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Comparative digestion in deer, goats, and sheep

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Abstract Comparisons were made between castrated male red deer, Angora × New Zealand feral goats, and Border-Leicester × Romney sheep fed chaffed lucerne hay ad libitum during summer and winter. Measurements were made of apparent digestibility, fractional outflow rate (FOR) of rumen digesta, rumen pool size, and particle size breakdown in the rumen, at voluntary feed intake (VFI) during both summer and winter. Both deer and sheep selected a diet lower in fibre and greater in nitrogen than the feed on offer, whereas goats showed no evidence of diet selection. Sheep did not show evidence ($P > 0.05$) of seasonal cycles (summer versus winter) in voluntary dry matter (DM) intake and apparent DM digestibility, whereas deer showed marked increases during summer in voluntary DM intake (35%) and rumen pool size of DM + liquid (51%), with no reduction in apparent DM digestibility. Goats showed evidence of a summer increase in VFI (17%), which did not attain significance, and in rumen pool size of DM + liquid (+ 27%; $P < 0.01$), which was associated with a decrease in the apparent digestibility of DM ($P < 0.01$). Deer digested total fibre better than sheep, especially in summer, and consistently had a higher digestibility of lignin. Goats digested total fibre better than sheep during winter when voluntary intakes were similar ($P < 0.001$) and to a similar extent during summer when voluntary intake was much higher than for sheep. However, goats digested lignin more efficiently than sheep in both seasons. Particles had to be reduced in size to pass a 1 mm sieve, in order to leave the rumen of sheep, deer, and goats. Deer had a faster rumen FOR of water (15.6%/h) than sheep (10.4%/h) and goats (10.0%/h), both in summer and in winter ($P < 0.01$). The FOR of particles from the rumen of deer showed a reduction during summer compared to winter, whereas sheep and goats showed no change with season. The ratio FOR Cr-EDTA/FOR lignin was greater in deer than in goats and sheep, indicating that water left the rumen proportionately faster than particulate matter in deer compared to sheep and goats. Relative to sheep, it was concluded that goats would use low-quality fibrous feeds more efficiently, whereas red deer would be likely to use feeds with high contents of soluble carbohydrate and protein more efficiently.

Keywords comparative digestion; deer; goats; sheep; ruminants

INTRODUCTION

Traditionally, pastoral livestock production in New Zealand has depended upon the farming of sheep and cattle. However, other ruminant species are making an impact, with the populations of farmed deer and goats in New Zealand now being c. 1 million of each. Projections are that these will grow to attain c. 2.5 and 4.0 million respectively by 1995, illustrating the importance of these species to New Zealand agriculture. The objective of the present investigation was to compare digestion in

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deer and goats with that of the sheep, the most extensively farmed ruminant in New Zealand.

Several studies have been undertaken comparing digestion in goats and sheep (Watson & Norton 1982; Doyle et al. 1984; Alam et al. 1985), and two studies have compared digestion in deer and sheep (Milne et al. 1978; Fennessy et al. 1980). However, only the studies of Fennessy et al. (1980) and Alam et al. (1985) were done in New Zealand, and there has never been a study which compared all three species when fed the same diet. Deer are well known to show seasonal cycles of voluntary feed intake (VFI), with a maximum in summer and a minimum in winter (Milne et al. 1978; Fennessy et al. 1981; Kay 1985), which could well affect digestive processes. Seasonal patterns of VFI in New Zealand goats and domestic sheep are unknown. The present study was therefore intended to compare digestive processes in deer, goats, and sheep in both summer and in winter, when offered the same forage ad libitum. This level of intake was selected because first, it would most closely correspond to farming practice, and second, any restriction of intake to a constant amount in relation to bodyweight posed problems of which scaler to use (i.e., $W^{1.0}$ or $W^{0.75}$) when comparing species and of keeping this constant if seasonal VFI changed markedly.

EXPERIMENTAL

Diet

Lucerne hay (*Medicago sativa*), purchased in bulk from a single source, was fed to the animals in summer and winter. The animals were allowed free access to a multimineral salt block (50 g; Dominion Salt (New Zealand) Ltd), placed in the feed bin. The hay was chaffed into 50–80 mm lengths and placed upon belt feeders which delivered the day's ration in 24 feeds at hourly intervals.

