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Digestion and digesta flow kinetics in goats fed two diets differing in forage to concentrate ratio

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SUMMARY – Two complete diets consisted of chopped alfalfa hay and concentrate (barley, corn and soybean meal; 39:44:17) with forage:concentrate ratios of 80:20 (C20 diet) and 20:80 (C80 diet) were fed (1.04 kg dry matter) to four Alpine goats according to a cross-over design. Daily evolution of ruminal pH and volatile fatty acids (VFA) were measured. Digestibility was determined by total faecal collection and Cr and Co were used as markers to estimate solid (k_p) and liquid (k_{liquid}) digesta passage rates. Microbial nitrogen flow at the duodenum (MNFD) was estimated from the urinary excretion of purine derivatives. Apparent digestibility of organic matter was lower (P<0.05) for C20 (73%) than for C80 (85%) diet. Rumen pH was higher (P<0.05) for C20 than for C80 diet (6.69 vs 6.15, respectively). k_{liquid} tended to be slower (P<0.10) for diet C80 than for diet C20 (0.0475 and 0.0810 h^{-1}, respectively), but k_p was not affected (P>0.05) by diet. NMFD was higher (P<0.05) for the C80 than for the C20 diet (13.7 vs 8.9 g/d, respectively). In conclusion, goats could be fed complete diets with high grain-based concentrate levels without negatively affecting NMFD.

Keywords: Forage, concentrate ratio, goat, passage rate, rumen fermentation.

RESUME – *"Digestion et cinétique du flux de digesta chez des chèvres alimentées avec deux régimes qui diffèrent par le rapport fourrage:concentré". On a étudié la digestion et le transit des digesta chez des chèvres qui ont reçu deux rations avec différentes proportions fourrage:concentré (foin de luzerne et concentré d'orge, maïs et farine de soja ; 39:44:17): 80:20 (ration C20) et 20:80 (ration C80). Quatre chèvres de race Alpine, munies d'une canule ruminale permanente, ont reçu 1,04 kg par jour de matière sèche de chacune des rations (n = 4) dans un dispositif expérimental en cross over design. L'évolution quotidienne du pH ruminal et la concentration d'acides gras volatils ont été mesurées. La digestibilité a été déterminée par la collection totale des fèces. Le chrome et le cobalt ont été utilisés comme marqueurs pour estimer les taux de passage des digesta. La digestibilité apparente de la matière organique a été plus élevée (P<0,05) pour la ration C80 que pour la ration C20 (85 et 73%, respectivement). Le pH ruminal a été plus elevé (P<0,05) chez C20 que chez C80 (6,69 vs 6,15, respectivement). Avec la ration C80 les taux de renouvellement de la phase liquide ont tendance à diminuer (P<0,01) par rapport à C20, mais le taux de passage ruminal de la phase solide n´a pas été différent entre les deux rations. Le flux d'azote microbien au duodénum a été plus élevé (P<0,05) avec la ration C80 (13,7 vs 8,9 g/d, pour C80 et C20, respectivement). En conclusion, les chèvres peuvent recevoir des rations complètes avec une haute proportion de concentré sans effets négatifs sur le flux d'azote microbien au duodénum.*

Mots-clés : *Proportion fourrage:concentré, chèvre, taux de passage, fermentation ruminale.*

Introduction

Cereal grains are often used as a major source of energy in concentrate foods for high producing ruminant livestock. Incorporation of grain based concentrates in ruminant diets may negatively affect both fibre digestion and ruminal fermentation (Mould, 1988; Archimède *et al.*, 1997). However, information about associative feed effects between forages and grain based concentrates is scarce in goats. The objective of the present work was to study the digestibility and digesta flow kinetics in goats given two complete diets with different forage to concentrate ratio at a fixed and restricted level of intake.

Material and methods

Animals and diets

Four healthy non-pregnant, non-lactating mature Alpine goats, each fitted with a permanent ruminal cannula (35 mm i.d.), were used in this study. All animals were between 2 and 3 years of age at the start of the experiment, with an average live weight of 38.2±2.64 kg. Animals were housed in individual pens and had free access to fresh water and mineral blocks through the experiment.

Diets consisted of two combinations of chopped lucerne hay and concentrate in the proportions (fresh matter basis) of 80:20 (C20 diet) and 20:80 (C80 diet). Concentrate was based on cracked barley grains, cracked corn grains and soya-bean meal (39:44:17 g/100 g; fresh matter basis), and was completely mixed with the lucerne hay before feeding. Crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and cellulose contents were: 166 and 164, 332 and 195, 209 and 95, and 174 and 82 g/kg dry matter (DM) for diets C20 and C80, respectively. Each animal received daily 1.04 kg of DM of the corresponding diet offered in two equal portions at 9:00 and 21:00 h. Animals consumed all the feed offered and there were no refusals.

