inclusion of non-protected fat in ruminant diets can adversely affect the fermentation process in the rumen by causing a reduction on fibre degradability and on diet's digestibility. Therefore, the recommended percentage of fat in ruminant diets is 3-5% (Palmquist and Jenkins, 1980). Fat is not fermented by rumen microorganisms and does not contribute to their growth (Stern et al., 1984). Thus the replacement of highly fermented carbohydrates by fat, can reduce protein synthesis in the rumen (Hvelplund and Madsen, 1990) and consequently animal amino acid requirements may not be met. From the literature it can also be seen that the fibre level of a diet can influence the effect of fat on rumen fermentation process. Thus an increased fibre level may reduce the negative effects of non-protected fat on rumen bacteria, due to the fact that the fatty acids are attached to fibre particles (Palmquist and Conrad, 1978; Palmquist and Jenkins, 1980).

The objective of this work was to study the effects of maize grain replacement by animal fat, when sheep's diet had high ADF content, on diet's digestibility, degradability and rumen fermentation process.

MATERIAL AND METHODS

Six adults fistulated wethers of the Karagouniko breed, with an average body weight (BW) of 63.3 (±3.45) kg, were used in a 2 x 2 Latin square experimental design in 3 replicates. The first treatment was a diet without fat (CC), while the second one had 7% animal fat (FC) in concentrate (Table 1) in replacement of maize grain on a weight basis. Feed intake was adjusted individually according to sheep BW and consisted of 320 g lucerne hay + 200 g wheat straw per day per sheep, and 9 g concentrates per kg BW. Thus the sheep were taking on average 520 g forage + 570 g concentrate per day with a forage : concentrate ratio of 47.7:52.3. No refusals where left during the whole experimental period, while water was available *ad libitum*.

TABLE 1

Concentrate composition, g kg^{-1}

Ingredients	CC[1]	FC[2]
Maize	527	452
Wheat middlings	195	195
Sunflower meal	140	140
Soyabean meal	90	90
Fat	-	70
$CaCO_3$	26	31
Calcium phosphate	12	12
NaCl	3	3
Trace mineral and vitamin premix	7	7

[1] CC: control concentrate

[2] FC: concentrate with fat

The sheep after weighing were put in metabolism cages. Each period lasted 21 days. The first 10 days were used as an adaptation period (pre - experimental), the next 7 days total faecal collection was carried out for digestibility determination, the following 2 days rumen liquid was collected through the fistula at time 0, 2 and 4 h after morning feeding, and the last 2 days dacron bags were put into the rumen through the fistula for dry matter (DM) and crude protein (CP) degradability determination of the two concentrates used in the experiment. The pH values, NH_3 and volatile fatty acids (VFA) concentration, and the number of protozoa were determined in rumen liquid samples. NH_3 concentration was determined by the method of Kolb and Kamyshnikov (1982), while concentrate degradability according to Mehrez and Ørskov (1977) method with dacron bags of pore size 45 μm, and incubation time of 24 h. The pH of rumen fluid was determined immediately after withdrawing the samples, with a pH-meter (ORION, SA 720, Boston, USA). The VFA concentration and the chemical composition of forages, concentrates and faeces samples were determined as described by Zervas et al. (1999).

The energy content of the whole diets, in Net Energy of Lactation (NE_L), was calculated according to Van Es (1978) and Schiemann et al. (1972) equations. Statistical analysis of the results was done according to Steel and Torrrie (1960), at the significance level of $P<0.05$ according to the following linear model:

$$Y_{ijk} = \mu + E_i + e_{ijk}$$

where Y_{ij} = the observation of j sheep of i treatment
μ = the overall mean
E_i = the fixed effect of i treatment and
e_{ijk} = experimental error $(0, \sigma^2)$

RESULTS

The chemical composition of the forages and concentrates is given in Table 2. The chemical composition of the consumed diets is given in Table 3 which didn't differ among treatments, except for EE content which was 5.1% and 1.7% for the diets with (FC) and without (CC) fat, respectively. NDF concentration was about 42% in both diets (treatments) and ADF concentration almost similar and rather high (~ 27%) for both diets.