Animals

Five castrated hand-reared red deer were used; these were aged 2.5 years and weighed 94.8 kg (SD 5.46) in winter, and were aged 3 years and weighed 96.2 kg (SD 5.60) in summer. Seven castrated Angora New Zealand feral goats were used; these were aged 2.5 years and weighed 42.5 kg (SD 4.83) in winter, and were aged 3 years and weighed 43.4 kg (SD 4.93) in summer. Eight Border Leicester × Romney wether sheep were used; these were aged 2.5 years and weighed 57.5 kg (SD 6.58) in winter and were aged 3 years and weighed 60.7 kg (SD 7.18) in summer. All animals were fistulated in the rumen, and were fitted with permanent rubber cannulae (63 mm i.d. for goats and sheep; 83 mm i.d. for deer). Goats and sheep were housed individually in conventional metabolic crates. Deer were kept in metabolic crates similar to those described by Milne et al. (1978). Between experiments, the animals grazed on perennial ryegrass/white clover pastures, and were supplemented with a concentrate pellet diet during periods of low pasture growth.

Experimental design

Two identical experiments were conducted comparing deer, goats, and sheep during winter a[illegible] summer. The winter experiment was conducted [illegible] May–June, and the summer experiment in November–December. VFI was measured with the animals fed at 1.15 times the previous day's DMI. VFI and apparent digestibility were measured from Day 13 to Day 20, after a pre-feeding period of 12 days. At the end of the VFI and apparent digestibility measurements, the animals were offered feed at 1.035 of that consumed, so that ad libitum intake would still be maintained but diet selection was minimised. To measure outflow rates, the non-radioactive dual-markers Cr-EDTA/Ru-phen were continuously infused into the rumen during Days 25–30, after which rumen contents were emptied out ("bailing") on Day 30, and subsamples taken before returning the warmed digesta back to the rumen.

Marker infusion procedures

The inert markers used were the chromium ([illegible] complex of ethylenediamine tetraacetic acid ([illegible] EDTA), prepared by the method of Binnerts et al. (1968), and ruthenium tris (1, 10-phenanthroline)-ruthenium (II) chloride (Ru-phen), prepared by the method of Tan et al. (1971). The two solutions were then combined in equal volumes, with a final (theoretical) Cr concentration of 2000 mg/kg solution, and a Ru concentration of 49.8 mg/kg solution of dual-phase marker and the pH adjusted to 6.5–7.0. Following a priming dose of 40 g, the dual-phase marker solution was continuously infused at a constant rate into the rumen for 5 days. The infusion rates of Cr-EDTA/Ru-phen (g/h), and of Cr (mg/h) and Ru (mg/h) are given in Table 1. All infusions were administered by a peristaltic pump (PLG-multipurpose pump, Desaga (Heidelberg) W. Germany).

Sample collection procedures

Feed, feed refusals, and faeces samples were taken daily during Days 13–20, pooled, and stored at −20°C, separately for each animal. A representative sample of the rumen digesta was taken from two deer, four goats, and four sheep, on Day 7 of the pre-feeding period in each of the summer and winter experiments. The rumen digesta was used as a matrix for the preparation of separate summer and winter Cr and Ru standard curves for deer, goats, and sheep.

After "bailing" on Day 30, the rumen contents were weighed, thoroughly mixed, and subsampled, before returning the remainder to the rumen. The whole process was completed in 10–12 min for goats and sheep, and 15–18 min for deer. The deer were lightly tranquilised 5 min before bailing with 20 mg xylazine (Rompun, Bayer AG).

Samples of feed, feed refusals, rumen digesta, and faeces were freeze-dried (FD 57 freeze-dryer; WGG Cuddon (New Zealand) Ltd.), ground (1 mm mesh sieve), and used for laboratory analysis. The rumen digesta samples for Cr and Ru determinations were freeze-dried and ground to pass a 0.5 mm mesh sieve.

Laboratory methods

Samples of feed, feed refusals, rumen digesta, and faeces were analysed for carbohydrate and lignin constituents (Bailey 1967), total nitrogen (N) by the Kjeldahl method, gross energy by adiabatic bomb calorimetry (Gallenkamp Autobomb (U.K) Ltd), and organic matter by ashing overnight at 550°C.

Inert Cr and Ru in rumen digesta samples were alysed by X-ray Fluorescence Spectrometry, XRFS (Philips RH 1404 Automatic Sequential X-ray Fluorescence Spectrometer), using the method described by Evans et al. (1977). Reference standards for Cr and Ru were prepared in rumen digesta matrix separately for sheep, deer, and goats.

