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in

Ranilla M.J. (ed.), Carro M.D. (ed.), Ben Salem H. (ed.), Morand-Fehr P. (ed.).
Challenging strategies to promote the sheep and goat sector in the current global context

Zaragoza : CIHEAM / CSIC / Universidad de León / FAO
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 99

2011
pages 41-46

Digestibility and ruminal fermentation of diets differing in forage type and forage to concentrate ratio in sheep and goats

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Abstract. The aim of this work was to compare digestibility and ruminal fermentation variables in sheep and goats fed good-quality diets at similar levels of intake. The four experimental diets had forage:concentrate ratios of 70:30 (H) or 30:70 (L) and either alfalfa hay (A) or grass hay (G) as forage. Four Granadina goats and 4 Merino sheep fitted with ruminal cannulae were used in a 4 x 4 Latin square design. Animals were fed the diets at a daily rate of 56 g dry matter (DM)/kg body weight$^{0.75}$ to minimise feed selection. Intake of neutral-detergent fibre (NDF; g/kg body weight$^{0.75}$) was lower in goats compared to sheep for HA, LA and HG diets (*P*=0.02, 0.03 and 0.02, respectively). No differences between AS were found in either DM (*P* =0.28) or NDF digestibility (*P*=0.23), but crude protein digestibility of HA and LG diets was 4.9 and 12.1% greater in goats than in sheep. Ruminal pH and proportions of propionate and isoacids were similar (*P*>0.05) in both animal species, but VFA concentrations in ruminal fluid were greater (*P*<0.003) and those of NH_3-N lower (*P*<0.01) in sheep. Sheep presented lower acetate and greater butyrate proportions (*P*<0.05) than goats with H diets, but no differences (*P*>0.05) were found with L diets. Total protozoa numbers were 5.8 and 3.7% greater in goats than in sheep for LA and LG diets, respectively, but no differences (*P*=0.10) were found in the proportion of Holotricha. The results indicate that both AS can show similar digestive capacities when they are fed good-quality diets at a restricted level of intake, in spite of subtle differences in ruminal fermentation.

Keywords. Sheep – Goat – Digestibility – Ruminal fermentation – Forage:concentrate ratio – Forage.

Digestibilité et fermentation ruminale de régimes renfermant differents types de fourrages et des rapports fourrage : concentré chez des caprins et des ovins

Résumé. *L'objectif de ce travail était de comparer la digestibilité et la fermentation ruminale chez les ovins et les caprins recevant des régimes de bonne qualité à des niveaux d'ingestion similaires. Les quatre régimes expérimentaux ont des rapports fourrage: concentré 70 : 30 (H) ou 30 : 70 (L) et de foin de luzerne (A) ou de foin de graminées (G) comme fourrage. Quatre chèvres Granadina et 4 ovins Merino munis de canules du rumen ont été utilisés selon un dispositif en carré Latin (4 x 4). Les animaux ont été nourris à un taux quotidien de 56 g de matière sèche (DM) / kg de poids^{0,75} á fin de réduire la sélection de l'aliment. L'ingestion des fibres totales (NDF, g / kg de poids^{0,75}) était plus faible chez les chèvres par rapport à des ovins pour les régimes HA, LA et HG (P = 0,02, 0,03 et 0,02, respectivement). Pas de différences entre les espèces animales ont été trouvées dans la digestibilité de la DM (P = 0,28) ou NDF (P = 0,23), mais la digestibilité des protéines brutes des régimes HA et LG a été de 4,9 et 12,1% supérieure chez les chèvres que celle obtenue sur des ovins. Le pH du rumen et les proportions de propionate et isoacides étaient similaires (P > 0,05) dans les deux espèces animales, mais les concentrations des VFA dans le liquide ruminal ont été plus importantes (P < 0,003) et celles de NH_3-N plus faible (P < 0,01) chez les ovins. Les ovins ont une proportion d'acétate plus faible et une proportion de butyrate plus élevée (P <0,05) que celles déterminée chez les chèvres recevant le régime H, mais aucune différence de ces acides gras volatils n'at été constatée entre les deux espèces animales (P > 0,05) soumis au régime L. Le nombre total de protozoaires a été 5,8 et 3,7% plus élevé chez les chèvres que chez les ovins recevant les régimes LA et LG, respectivement, mais la proportion de Holotricha. L n'a pas été affectée (P = 0,10). Les résultats montrent que les caprins et les ovins peuvent avoir des capacités digestives similaires lorsqu'ils sont nourris avec des régimes de bonne qualité.*

