# Digestion and rumen metabolism of forages by red deer, goats and sheep

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**ABSTRACT**
Digestive efficiency was compared in Red deer, goats and sheep fed chaffed lucerne hay (Experiment 1). Goats digested fibre more efficiently than sheep and had the greatest rate of rumen ammonia production. Red deer showed the capacity to increase VFI from winter (W) to summer (S) without depressing apparent digestibility, through slowing the rate of rumen particulate outflow. Fractional outflow rate (FOR) of water from the rumen and the ratio FOR water/ FOR particulate matter were both considerably greater for deer than for sheep and goats. It was concluded that this would enable deer tc digest soluble ration components more efficiently, while allowinf effective selective retention of fibre, and explains the absence ol rumen bloat when deer are fed red clover (RC). The lower rumen FOR and greater fibre digestibility in deer fed RC compared with perennial ryegrass-based pasture (Experiment 2) suggests that the higher VFI found for RC in the field is due to more rapid disintegration of plant components in the rumen rather than to increased rumen outflow rate.

KEYWORDS: deer, digestive efficiency, goats, Red deer, rumen metabolism, rumen outflow rate, sheep

## INTRODUCTION

Pastoral livestock production in New Zealand (NZ) has traditionally depended on the farming of sheep and cattle. However, other ruminant species are now increasing, populations of farmed deer and goats now being, respectively, 1.4 and 2.5 million. An objective of the present investigation was to compare digestive efficiency and rumen metabolism in deer, goats and sheep during winter and summer when fed the same forage diet.

A second objective was to compare digestion and rumen metabolism in Red deer fed either perennial ryegrass (*Lolium perenne* L.)-white clover (*Trifolium repens* L.) pasture (PRG) or red clover (*Trifolium pratense* L.) (RC), as a means of explaining the greater productivity of deer in the field on RC (Barry et al. 1993).

## MATERIALS AND METHODS

Two experiments were conducted, with animals kept indoors in metabolism cages. All animals were castrate males fistulated in the rumen and all were fed at hourly intervals from overhead feeders.

### Experiment 1

Five Red deer, 7 goats and 8 sheep were fed lucerne chaff *ad lib.* for 6-week periods during winter (W) and summer (S). The hay contained 31.2 g N and 435 g fibre/kg plant organic matter (OM). Voluntary feed intake (VFI) and apparent digestibility were determined over 8-day periods, by feeding at 1.15 times the previous day's dry matter intake (DMI). Rumen pool size (liquid + DM) was determined by bailing, at the end of each feeding period. Rumen fractional outflow rate (FOR) was determined by the continuous infusion and total sampling procedure (Faichney 1975), using Cr-EDTA as the liquid phase marker and lignin as the particulate phase marker. Samples of rumen fluid for volatile fatty acid (VFA) and ammonia concentration were removed from the rumen at 1000 h and 1500 h on 3 days during each period. Rumen ammonia irreversible loss (IRL) was determined from continuous rumen infusion of $^{15}NH_4Ci$, added to the Cr-EDTA during the last 42 h of infusion, with samples of rumen fluid for $^{15}NH_3$ enrichment being taken at rumen bailing.

### Experiment 2

The PRG and RC used contained respectively 179 and 124 g DM/kg fresh weight, 29 and 44 g N/kg DM, and 479 and 303 g fibre/kg DM. Both forages contained approximately 0.25 of white clover. Both feeds were cut fresh each day, at 0900 h, and fed to the deer during late spring-early summer. Eight deer were used, in a changeover design involving 2 periods, with 4 deer fed each forage in each period. Initial DM content was determined by rapid microwave drying and equal amounts of DM of the two feeds were offered. Apparent digestibility, rumen pool size, rumen FOR and rumen ammonia concentration were measured as described in Experiment 1.

### Laboratory methods

All samples of feed, digesta and faeces were freeze dried and ground (1 mm sieve), before laboratory analyses. Total N was determined by the Kjeldahl procedure and total fibre and lignin by either sequential extraction (Bailey 1967; Experiment 1) or by the detergent fibre system (Experiment 2). Chromium was determined by X-ray fluorescence spectrometry and $^{15}N$ by mass spectrometry.