Particle size distribution in rumen digesta and faeces samples was determined in winter samples only by wet-sieving, using the procedures described by Domingue et al. (1991a). Sieve sizes (length of side of square hole) were 4.0, 2.0, 1.0, 0.5, and 0.25 mm.

Table 1 Infusion rates of Cr-EDTA/Ru-Phen (g/h), Cr and Ru (mg/h) into the rumen of deer, goats, and sheep fed on lucerne hay, at ad libitum intake, in summer and winter.

	Deer	Goats	Sheep
Summer			
Cr-EDTA/Ru-Phen (g/h)	20.8	12.5	13.5
Cr (mg/h)	41.6	25.0	27.0
Ru (mg/h)	1.04	0.62	0.67
Winter			
Cr-EDTA/Ru-Phen (g/h)	16.7	11.7	14.6
Cr (mg/h)	33.4	23.4	29.2
Ru (mg/h)	0.83	0.58	0.73

Calculations

The marker fractional outflow rate from the rumen (FOR, %/h), was determined from the following relationship:

$$\text{FOR}\ (\%/\text{h}) = \frac{\text{Infusion rate (mg/h)} \times 100}{\text{Rumen pool size (mg)}} \qquad (1)$$

The relationship was used for both Cr and Ru markers. For lignin, faeces flow was substituted for infusion rate, on the assumption that there was minimal post-ruminal degradation of lignin (Faichney 1980).

Statistical methods

Analysis of variance procedures were used to determine differences between animal species and seasons. Mean values with the standard error of the means (SEM) are presented.

RESULTS

Chemical composition of diet

The chemical composition (g/kg organic matter (OM)) of the lucerne hay did not change from winter to summer (Table 2). The feed refusals of sheep and deer (g/kg OM) were not different in chemical composition ($P > 0.05$) either in summer or in winter, and contained lower contents of total N and higher proportions of total fibre than the feed offered (Table 2). The refusals of goats contained higher proportions of total N than those of sheep ($P < 0.01$) and deer ($P < 0.1$), and lower contents of total fibre both in summer and in winter. Both deer and sheep appeared to select for a diet higher in total N and lower in total fibre than the feed offered, whereas goats showed no evidence of any feed selection.

Voluntary intake and digestion of dry matter and organic matter

Seasonal effects

Sheep showed no seasonal differences ($P > 0.05$) in voluntary DMI, organic matter intake (OMI), digestible dry matter intake (DDMI), digestible organic matter intake (DOMI) (g/kg $W^{0.75}$ per day), or calculated MEI (MJ/kg $W^{0.75}$ per day) (Table 3), and no changes ($P > 0.05$) in the apparent digestibilities of DM and OM, and in the rumen pool sizes (g/kg $W^{0.75}$) of DM and liquid (Table 4).

Deer increased ($P = 0.06$) their voluntary DMI, OMI, DDMI, and DOMI (g/kg $W^{0.75}$ per day) from winter to summer by c. 30% and metabolisable energy intake (MEI) (MJ/kg $W^{0.75}$ per day) by c. 25%. The increase in intake from winter to summer was associated with an increase in the rumen pools of DM ($P < 0.05$) and liquid ($P < 0.01$), when expressed g/kg $W^{0.75}$. Total rumen pool (DM + liquid) (g/kg $W^{0.75}$) was increased ($P < 0.01$) by 51% from winter to summer. There was no decrease in the apparent digestibility of DM and OM in the deer, as voluntary feed intake increased from winter to summer. Rumen contents of deer contained significantly higher concentrations of DM than those of sheep and goats ($P < 0.001$), both in summer and in winter.

Goats showed evidence of increases in the voluntary intake of DM (20%) and OM (14%) in summer, compared to winter, which did not attain significance ($P > 0.05$), and decreases in the apparent digestibilities of DM ($P < 0.01$), and OM ($P < 0.001$). This resulted in no seasonal changes ($P > 0.05$) in the DOMI (g/kg $W^{0.75}$ per day) and MEI (MJ/kg $W^{0.75}$ per day). The rumen pool sizes (g/kg $W^{0.75}$) of DM ($P < 0.01$) and liquid ($P < 0.05$) increased from winter to summer, with total rumen pool (DM + liquid) in goats increasing by 27% ($P < 0.01$).

Deer versus sheep

Deer and sheep digested DM and OM with similar efficiencies during winter, when their voluntary intakes did not significantly differ. The summer DMI and OMI (g/kg $W^{0.75}$ per day) of deer was 20% greater than that of sheep ($P < 0.05$), yet deer digested the DM ($P = 0.06$) and the OM ($P < 0.05$) components of the feed better than sheep at this time.

