Sessions 5/6 Limitations of rumen fermentation

Rumen fermentative activity in the goat and sheep

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Measurements of rumen function were made on sheep and goats fed the same range of diets. Differences between sheep and goats with respect to gas production rate, glucose fermentation, nitrate reduction capacity, total VFA production and individual VFA concentration were found especially when the inoculum was obtained from lucerne fed animals. The results suggest that different pathways or groups of micro-organisms may be involved in the two species of ruminants.

Metings van rumen funksie is gedoen op skape en bokke wat dieselfde reeks rantsoene gevoer is. Verskille tussen skape en bokke ten opsigte van tempo van gasproduksie, glukose fermentasie, nitraat reduksie kapasiteit, totale vlugtige vetsuur produksie en individuele vlugtige vetsuurkonsentrasie is veral gevind wanneer die inokulum verkry is van diere wat lusern gevoer is. Die resultate dui aan dat verskillende metaboliese bane of groepe van mikro-organismes moontlik betrokke is in die twee herkouer spesies.

Keywords: Rumen microenvironment, fermentation, goat-sheep, different quality diets

Introduction

Superior biological efficiency has been claimed for the goat (Fitzhugh, 1981) and its superior digestive efficiency has been mostly associated with utilization of plant structural polymer (Gihad, 1976; Devendra, 1978) and with a larger digestive capacity compared to sheep (Huston, 1978). However, information on rumen function in the goat is extremely scarce, especially in relation to degradation of most of the soluble dietary components. The present experiments were undertaken to study the comparative behaviour of some of the rumen microenvironmental measurements in relation to dietary components, and represent the initial stage of a systematic longterm study of the comparative rumen function of the goat.

Experimental Procedure

Mature Anglo Nubian crossbred goats and French Merino sheep fitted with permanent rumen cannulae were used in three different trials. All the animals were confined in individual crates during the entire experimental period and were fed twice daily (9:00 and 16:00 hrs) at maintenance level, with free access to water during the evening meal.

Trial I

In the first trial one goat (6 yr) and one sheep (8 yr) maintained on a uniform diet of good quality lucerne hay were used. Samples of rumen content (300 g) were obtained twice a week 0, 2 and 4 hours after feeding. Rumen fluid was obtained by filtration and pH and oxidation-reduction potential immediately measured with a pH meter. A sample of rumen fluid was centrifuged at 3000 rpm for 5 minutes and ammonium concentration was measured in the supernatant by the Conway microdiffusion technique. The remaining supernatant was centrifuged at 27 000 g for 45 min and utilized for the determination of osmotic pressure with an osmometer and total volatile fatty acids (VFA) by steam distillation. Equal volumes of the original rumen fluid and Hungate buffer solution were mixed, gasified with CO_2 and incubated at 39°C for one hour with or without 0,4% D(+) glucose. Total fermentation gas production was measured for one hour using a constant pressure manometric system. Nitrate reduction capacity was measured in the presence of 0,06% $NaNO_3$ and 0,4% D(+) glucose by the phenoldisulphonic acid technique in the 3000 rpm supernatant. Intraruminal, rectal and environmental temperature were also measured 0; 2 and 4 hours after feeding.

Trial II

In a second trial, lasting 5 months, two goats (6 yr) and two sheep (3,5 yr) were kept for one month on each of the three diets decreasing in quality: Diet 1 – 100% of TDN requirements provided by good quality lucerne hay; Diet 2 – 50% of the requirements provided by lucerne hay and 50% by wheat straw; Diet 3 – 100% of the requirements provided by wheat straw. There was a 15 day adaptation period between diets and all the feed was chopped and offered using the same schedule as in the first trial. Total fermentation gas production, pH, NH_4^+-N and total VFA's were measured in each animal at 0, 1, 2 and 5 hours after feeding. Whole rumen content samples were used instead of rumen fluid for gas production measurements. In addition, population size and growth rate of rumen micro-organisms were measured at the same sampling times as described by El-Shazly and Hungate (1965). Mitotic index and number of Langerhans cells in rumen epithelial cells were determined in 1 μm toluidine blue stained sections after fixation with glutaraldehyde and osmium tetroxide and embedding in low viscosity Spurr epoxy resin. Rumen papillae biopsies were performed the first day of the second and fourth week on each diet.

Trial III

In a third trial, lasting 2 months, three goats (2 yr) and three sheep (5 yr) were kept on a good quality lucerne hay diet as in the first trial. Total fermentation gas production was measured for one hour using samples of whole rumen content obtained 0, 1, 2, 3, 4 and 5 hours after feeding and incubated with Argon instead of CO_2. Rumen gas samples were kept for CO_2-CH_4 analysis and total and individual VFA's concentrations were measured in a 2.800 Varian chromatograph.