The inclusion of fat to the FC diet had no significant effect on nutrients apparent digestibility coefficients, except of that of EE which was significantly ($P<0.001$) higher in FC group, compared to the CC diet (Table 4). However, the energy content of the diet with fat (FC) was increased by 3.4% compared to the control (CC) diet ($P<0.05$). Ruminal pH, ammonia concentration and concentrate DM degradability were not affected by fat inclusion (Table 5), while CP degradability increased

TABLE 2

Chemical composition of feed

Nutrients	CC[1]	FC[2]	Lucerne hay	Wheat straw
Dry matter, g/kg	878.8	897.4	897.2	899.9
		g/kg DM		
Organic matter	938.6	917.2	894.8	891.9
Crude protein	166.4	159.0	180.5	47.9
Ether extract	22.4	86.1	11.5	8.4
Crude fibre	88.0	82.4	309.3	452.4
N-free extractives	661.8	589.7	393.2	383.2
NDF	251.3	237.9	467.7	847.1
ADF	123.1	119.7	377.0	510.4
Lignin + coutin	40.1	46.2	99.2	68.4

[1] CC: control concentrate
[2] FC: concentrate with fat

TABLE 3

Chemical composition of the ingested diets

Nutrients	Treatments	
	CC[1]	FC[2]
Dry matter, g/kg	889	899
	g/kg DM	
Organic matter	917	906
Crude protein	148	145
Ether extract	17	51
Crude fibre	221	216
N-free extractives	531	494
NDF	424	415
ADF	269	266
Lignin + coutin	63	66

[1] CC: control concentrate
[2] FC: concentrate with fat

significantly ($P<0.001$) by 4%. Protozoa counts in the ruminal liquid were reduced ($P<0.001$) by 32% in the diet with fat. Total VFA's concentration and molar proportion of acetate didn't differ among treatments (Table 6), while the molar proportion of propionate increased ($P<0.05$) by 10.7%, and the molar proportion of butyrate decreased ($P<0.05$) by 6.1%. Finally the acetate to propionate ratio decreased ($P<0.01$) by 13.2% for the diet with fat.

TABLE 4

Apparent digestibility coefficients of nutrients and diet energy content, %

	Treatments		SEM	Significance level[3]
	CC[1]	FC[2]		
Dry matter	71.66	70.90	0.798	NS
Organic matter	74.79	73.58	0.672	NS
Crude protein	80.18	81.37	0.683	NS
Ether extract	82.31	93.06	1.486	***
Crude fibre	52.12	49.26	1.360	NS
N-free extractives	81.94	80.40	0.602	NS
NDF	58.83	57.93	1.050	NS
ADF	52.99	54.60	1.197	NS
NEL, MJ/kg DM	6.54	6.76	0.057	*

[1] CC: control concentrate

[2] FC: concentrate with fat

[3] *** P<0.001, * P<0.05, NS: not significant

TABLE 5

Mean concentrate DM and CP degradability, pH values, NH_3 concentration and protozoa counts in rumen liquid samples of sheep

	Treatments		SEM	Significance level[3]
	CC[1]	FC[2]		
DM degradability, %	81.60	81.09	.456	NS
CP degradability, %	84.42[a]	87.79[b]	.556	***
pH	6.47	6.22	.068	NS
NH_3 concentration, mg/dl	24.65	23.75	1.480	NS
Protozoa counts x, 10^5/ml	6.34	4.31	.290	***

[1] CC: control concentrate

[2] FC: concentrate with fat

[3] *** P<0.001, NS: not significant

DISCUSSION

The lack of effect of added fat on nutrients apparent digestibility coefficients (Table 4) may be due to relatively high level of dietary ADF (27%), that may reversed the negative effect of fat (Palmquist and Conrad, 1978; Palmquist and Jenkins, 1980), or to the fact that fat concentration was not high enough and the fat itself was saturated (Palmquist and Jenkins, 1980; Moore et al., 1986). However, in the present study, the lack of significant difference in DM degradation (Table 5), in total VFA concentration and in molar proportion of acetate (Table 6) are

TABLE 6

Mean volatile fatty acids (VFAs) concentration in rumen liquid, %

	Treatments		SEM	Significance level
	CC[1]	FC[2]		
Total VFAs	73.93	70.96	3.79	NS
		molar proportion, %		
Acetate	61.28	60.97	.413	NS
Propionate	20.18	22.34	.398	*
Isobutyrate	2.24	1.52	.077	***
Butyrate	12.51	11.75	.270	*
Isovaleric	2.02	1.63	.084	**
Valeric	1.50	1.79	.079	NS
Acetic:propionic	3.10	2.69	.071	**

[1] CC: control concentrate

[2] FC: concentrate with fat

*** P<0.001, ** P<0.01, * P<0.05, NS: not significant

indications for absence of disturbance in rumen fermentation process. Therefore, it seems that the low feeding level (maintenance) and the starch replacement by fat on a weight basis and at a low level are the two major reasons for non significant differences in nutrient digestibility coefficients.

The increased ether extract (EE) digestibility for the diet with fat is in general agreement with the results of Palmquist and Conrad (1980), Jenkins and Palmquist (1984) and Moore et al. (1986), who used animal fat in rations of dairy cows and steers. The addition of animal fat in ruminant diet generally increases EE digestibility (Palmquist, 1984), depending on reduced ratio of non digestible lipids in the diet, or reduced ratio of endogenous lipids in the faeces (Palmquist and Conrad, 1978; Elliott et al., 1993).