Goats versus sheep

The DMI and OMI (g/kg $W^{0.75}$ per day) of goats and sheep were similar in winter ($P > 0.05$), with goats digesting DM and OM ($P < 0.01$) more efficiently than sheep. Hence the DDMI and DOMI (g/kg $W^{0.75}$ per day) of goats in winter were about

Table 2 Chemical composition (g/kg organic matter (OM)) of lucerne hay, and the feed refusals by deer, goats, and sheep when fed ad libitum in summer and in winter.

		Lucerne hay offered	Lucerne hay refused: Deer	Goats	Sheep	SEM
Heat of combustion (MJ/kg OM)	S[b]	20.5	20.0	20.2	20.2	0.03
	W	20.5	20.0	20.4	20.2	0.08
Total nitrogen	S	31.5	21.2	28.6	22.3	0.78
	W	31.0	20.8	30.2	24.6	1.42
Cellulose	S	246	276	244	306	5.9
	W	228	302	244	250	8.2
Hemicellulose	S	82	99	87	97	1.7
	W	83	104	97	109	2.1
Lignin	S	116	126	125	132	0.93
	W	113	124	120	123	1.4
Total fibre[a]	S	445	500	457	535	8.1
	W	425	530	461	488	10.4

[a] = cellulose + hemicellulose + lignin.
[b]S = summer; W = winter.

Table 3 Voluntary intake and digestible intakes of dry matter (DM) and organic matter (OM) (g/kg $W^{0.75}$ per day) together with their apparent digestibilities (%), and metabolisable energy intake (MJ/kg $W^{0.75}$ per day) of deer, goats, and sheep fed on lucerne hay in summer and in winter.

		Deer	Goats	Sheep	SEM
Voluntary intake (g/kg $W^{0.75}$ per day)					
DM	S[b]	62.5	68.7	52.2	3.20
	W	46.7	57.4	54.8	4.24
OM	S	56.6	62.2	47.2	2.90
	W	45.7	54.7	52.0	5.52
Digestible DM	S	35.6	38.6	28.2	0.88
	W	27.4	36.9	31.6	1.77
Digestible OM	S	34.2	36.4	27.0	1.79
	W	27.0	35.4	31.0	1.73
Metabolisable energy intake[a]	S	0.50	0.58	0.43	0.029
(MJ/kg $W^{0.75}$ per day)	W	0.40	0.56	0.49	0.028
Apparent digestibility					
DM	S	0.57	0.56	0.54	0.0044
	W	0.55	0.62	0.56	0.0078
OM	S	0.60	0.58	0.57	0.0046
	W	0.59	0.65	0.60	0.0075

[a]Digestible energy intake × 0.82.
[b]S = summer; W = winter.

15% greater than sheep. In summer, the DMI and OMI (g/kg $W^{0.75}$ per day) of goats were greater than sheep ($P < 0.05$), with DM and OM being digested with similar efficiencies in the two species ($P > 0.05$).

Fibre digestion

Seasonal effects

Sheep digested the total fibre of the diet better in summer than in winter ($P < 0.001$). This was reflected in greater apparent digestibilities for cellulose ($P < 0.001$), hemicellulose ($P < 0.1$), and lignin ($P < 0.001$) (Table 5). There were no significant effects of season on apparent fibre digestibility in deer and goats.

Deer versus sheep

In winter, deer tended to digest the total fibre of the feed more efficiently than sheep ($P = 0.13$), but the difference attained significance ($P < 0.01$) only for the least digestible component of the fibre, lignin. In summer, deer digested the total fibre of the feed more efficiently ($P = 0.09$) than sheep, despite the superior summer voluntary DMI (g/kg $W^{0.75}$ per day) of deer. Hence, the apparent digestibilities of cellulose ($P < 0.05$) and lignin ($P = 0.07$) were both greater in deer than in sheep in summer.

Goats versus sheep

Goats digested the total fibre of the diet more efficiently ($P < 0.001$) than sheep in winter, when voluntary DMI (g/kg $W^{0.75}$ per day) was similar between the two species. This was reflected in greater apparent digestibilities of cellulose ($P < 0.01$), hemicellulose ($P < 0.05$), and especially lignin ($P < 0.001$). In summer, when the goats achieved superior ($P < 0.05$) voluntary DMI (g/kg $W^{0.75}$) than sheep, there were no differences ($P > 0.05$) in the apparent digestibilities of total fibre, cellulose, and hemicellulose between the two species. However, goats digested the least digestible component of fibre, lignin, more efficiently than sheep ($P < 0.05$).