Results

Trial I

Rumen microenvironment measurements related to feed ingestion were similar in both species. Oxido-reduction potential, pH, osmotic pressure, NH_4^+-N levels, VFA's concentration, temperature and DM content values were not significantly different between goats and sheep at any of the sampling times, excepting pH values at zero time (7,21 ± 0,11 and 7,38 ± 0,11, in the goat and sheep respectively, $p < 0,01$). The fermentation gas production rate and the nitrate reduction capacity of the rumen fluid are shown in Table 1. Gas production differed significantly between goats and sheep at each of the sampling times, values for goats always being higher than the values for sheep (133% higher at time 0 and 60% at 4 hours). However, when the incubation was carried out with glucose, values for sheep became higher than for goat's. Reduction capacity of the rumen content from goats was always lower than that of the sheep, this difference being statistically significant at zero and at two hours.

Trial II

In both species all the rumen measurements decreased and changed their pattern as fermentable materials became less available when the diet changed from lucerne hay to wheat straw. Fermentation gas production rate, total VFA's and NH_4^+-N concentrations, microbial population size (all measured at maximum fermentation time) and mitotic index of the rumen epithelium, are shown in Table 2. The dramatic increase of gas production (about 15-fold) observed on the first diet at the point of maximum

Table 1 Fermentation gas production rate, with or without added glucose and nitrate reduction capacity of rumen fluid from goat and sheep

Measurement	Species	Sampling time (h) 0	2	4
Gas production rate ($\mu l \cdot g^{-1} \cdot min^{-1}$)	Goat	2,80 ± 0,80*	9,60 ± 2,00	6,40 ± 0,80
	Sheep	1,20 ± 0,80	5,20 ± 1,20	4,00 ± 0,80
		$p < 0,001$	$p < 0,001$	$p < 0,001$
Gas production rate with 0,4% Glucose ($\mu l \cdot g^{-1} \cdot min^{-1}$)	Goat	16,40 ± 3,60	20,40 ± 5,20	17,20 ± 1,60
	Sheep	20,00 ± 2,00	25,20 ± 2,80	23,20 ± 1,20
		$p < 0,05$	$p < 0,05$	$p < 0,001$
NO_3^- reduction capacity (mg %)	Goat	2,01 ± 0,97	4,81 ± 1,48	3,61 ± 1,64
	Sheep	4,04 ± 1,22	6,96 ± 1,47	5,16 ± 1,04
		$p < 0,01$	$p < 0,02$	N.S.

*All values are the mean of 10 determinations ± SD.

Table 2 Fermentation gas production rate, total VFA's concentration, NH_4^+-N concentration, microbial population size and rumen epithelium mitotic index in goats and sheep on three different diets*

Measurement	Species	Diet 1	Diet 2	Diet 3
Gas production rate ($\mu l \cdot g^{-1} \cdot min^{-1}$)	Goats	15,42 ± 2,82**	10,57 ± 4,00	2,75 ± 1,21
	Sheep	13,92 ± 2,57	7,71 ± 1,35	1,54 ± 1,01
		N.S.	$p < 0,001$	N.S.
Total VFA's concentration ($\mu mol \cdot ml^{-1}$)	Goats	107,98 ± 16,91	78,48 ± 10,51	33,10 ± 4,14
	Sheep	101,22 ± 15,70	74,85 ± 5,36	36,61 ± 5,81
		N.S.	N.S.	N.S.
NH_4^+-N concentration (mg %)	Goats	48,34 ± 7,86	26,45 ± 2,43	5,30 ± 1,24
	Sheep	47,93 ± 5,64	22,56 ± 1,94	2,93 ± 1,06
		N.S.	$p < 0,001$	N.S.
Microbial population size	Goats	83,90 ± 7,67	56,60 ± 5,98	7,33 ± 1,56
	Sheep	70,00 ± 6,06	36,60 ± 3,32	3,33 ± 2,44
		N.S.	$p < 0,05$	$p < 0,001$
Mitotic index (%)	Goats	0,28 ± 0,09	0,19 ± 0,07	0,05 ± 0,04
	Sheep	0,33 ± 0,08	0,28 ± 0,10	0,20 ± 0,11
		N.S.	N.S.	$p < 0,05$

*Values for first hour after feeding, excepting mitotic index.