Mots-clés. *Ovin – Caprin – Digestibilité – Fermentation ruminale – Fourrage: concentré – Fourrage.*

I – Introduction

Comparative feeding behaviour and digestive capacity in sheep and goats have been extensively investigated (Brown and Johnson, 1984), but the results have been often inconsistent. In general, goats are considered better browsers than sheep, have a higher voluntary feed intake, and can digest fibre more efficiently, particularly when fed low or medium-quality diets (García *et al.*, 1994; Molina-Alcaide *et al.*, 1997; Yáñez-Ruiz *et al.*, 2004ab). Only few studies have, however, compared the two species when they consume high-quality diets representative of those used in practical conditions in producing animals (Ramanzin *et al.*, 1997), and some of them (Ranilla *et al.*, 2005) were conducted at different levels of intake making difficult direct comparisons of data. The aim of the present work was therefore to compare digestibility and ruminal fermentation in sheep and goats fed four good-quality diets at similar levels of intake. The diet ingredients were selected to represent those most frequently used under practical feeding conditions of both animal species in Spain.

II – Material and methods

1. Animals and diets

Four Granadina goats [48.3 ± 1.43 kg body weight (BW)] and 4 Merino sheep (52.5 ± 3.10 kg BW) fitted with ruminal cannulas were used in a 4 x 4 Latin square design. Animals were housed in individual pens and had continuous access to fresh water and vitamin/mineral block over the experimental period. Animals were cared and handled in accordance with the Spanish Animal Care Regulations (Royal Decree 1201/2005 of October 10th on the protection of animals used for experimentation or other scientific purposes). Four total mixed diets were formulated according to a 2 x 2 factorial arrangement of treatments. The diets had forage:concentrate [FC; dry matter (DM) basis] ratios of 70:30 (H) or 30:70 (L) with either alfalfa hay (A) or grass hay (G) as forage, and were designated as HA, LA, HG and LG. The concentrate was based on barley, gluten feed, wheat middlings, soybean meal, palmkern meal, wheat, corn and mineral-vitamin premix in the proportions of 215, 204, 200, 135, 115, 50, 50 and 31 g/kg, respectively (fresh matter basis). Diets were offered to the animals twice daily (08:00 and 14:00 h) at a daily rate of 56 g DM/kg $BW^{0.75}$ to minimise feed selection. Samples of diets and refusals were collected daily over the trial and composited weekly. Samples were dried at 55°C in an oven for 48 h and ground through a 1-mm screen before chemical analyses (Table 1).

Table 1. Dry matter content (g/kg; DM) and chemical composition (g/kg DM) of the experimental diets

Diets†	Dry matter	Organic matter	Crude protein	Neutral-detergent fibre	Acid-detergent fibre
HA	927	913	168	426	270
LA	925	913	177	374	189
HG	925	927	121	499	239
LG	924	919	160	401	176

† HA: 70:30 alfalfa hay:concentrate; LA: 30:70 alfalfa hay:concentrate; HG: 70:30 grass hay:concentrate; LG: 30:70 grass hay:concentrate.