## RESULTS

### Experiment 1

Deer increased their VFI and rumen pool size by 30% (P=0.06) and 51% (P<0.01) respectively from W to S, without depressing digestibility (Table 1). Goats showed evidence of a 20% increase in VFI from W to S (which did not attain significance), accompanied by a 27% increase in rumen pool size (P<0.01) and a decrease in DM digestibility (P<0.01). Sheep showed no seasonal changes in VFI or DM digestibility.

Goats digested total fibre of the diet more efficiently than sheep during W (P<0.01), when VFI for the two species were similar. However, there were no differences in fibre digestibility during S, when VFI was much greater for goats. Deer tended to digest total fibre more efficiently than sheep, but the difference attained significance (P<0.10) only during S.

**Table 1** Voluntary intake, rumen pool size, apparent digestibility and rumen fractional outflow rate (FOR) in Red deer, goats and sheep fed lucerne chaff *ad lib.*

| | Season | Deer | Goats | Sheep | s.e.m. |
|---|---|---|---|---|---|
| Voluntary DMI | S | 62.5 | 68.7 | 52.2 | 3.20 |
| ($g/kgW^{0.75}/day$) | W | 46.7 | 57.4 | 54.8 | 4.24 |
| Rumen pool size | S | 289 | 340 | 275 | 17.5 |
| ($g/kgW^{0.75}$) | W | 191 | 268 | 307 | 13.4 |
| Apparent digestibility: Dry matter | S | 0.57 | 0.56 | 0.54 | 0.0044 |
| | W | 0.55 | 0.62 | 0.56 | 0.0078 |
| Fibre | S | 0.45 | 0.43 | 0.41 | 0.0065 |
| | W | 0.40 | 0.45 | 0.37 | 0.080 |
| Rumen FOR: Cr-EDTA | S | 15.8 | 10.8 | 10.4 | 0.54 |
| (%/h) | W | 16.3 | 9.6 | 10.3 | 0.56 |
| | S/W | 0.97 | 1.13 | 0.99 | 0.062 |
| Lignin | S | 2.77 | 3.66 | 3.32 | 0.163 |
| (%/h) | W | 3.47 | 3.47 | 3.29 | 0.142 |
| | S/W | 0.81 | 1.04 | 1.03 | 0.050 |
| Cr-EDTA / Lignin | S | 6.0 | 3.1 | 3.2 | 0.31 |
| | W | 4.8 | 2.8 | 3.1 | 0.11 |

S, summer; W, winter

Rumen water FOR, as marked by Cr-EDTA, was much faster in deer than in sheep and goats (P<0.01), during both S and W. The ratio of rumen particulate FOR in S/W was lower for deer than for the other species (P<0.05), showing that rate of particulate outflow in deer slowed during S. The ratio FOR Cr-EDTA/FOR lignin was consistently greater for deer than for sheep and goats (P<0.001), showing that water left the rumen at a greater rate relative to particulate matter in deer.

Whereas sheep showed no seasonal changes in rumen ammonia concentration or acetate/propionate (Ac/Pr) ratio, deer showed higher values for both ammonia concentration (P<0.01) and Ac/Pr (P<0.05) in S compared with W (Table 2). Goats showed no seasonal change in ammonia concentration, but showed a small increase in Ac/Pr in S compared to W. Rumen ammonia IRL during W was in the order goats>sheep>deer, the difference between goats v. sheep and goats v. deer attaining significance (P<0.05).