**All values are the mean of 12 determinations ± SD.

fermentation activity, decreased concomitantly with the diet quality and almost disappeared on the third diet. This measurement was always higher in goats and the differences between species increased as the diet quality decreased, this being statistically significant only for the second diet (50% lucerne hay and 50% wheat straw). Total VFA's and NH_4^+ -N concentration also decreased in relation to changes in diet quality, showing no differences between species, excepting NH_4^+ -N on the second diet. Changes in microbial population size and growth index closely followed the fermentation activity and the NH_4^+ -N concentration in both species. Rumen population size in the goats was significantly higher than in the sheep on the 2nd and 3rd diets. The decreasing availability of fermentable substrate was also reflected in the mitotic index and in the number of Langerhans cells of the rumen epithelium that also decreased with the diet quality.

Trial III

In the third trial in which goats and sheep were fed with good quality lucerne hay, differences between species in both total fermentation gas production rate and total VFA's production were clearly shown (Figure 1). Although

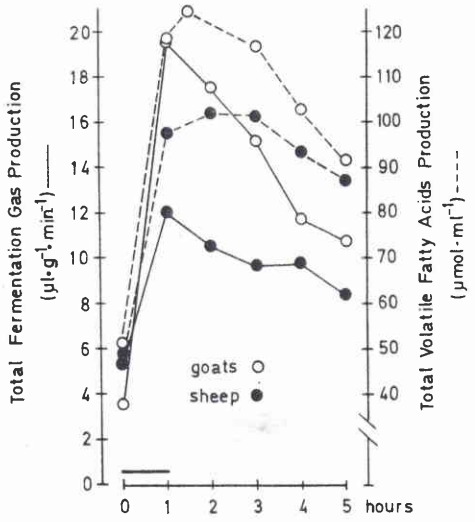

Figure 1 Fermentation gas production rate and total volatile fatty acids production of the rumen contents of goats and sheep on a lucerne hay diet (Trial III).

values before feeding were similar in both species, values after feeding were markedly different especially two hours after feeding, values for goats being 65% and 22% higher than the gas and VFA's production values of the sheep (17,42 ± 1,95 vs 10,55 ± 1,93 $\mu l \cdot g^{-1} \cdot min^{-1}$ gas production and 124,38 ± 1,92 vs 101,76 ± 2,33 $\mu mol \cdot ml^{-1}$ VFA's production). Individual VFA's molar percentages in the goats were 71,84; 20,06 and 8,09 (for acetic, propionic and butyric acids respectively) which were similar to the values for sheep. The biggest difference in concentration of individual VFA's was butyric acid which was found to be 89% and 54% higher at zero and two hours after feeding respectively in the goat as compared to the sheep.

Discussion

Under the experimental conditions described, all the rumen microenvironmental analyses, followed a similar pattern in goats and sheep, at least up to the fifth hour after feeding. Most of the measurements showed no significant differences between species. As goats and sheep moved to diets where the fermentable substrate in the plant materials was less accessible, i.e. going from lucerne hay to wheat straw, the rumen parameters changed significantly, but similarly, in both species, fermentative activity and microbial growth being affected together with NH_4^+ levels. Changes in total VFA's concentration in the rumen were related to the proliferation rate of the cells of the rumen epithelium and in the number of Langerhans cells. Even though there were some differences between species, they were not very marked. On the other hand, rumen microenvironment of goats showed some clear cut differences from that of the sheep under good quality diet conditions, at least with respect to fermentation gas production, glucose fermentation, nitrate reduction capacity, total VFA's production and individual VFA's concentrations. The results obtained suggest that different metabolic pathways and/or groups of microorganisms may be involved in the utilization of some of the soluble materials in the goat rumen microenvironment. Research designed to explore this possibility is currently in progress in our laboratory.

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References

DEVENDRA, C., 1978. The digestive efficiency of goats. *World Rev. Anim. Prod.* 14, 9.

EL-SHAZLY, K. & HUNGATE, R.E., 1965. Fermentation capacity as a measure of net growth of rumen microorganisms. *Appl. Microbiol.* 13,62.

FITZHUGH, H.A., 1981. Small ruminants as food producers. In: New Protein Foods (eds. A.M. Altschul and H.L. Wilcke), 135. New York: Academic Press.

GIHAD, E., 1976. Intake, digestibility and nitrogen utilization of tropical natural grass hay by goats and sheep. *J. Anim. Sci.* 43, 879.

HUSTON, J.E., 1978. Forage utilization and nutrient requirements of the goats. *J. Dairy Sci.* 61, 988.