2. Experimental procedure

Each 19-d experimental period consisted of 10 days of dietary adaptation and 9 days for sample and data collection. On day 4, animals were moved to metabolism cages equipped for quantitative collection of faeces. After 6 days of adaptation, faeces voided by each animal in 24 h were

quantitatively collected for 7 days. An aliquot (20%) of total fecal output was collected each day for digestibility determination and dried at 55ºC to constant weight before analysis. Samples of faeces were pooled for each animal to form composite samples. On day 17, animals were moved again to floor pens. On day 19, ruminal content samples (about 100 g) were taken through the cannula of each animal at 0 and 4 h after the morning feeding. Ruminal content was strained through four layers of cheesecloth, the pH of the fluid was immediately measured, 5 ml of fluid were added to 5 ml of deproteinizing solution for volatile fatty acid (VFA) analyses, 2 ml were added to 2 ml 0,5 M HCl for NH_3-N determination, and 5 ml were added to 5 ml of methylgreen-formalin solution and stored at room temperature in the dark until used for protozoal counting. Protozoa were counted using a Neubauer Improved Bright-Line counting cell (Hausser Scientific, Horsham, PA, USA), and total protozoa numbers and holotricha proportion were recorded.

3. Analytical procedures and statistical analyses

Procedures for determination of DM, ash, NDF, N, VFA and ammonia-N have been reported by Cantalapiedra-Híjar *et al.* (2009). Data were analyzed using the MIXED procedure (SAS Inst. Inc., Cary, NC). The effects of animal species (AS), FC ratio, type of forage (FOR), period, and the interactions AS x FC, AS x FOR were considered fixed, and animal within specie effect was considered random. When a significant effect of treatment (P<0.05) was detected, differences among means were tested using the Tukey's multiple comparison test.

III – Results and discussion

There was no difference (P=0.26) in the initial BW between species, and BW was not affected either by FC (P=0.69) or FOR (P=0.53) through the trial (results not shown). The study was designed to avoid diet selection, in order to compare animals of the two species on similar diet composition. The selective behaviour of goats was, however, not completely inhibited. The diets were offered at a daily rate of 56 g DM/kg $BW^{0.75}$, but intakes in goats ranged from 45.8 to 51.1 g DM/kg $BW^{0.75}$ (Table 2). In sheep, DM intake values for diets containing A were close to the amount offered (54.6 and 55.3 g DM/kg $BW^{0.75}$ for HA and LA, respectively), but intake of G diets was lower (50.3 and 51.7 g DM/kg $BW^{0.75}$ for HG and LG, respectively). The greater (P=0.02) intake of A diets observed in both species may have been be due to a higher palatability of A compared to G, and to differences in chemical composition and digestibility between both forages. Forage legumes usually have lower cell wall content, higher ruminal degradability, and faster digestion and passage rates compared to grasses. Intake of CP was similar (P=0.79) in both AS, but NDF intake (g/kg $PV^{0.75}$) was lower in goats compared to sheep for HA, LG and HG diets (P=0.02, 0.03 and 0.02, respectively) and tended to be lower for LA diet (P=0.10). For both AS, intakes of CP (P<0.001) and NDF were greater (P<0.001) and lower (P<0.001), respectively, for diets containing A than for G diets, which was attributed to differences between forages in the CP and NDF content (Table 1).

No differences between sheep and goats were found in either DM (P=0.28) or NDF digestibility (P=0.23). These results are consistent with those found in the literature (Domingue *et al*., 1991; Ranilla *et al*., 2005), and suggest that no differences in digestibility might be expected between sheep and goats fed good quality diets. However, CP digestibility of HA and LG diets was greater (P=0.006) in goats than in sheep. These results are in accordance with the greater NH_3-N concentrations found in the rumen of goats in this (P=0.01; Table 3) and other studies (Molina-Alcaide *et al*., 2000), which would indicate a greater proteolytic activity compared to sheep and/or a more efficient N recycling (Domingue *et al*., 1991). Both DM and NDF digestibilities were higher (P<0.001) for L than for H diets, but significant AS x FC ratio interactions were detected. Whereas no differences among diets (P>0.05) on NDF digestibility were detected in sheep, HA diet had lower (P<0.05) NDF digestibility compared to the other diets in goats.