Experimental procedure

The experiment was conducted over two periods of 32 days and in each period two goats received one of the diets according to a cross-over arrangement. After an adaptation period of 21 days the following measurements were made:

Ruminal parameters and marker dilution rate in the rumen

Co-EDTA was used as marker for estimating rumen liquid outflow rates (Udén *et al.*, 1980). Two g of Co-EDTA (dissolved in 50 ml of distilled water) were injected into the rumen of each animal through the cannula just before feeding. Rumen contents were sampled just before marker administration and 2, 4, 6, 8, 10, 12, 14, 16, 18, 20 and 24 h after dosing. Samples were then filtered through four layers of cheesecloth, the pH of the fluid was measured immediately and 1 ml subsample was added to a deproteinizing solution for volatile fatty acids (VFA) analysis. The rest of the samples were stored at -20ºC for Co determination.

Digestibility, rate of passage and urine collection

On day 23 animals were moved to metabolism cages. Chromium (Cr III) mordanted fibre prepared from the lucerne hay fed to the animals was used as solid-phase particles flow marker. The hay was ground through a 2-mm sieve and prepared according to the method of Udén *et al.* (1980). Fifty g of Cr-mordanted fibre were dosed into the rumen of each animal through the cannula on day 26 just before morning feeding. Faeces were collected at 6, 10, 15, 20, 24, 32, 40, 48, 60, 72, 84, 96, 120 and 144 h after marker administration. Faeces were weighed at each sampling time and approximately 50 g were dried to constant weight, ground and stored for Cr determination. An aliquot of 0.10 of total faecal output was also collected at each sampling time for digestibility determination. Samples were dried to constant weight, ground and analysed for ash, N, NDF, acid detergent fibre (ADF) and acid detergent lignin (ADL). Total collection of urine was made during 6 days starting on day 26 at 10:00 h. Urine was collected in a solution of H_2SO_4 (0.10; v/v) to keep the pH below 3. Daily volume of urine was determined and a subsample (0.02) was composed daily for each animal and stored at -20ºC until analysed for purine derivatives.

Chemical analyses

Samples of feed and faeces were ground (1 mm screen) prior to laboratory analyses. DM, ash and Kjeldahl N were determined following standard procedures (Association of Official Analytical Chemists, 1990). NDF, ADF and acid lignin analyses were carried out according to the methods of Van Soest *et al.* (1991). Faecal samples were dried and after mineralization at 500ºC, were dissolved and analysed for Cr III by a wet digestion colorimetric method. Co was determined in centrifuged rumen fluid (2,500 g for 20 min) by atomic absorption spectrophotometry (Perkin-Elmer 3110) at a wavelength of 240 nm. VFA were determined in centrifuged samples as described in Ranilla *et al.* (1998). Samples of urine were centrifuged at 2,500 g for 5 min and purine derivatives (allantoin, uric acid, xanthine and hypoxanthine) were analysed by HPLC according to Balcells *et al.* (1992).

Calculations and statistical analyses

Liquid dilution rate (k_{liquid}) was estimated as the slope of the linear regression between the natural log of Co concentration in the rumen fluid and the time of sampling following marker administration. The rate of turnover of marker in the reticulo-rumen (k_p) and the total mean retention time (TMRT) were estimated by fitting Cr III concentration data of faecal samples with the time to the model described by Grovum and Williams (1973). Purine derivatives were measured as the sum of allantoin, uric acid, xanthine and hypoxhantine. The intestinal flow of microbial N (MNFD) was estimated based from daily purine derivatives excretion according to Belenguer *et al.* (2002).

Effects of diet on the measured parameters were tested by analysis of variance, with treatment (diet), animal and experimental period as main effects. Time-sequence data (pH and VFA) were analysed as a split-plot design, with sampling time and the interaction of sampling time × diet added to the model. When a significant F value ($P<0.05$) was detected, means were compared by the least significance difference test. All statistical analyses were performed using the GLM procedures of the Statistical Analysis Systems Institute (SAS, 1985).