Table 4 Total rumen (DM + liquid) pool size, dry matter (DM), and liquid pool sizes (g/kg $W^{0.75}$) of deer, goats, and sheep fed on lucerne hay in summer and in winter, and DM content (%) of rumen digesta.

		Deer	Goats	Sheep	SEM
Rumen pool size (g/kg $W^{0.75}$):					
Total rumen pool	S[*]	289	340	275	17.5
(DM + liquid)	W	191	268	307	13.4
Rumen DM pool	S	43	45	37	2.4
	W	31	37	40	1.8
Rumen liquid pool	S	245	294	237	15.2
	W	159	231	267	11.7
DM of rumen	S	15.1	13.4	13.7	0.19
digesta (%)	W	16.6	13.8	13.2	0.26

[*]S = summer; W = winter.

FOR of rumen digesta

Rumen water FOR, as marked by Cr-EDTA, was much faster in deer than sheep and goats ($P < 0.01$), both in summer and in winter (Table 6). As measured with lignin, the ratio of particulate matter FOR in summer to winter was lower for deer ($P < 0.05$) than the other species, indicating that rumen outflow rate in deer slowed during summer, especially for particles. Sheep showed no seasonal changes in rumen FOR, whereas goats showed evidence of an increase during summer, but this did not attain significance ($P > 0.05$). The ratio FOR Cr-EDTA : FOR lignin was much greater in deer than in sheep or goats ($P < 0.001$), showing that water left the rumen at a greater rate relative to particles in deer compared to sheep and goats. The ratio also tended to be higher in deer in summer than in winter ($P = 0.13$).

Particle size breakdown in the rumen in winter

Figure 1 shows that particles had to be reduced in size to pass a 1 mm sieve, in order to pass through the reticulo-omasal orifice of sheep, deer, and goats. The rumen contents of both deer and sheep contained larger proportions of particles which were above this size than the rumen contents of goats ($P < 0.01$) (Table 7). The rumen contents of deer contained greater proportions of particles retained on the 1.0 mm sieve than the rumen contents of either sheep and goats ($P < 0.01$).

DISCUSSION

Voluntary intake and digestion of dry matter and organic matter

The results of the present experiment have indicated that the domestic sheep showed a seasonal cycle in fibre digestion when given dried lucerne hay, with higher values in summer and lower values in winter, but showed no seasonality in DMI (g/kg $W^{0.75}$ per day) or rumen pool size. This is in contrast to domesticated sheep in the United Kingdom fed a range of different diets, which showed a very low amplitude cycle of higher VFI and heat production in summer than in winter (Kay 1979; Blaxter & Boyne 1982).

In contrast to sheep, deer showed marked seasonal cycles of VFI and rumen pool size of DM + liquid, with higher values in summer and lower values in winter, but no evidence of a summer decline in apparent digestibility of DM and OM. Goats appeared to occupy an intermediary position, with seasonal cycles of VFI, and rumen pool size of DM + liquid, which showed an increase in summer compared to winter, but the cycles were of reduced amplitude compared to deer. The summer increase in the VFI of goats occurred at the expense of a decrease in the apparent digestibilities of DM and OM, with the net effect being no seasonal change in MEI (MJ/kg $W^{0.75}$ and DDMI (g/kg $W^{0.75}$ per day).

The seasonal cycle of VFI in deer is associated with their seasonal cycle of body growth, and of protein and energy metabolism (Silver et al. 1969; Mitchell et al. 1976; Moen 1978; Barry et al. 1991). In addition to VFI, the present study has shown that there are seasonal effects upon several other digestive criteria in sheep, deer, and goats, and it is suggested that these all are associated with the seasonal rhythms of metabolism and growth.

The factors which will contribute to an increase in VFI are (a) rumen pool size, (b) rate of particle size reduction, and (c) FOR of rumen digesta.