**Table 2** Concentration and irreversible loss of ammonia and acetate-propionate ratio in the rumen fluid of deer, goats and sheep fed lucerne chaff *ad lib.*

| | Season | Deer | Goats | Sheep | s.e.m. |
|---|---|---|---|---|---|
| Ammonia concentration | S | 172 | 158 | 181 | 5.5 |
| (mg N/l) | W | 110 | 165 | 172 | 6.3 |
| Ammonia IRL (mg N/g N intake) | W | 535 | 692 | 607 | 35.9 |
| Acetate/propionate | S | 4.20 | 3.76 | 4.01 | 0.085 |
| ratio | W | 3.62 | 3.37 | 3.76 | 0.061 |

S, summer; W, winter

### Experiment 2

At similar VFI, rumen pool size (P<0.1) and rumen FOR of both Cr-EDTA (P<0.05) and lignin (P<0.01) were lower for deer fed RC than PRG (Table 3), whilst apparent digestibility of DM (P<0.05) and of fibre (P<0.05) were greater for deer fed RC than PRG. Rumen FOR of Cr-EDTA was very high, as observed for deer in Experiment 1, and the ratio FOR Cr-EDTA/FOR lignin was greater (P<0.01) in deer fed RC. Rumen ammonia concentration was very high, especially in deer fed RC.

## DISCUSSION

Relative to sheep, Experiment 1 showed the greater fibre digestion and rumen ammonia IRL (i.e., production rate) in the goat. Components of these are probably the longer eating time, faster rate of chewing during eating, more efficient particle breakdown during eating and greater salivary N secretion during eating in goats than sheep (Domingue et al. 1991). These characteristics probably make goats more efficient utilisers of low quality fibrous feeds than sheep.

Unlike the goat, Red deer seem to have evolved a mechanism for increasing VFI in S without depressing apparent digestibility, through reducing rumen particulate matter FOR (i.e., actually increasing mean particulate retention time from 28.8 to 36.1 hrs). The high ratio of rumen FOR Cr-EDTA/FOR lignin in deer means that they have a better system for selective retention of insoluble material (i.e., fibre) in the rumen and for washing soluble material out of the rumen into the intestines. This may have developed as part of their evolution between a grazer and a concentrate selector (Hoffman 1985) and illustrates that in a farming system deer may be efficient users of both the fibre and soluble components of the forage. As such, they should be efficient utilisers of high digestibility feeds, containing high contents of soluble protein and carbohydrate.

Rumen frothy bloat is caused by the development of a stable foam from a high content of forage soluble proteins (Mangan 1959). The very rapid FOR of water from the rumen relative to particles probably explains why forages such as RC, which are well known to induce bloat in cattle, do not cause bloat in deer.

As outflow rates from the rumen were in fact slower for deer fed RC than PRG, it is evident that the greater voluntary intakes observed during lactation (Niezen et al. 1992) and during post-weaning growth (Semiadi et al. 1992) in deer grazing RC cannot be explained in terms of rumen outflow rate. Rather, the greater apparent digestibility of RC may indicate faster degradation of plant components in the rumen, causing reduced rumen digesta load, and hence allowing an increase in VFI.

The very high rumen ammonia concentration in deer fed RC indicates extensive microbial degradation of soluble proteins. It seems that forages containing low concentrations of condensed tannins, such as *Lotus corniculatus*, which reduce rumen proteolysis of plant proteins in sheep (Barry 1989) should be evaluated for their digestive characteristics in deer, with a view to increasing the protein to energy ratio of absorbed nutrients.

Table 3 Digestibility and rumen fractional outflow rate (FOR) in Red deer fed fresh perennial ryegrass-white clover and red clover at the same level of dry matter intake

| | Perennial ryegrass-white clover | Red clover |
|---|---|---|
| Voluntary DM intake ($g/kg\ W^{0.75}/d$) | 49.1 ± 1.2 | 52.9 ± 0.6 |
| Rumen pool ($g/kg\ W^{0.75}$) | 251 ± 18 | 228 ± 19 |
| Apparent digestibility: | | |
| Dry matter | 0.74 ± 0.007 | 0.80 ± 0.005 |
| Fibre | 0.67 ± 0.022 | 0.75 ± 0.011 |
| Rumen FOR (%/h): | | |
| Cr-EDTa | 15.1 ± 0.7 | 13.3 ± 0.9 |
| Lignin | 4.3 ± 0.6 | 2.5 ± 0.3 |
| Cr-EDTA/lignin | 3.8 ± 0.45 | 5.5 ± 0.37 |
| Ammonia (mg N/l) | 215 ± 23 | 321 ± 25 |

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