Table 2. Intake and digestibility of dry matter (DM), crude protein (CP) and neutral-detergent fibre (NDF) in sheep and goats fed diets diets with forage:concentrate (FC) ratios of 70:30 (H) or 30:70 (L) and alfalfa hay (A) or grass hay (G) as forage (FOR)

Item	AS†	Diet				SEM	Statistical effect (*P* =)				
		HA	LA	HG	LG		AS	FC	FOR	AS x FC	AS x FOR
Intake, g/d											
DM	Sheep	1061[b]	1094[b]	986[b]	1005[b]	42.3	0.01	0.46	0.02	0.92	0.93
	Goat	865[a]	924[a]	828[a]	809[a]						
Intake, g/kg body weight$^{0.75}$											
DM	Sheep	54.6	55.3	50.3	51.7	2.13	0.02	0.55	0.02	0.75	0.93
	Goat	49.0	51.1	46.3	45.8						
CP	Sheep	8.63	9.95	5.90	8.20	0.39	0.79	<0.001	<0.001	0.27	0.16
	Goat	9.53	10.0	5.80	7.68						
NDF	Sheep	23.1[b]	20.6	25.4[b]	21.1[b]	0.84	0.004	<0.001	0.05	0.63	0.79
	Goat	19.9[a]	18.4	22.4[a]	18.1[a]						
Digestibility, %											
DM	Sheep	69.5	71.5	67.4	72.2	0.99	0.28	<0.001	0.87	<0.001	0.28
	Goat	66.9	74.2	65.6	77.3						
CP	Sheep	75.4[a]	77.5	64.9	70.0[a]	3.04	0.006	<0.001	<0.001	0.02	0.36
	Goat	80.3[b]	79.2	63.2	82.1[b]						
NDF	Sheep	59.4	56.8	60.6	61.3	2.18	0.23	0.02	0.006	0.007	0.18
	Goat	52.5	64.1	62.6	68.3						

[a, b] Within a column and for each variable, means with unlike superscripts differ (*P*<0.05).

† AS: animal species.

In agreement with the results of Molina-Alcaide *et al.* (2000), ruminal pH was similar (*P*=0.18) in the two AS. In contrast, Ranilla *et al.* (2005) and Yáñez-Ruiz *et al.* (2004a) observed greater ruminal pH values in goats compared to those in sheep when animals of both species were fed a high-grain diet and diets containing alfalfa hay and two-stage olive cake, respectively. The greater pH values in goats have been attributed to greater rates of saliva secretion (Ranilla *et al.*, 2005; Domingue *et al.*, 1991). The different FC ratios and type of concentrate used in the different studies could help to explain the variability in comparative studies in sheep and goats, because the effects of feeding concentrates on fermentation variables may depend on the nature and proportion of the concentrate as well as the quality of the basal forage (Ramos *et al.*, 2007; Cantalapiedra-Hijar *et al.*, 2009).

For all diets, VFA concentrations in the rumen of sheep were higher (*P*<0.003) compared to those found in goats (Table 3). This could be due to differences in the rate of VFA production and/or absorption. Propionate and other VFA (calculated as the sum of isobutyrate, isovalerate and valerate) proportions were similar (*P*=0.59 and 0.38, respectively) in both AS for all diets, but goats presented greater (*P*<0.05) acetate and lower (*P*<0.05) butyrate proportions than sheep for both H diets. Total protozoa numbers were in the range of those previously reported for sheep and goats (Yáñez-Ruiz *et al.,* 2004ab), and were 5.8 and 3.7% greater in goats than in sheep for LA and LG diets, respectively. Similar AS differences were observed Santra *et al.* (1998) and Yáñez-Ruiz *et al.* (2004ab) in animals fed diets of variable composition. In agreement with previous studies (Yáñez-Ruiz *et al.*, 2004ab), no differences (*P*=0.10) between AS were found in the proportion of Holotricha, which was lower (P<0.001) with L than with H diets.