The increased energy content (NE_L) of the diet, when an amount of maize (a feed with high energy density) was replaced by the same amount of animal fat (Table 4), provides evidence that cereal grains could be replaced by fat in sheep diet without any adverse effects on the animals.

The addition of animal fat in the diet had no significant effect on DM degradability (Table 5) which can be explained by the arguments reported previously for digestibility coefficients. The absence of effect on DM degradability perhaps is also due to high ratio of saturated fatty acids in animal fat, which have smaller negative effect than unsaturated fatty acids (Palmquist and Jenkins, 1980). The increased CP degradability could be attributed to the declined counts of protozoa (Ushida et al., 1991), to the modification of bacterial population and to their increased activity, or mainly to the reduced contribution of low degradability maize protein to FC concentrate protein. Similar results were found by Goulas (2000) who also used animal fat. On the contrary, Weisbjerg et al. (1992) added animal fat in cows' diets and he found unaffected CP degradability.

Supplementation of diet with fat didn't affect significantly ruminal pH (Table 5) and this is in agreement to the lack of difference in total VFA concentration (Table 6). Grummer et al. (1993) found a decline in ruminal pH, but also an increased concentration of VFA. Such a decline in pH was apparent also in this work, but it was not significant. The decrease of protozoa count in the present study may be due to the negative effect of fat on protozoa survival. Similar results were reported by Czerkawski (1973) and Ikwuegbu and Sutton (1982) who used vegetable oil, while Weisbjerg et al. (1992), who used tallow, found a declining trend on protozoa count.

The concentration of total VFA didn't differ among treatments (Table 6) and this is associated to the absence of differences in DM degradability between diet with or without fat (Table 5). Supplementation of diets with fat does not affect total VFA concentration (Palmquist and Conrad, 1980; Jenkins et al., 1998). However, Weisbjerg et al. (1992) found a significant decline in VFA concentration, while Grummer et al. (1993) found that the addition of tallow up to 3% in dairy cows' diet increased linearly total VFA concentration.

The molar proportion of acetate for the diet with fat didn't differ compared to the diet without fat, and that reflects the lack of disturbance of fibre fermentation in the rumen by the inclusion of animal fat (Kowalczyk et al., 1977; Weisbjerg et al., 1992; Elliott et al., 1993,1997; Bertrand and Gimes, 1997). Increased molar proportion of propionate and decreased acetate to propionate ratio were found by Kowalczyk et al. (1977), Weisbjerg et al. (1992), Bertrand and Gimes (1997) and Elliott et al. (1997) who added animal fat to dairy cows' diets. Finally, the significant reduction of molar proportion of butyrate is in agreement to the results of Tackett et al. (1996) and Bertrand and Gimes (1997).

CONCLUSIONS

The unaffected nutrients apparent digestibility coefficients and DM degradability, indicated that animal fat didn't disturb the rumen fermentation process, while increased the energy content of the diet. Consequently, it could be concluded that the replacement of cereal grains by animal fat, is feasible up to 5% total fat concentration in sheep diets, particularly when the ADF content of the diet is relatively high.

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STRESZCZENIE

Wpływ dodatku tłuszczu zwierzęcego na strawność składników pokarmowych dawki, degradację białka i procesy fermentacyjne w żwaczu

Badano wpływ zastąpienia ziarna kukurydzy tłuszczem zwierzęcym w dawce z wysoką zawartością ADF (27%) na strawność składników pokarmowych, przebieg fermentacji w żwaczu oraz wartość energetyczną dawki. Doświadczenie przeprowadzono na 6 przetokowanych skopach w układzie kwadratu łacińskiego 2 x 2. Stosunek paszy objętościowej do treściwej w dawkach wynosił 47,7 : 52,3; udział tłuszczu zwierzęcego stanowił 7% paszy treściwej, zastępując wagowo ziarno kukurydzy.

Strawność ekstraktu eterowego dawki z tłuszczem zwiększyła się ($P<0,001$) o 13,1% w porównaniu z kontrolną, podczas gdy strawność pozostałych składników pokarmowych nie różniła się. Wartość energetyczna dawki z dodatkiem tłuszczu zwiększyła się o 3,4% ($P<0,05$) w porównaniu z kontrolną. Przy skarmianiu dawki z udziałem tłuszczu zwierzęcego istotnie zwiększył się ($P<0,05$) molarny udział propionianów, o 10,7%, oraz rozkład białka ogólnego o 4% ($P<0,001$), a obniżył się molarny udział maślanów o 6,1% ($P<0,05$), stosunek octanów do propionianów o 13,2% ($P<0,001$) oraz liczba pierwotniaków o 32% ($P<0,001$).

Otrzymane wyniki wskazują, że tłuszczem zwierzęcym można częściowo (do 5%) zastąpić ziarno zbóż w dawkach dla owiec bez zakłócenia przebiegu fermentacji w żwaczu.