Results and discussion

As shown in Table 1, organic matter (OM) apparent digestibility was higher ($P<0.05$) for C80 than for C20 diet, and apparent digestible OM intake (DOMI) followed the same pattern. NDF digestibility did not differ ($P>0.05$) between diets. The inclusion of greater proportions of concentrate in the diet of goats resulting in lower fibre digestibility has been frequently reported (Archimède *et al.*, 1997, Ramanzin *et al.,* 1997). However, a lack of effect of grain supplementation on NDF digestibility (Cerrillo *et al.*, 1999) or even and increase on fibre digestibility (Molina Alcaide *et al.*, 2000) have also been reported.

Table 1. Apparent digestibility coefficients, digestible organic matter (DOM) intake, liquid fractional rate (k_{liquid}), particulate passage from the rumen (k_p), total mean retention time (TMRT), microbial nitrogen flow at the duodenum (MNFD) and efficiency of microbial synthesis (EMS)

	Diet		
	C20	C80	SED
Apparent digestibility coefficients (%)			
Organic matter	72.8	84.6*	1.61
Neutral-detergent fibre	57.2	52.1	2.36
DOM intake (g/d)	669	813*	14.8
Digesta kinetics			
k_{liquid} (per h)	0.081	0.048**	0.0080
k_p (per h)	0.045	0.030	0.0072
TMRT (h)	47.2	63.2	5.65
MNFD (g/day)	8.9	13.7*	0.76
EMS (g MNFD/kg DOMI)	13.3	16.7*	0.54

*: $P<0.05$; **: $P<0.50$.

k_{liquid} tended to be faster ($P<0.10$) in animals fed C20 diet (Table 1), but neither k_p nor TMRT were significantly affected by diet ($P>0.05$). MNFD was higher ($P<0.05$) for the C80 than for the C20 diet, which could be the result of the higher availability of rumen fermentable carbohydrates (higher DOMI). The estimated energetic efficiency of microbial synthesis (g MNFD/kg DOMI) followed the same pattern (13.3 and 16.7 g/kg for C20 and C80 diets, respectively; $P<0.05$).

Rumen fluid pH decreased whereas VFA concentration increased after feeding time for both diets (Fig. 1). Rumen pH was higher ($P<0.10$) for C20 than for C80 diet at most of the sampling times (see Fig. 1). Similar results have been reported in goats fed diets with different forage to concentrate ratio

(Archimède *et al.*, 1996; Cerrillo *et al.*, 1999). In fact, an increase in the acidity of rumen fluid with higher levels of concentrate is a classic result, and partially depends on VFA concentration, which is consistent with our results (see Fig. 1).

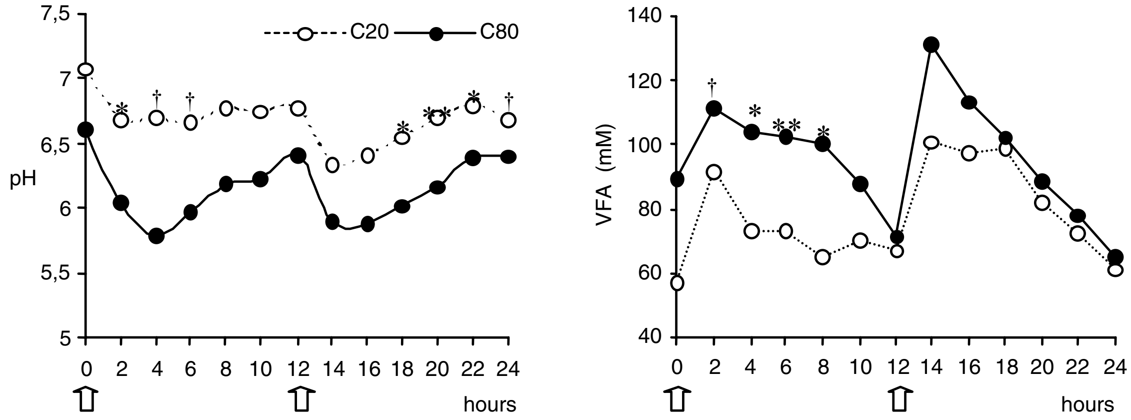

Fig. 1. Rumen pH and VFA concentrations at the different sampling times. The arrows mark feeding time. Significance: †: P<0.10; *: P<0.05; ** P<0.01.

Conclusions

In conclusion, when goats were fed complete good quality diets, high grain-based concentrate levels (80%) could be included without negatively affecting fibre digestion or microbial nitrogen flow to the duodenum. However, it is possible that the moderate level of feeding and the nature of the concentrate used in the present experiment [combining a rapidly degraded starch source (barley) with a slowly degraded one (corn)] have contributed to the obtained results.

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