Most fermentation variables were affected by FC ratio and FOR, with lower (*P*<0.001) pH values and acetate proportions, and greater NH_3-N concentrations and butyrate proportions for L com-

pared to H diets. However, significant AS x FC interactions (P=0.01 to 0.04) were detected for NH_3-N, proportions of acetate and acetate:propionate ratio, indicating differences in the response of sheep and goats to changes in dietary FC ratio. In contrast, no AS x FOR interactions (P=0.05 to 0.98) were detected for any fermentation variable.

Table 3. Values of pH, concentration of NH_3-N and volatile fatty acids (VFA), molar proportions of individual VFA, acetate:propionate ratio, total protozoa numbers and holotricha proportion in sheep and goats fed diets with forage:concentrate (FC) ratios of 70:30 (H) or 30:70 (L) and alfalfa hay (A) or grass hay (G) as forage (FOR)

Item†	AS††	Diet				SEM	Statistical effect (P =)				
		HA	LA	HG	LG		AS	FC	FOR	AS x FC	AS x FOR
pH	Sheep	6.66	6.39	6.54	6.34	0.077	0.18	<0.001	0.07	0.89	0.59
	Goat	6.78	6.53	6.64	6.39						
NH_3-N,	Sheep	252	239^a	93.4	170^a	16.8	0.01	<0.001	<0.001	0.01	0.95
mg/l	Goat	227	306^b	139	304^b						
Total VFA,	Sheep	99.6^b	95.7^b	85.0^b	91.1^b	3.71	0.003	0.32	<0.001	0.17	0.65
mmol/l	Goat	77.2^b	62.8^a	57.2^a	58.6^a						
Acetate,	Sheep	66.6^a	65.3	68.7^b	67.4	0.82	0.01	<0.001	0.003	0.03	0.98
mol/100 mol	Goat	69.8^b	66.0	72.2^b	67.8						
Propionate,	Sheep	15.1	15.3	17.3	16.1	0.59	0.30	0.53	0.22	0.07	0.05
mol/100 mol	Goat	15.2	16.1	14.6	15.9						
Butyrate,	Sheep	12.4^b	14.2	11.1^b	12.7	0.65	0.04	<0.001	0.06	0.40	0.31
mol/100 mol	Goat	10.4^a	12.7	9.80^a	12.5						
Other VFA†††,	Sheep	5.90	5.22	2.98	3.87	0.291	0.38	0.17	<0.001	0.36	0.05
mol/100 mol	Goat	4.61	5.16	3.41	3.86						
Ac:Pr,	Sheep	4.40	4.27	3.98	4.25	0.205	0.09	0.09	0.92	0.04	0.12
mol/mol	Goat	4.63	4.16	5.01	4.23						
Protozoa,	Sheep	69.4	97.9^a	64.6	86.8^a	10.6	0.02	<0.001	0.08	0.005	0.42
x10^4/ml	Goat	75.6	167^b	71.6	131^b						
Holotricha,	Sheep	5.68	3.13	6.64	6.25	0.918	0.10	<0.001	0.74	0.05	0.01
% total	Goat	6.66	2.97	5.61	0.83						

$^{a, b}$ Within a column and for each variable, means with unlike superscripts differ (P<0.05).

† Values were averaged over sampling times at 0 and 4 h after feeding.

†† AS: animal species.

††† Calculated as the sum of isobutyrate, isovalerate and valerate.

IV – Conclusions

When goats and sheep were fed good quality diets at a restricted intake level, goats showed lower DM and NDF intakes, but similar digestibility values for both fractions. Compared with sheep, goats had greater CP digestibility, NH_3-N concentrations in the rumen and protozoa numbers, but lower ruminal VFA concentrations. The results indicate that both animal species can show similar digestive capacities, in spite of subtle differences in ruminal fermentation.

Acknowledgements

The authors wish to acknowledge the financial support received from the MCYT of Spain (projects AGL2004-04755-C02-01 and C02-02). Thanks are given to Dr. A.R. Mantecón for his help in purchasing the experimental feeds. S. Ramos and G. Cantalapiedra-Híjar gratefully acknowledge the receipt of scholarships from the MEC of Spain (BES-2005-6842 and AP2004-1908, respectively).

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