The results of the present experiment on deer agree with previous reports which show a marked decrease in appetite in castrated deer in winter, and an increase in VFI in summer (Pollock 1975; Milne et al. 1978; Suttie & Simpson 1985). The increased DMI in summer, in the present experiment, is associated with the ability of the rumen to accommodate a greater (+ 51%) digesta load (rumen pool size of DM + liquid). Domingue et al. (1991b) have shown that there is a small increase in rum capacity (i.e., volume) and a substantial increase in the proportion of rumen total capacity occupied by digesta in deer in summer, compared to winter. These two factors are components which probably contributed to the increase in VFI in summer. The combined effects of a greater rumen pool size, with a decrease in rumen FOR of particulate DM, probably explain the mechanism of how the deer were able to increase their VFI in summer, without decreasing the apparent digestibility of DM or fibre. The decline in rumen particulate FOR in summer is in contrast to the results of Milne et al. (1978), who found that the increase in VFI was associated with an increase (when fed on low-quality forage), or with no change (when fed on high-quality pelleted grass diet) in the rumen FOR of Ru-phen. Based upon the results in Table 6, rumen FOR of Ru-phen

Table 5 Voluntary intake and apparent digestibility of total fibre and its components by deer, goats, and sheep fed on lucerne hay in summer and in winter.

		Deer	Goats	Sheep	SEM
Total fibre					
Voluntary intake[a] (g/kg $W^{0.75}$ per day)	S[b]	26.4	27.7	21.0	1.36
	W	19.4	23.2	22.0	1.29
Apparent digestibility[a] (%)	S	0.45	0.43	0.41	0.0065
	W	0.40	0.45	0.37	0.0080
Cellulose					
Voluntary intake[a] (g/kg $W^{0.75}$ per day)	S	14.6	15.3	11.6	0.75
	W	10.5	12.5	11.9	0.69
Apparent digestibility[a] (%)	S	0.64	0.59	0.60	0.0064
	W	0.57	0.61	0.54	0.0105
Hemicellulose					
Voluntary intake[a] (g/kg $W^{0.75}$ per day)	S	4.92	5.17	3.92	0.253
	W	3.80	4.54	4.31	0.258
Apparent digestibility[a] (%)	S	0.52	0.50	0.50	0.0096
	W	0.47	0.53	0.47	0.0111
Lignin					
Voluntary intake[a] (g/kg $W^{0.75}$ per day)	S	6.87	7.21	5.47	0.364
	W	5.14	6.15	5.86	0.343
Apparent digestibility[a] (%)	S	0.19	0.19	0.15	0.0077
	W	0.16	0.22	0.09	0.0076

[a]Animals fed ad libitum.
[b]S = summer; W = winter.

Table 6 Fractional outflow rate (FOR, %/h) of Cr-EDTA, Ru-phen, and lignin from the rumen of deer, goats, and sheep fed on lucerne hay at ad libitum.

Fractional outflow rate (%/h)		Deer	Goats	Sheep	SEM
Cr-EDTA	S[a]	15.8	10.8	10.4	0.54
	W	16.3	9.6	10.3	0.56
	S/W	0.97	1.13	0.99	0.062
Ru-phen	S	7.0	7.6	6.9	0.38
	W	7.6	6.8	6.9	0.34
	S/W	0.93	1.09	1.00	0.067
Lignin	S	2.77	3.66	3.32	0.163
	W	3.47	3.47	3.29	0.142
	S/W	0.81	1.04	1.03	0.050
Cr-EDTA/lignin	S	5.97	3.07	3.24	0.308
	W	4.77	2.82	3.12	0.110

[a]S = summer; W = winter.

(measured indirectly by Milne et al. 1978)) would not be a good predictor of particulate FOR (measured here from rumen lignin sampling).

Although goats tended to show an increase in VFI in summer compared to winter, the ability of the rumen to accommodate an increase in digesta load (+ 27%), was more restricted than in deer (+ 51%); as there was no reduction in rumen particulate FOR in summer, as occurred in deer, it seems apparent digestibility fell as a consequence. There are no other published data on the seasonality of nutrient supply in goats. It is known that goats enter a period of growth stasis in late autumn/winter (McCall et al. 1989), and the seasonal cycles of feed intake in goats may be linked to the metabolic demand of growth in the same way as they are in deer.

Fibre digestive efficiency

Factors which could influence fibre digestive efficiency include (a) rumen pool size, (b) digesta FOR, (c) particle size distribution, and (d) rumen environment.

The increased apparent fibre digestibility of sheep in summer was not associated with any seasonal changes in rumen FOR of Ru-phen, Cr-EDTA, and lignin or rumen pool size. As the summer increase in apparent fibre digestibility cannot be explained by events within the rumen, it is possible that it represents increased post-ruminal digestion.

The results of the present experiment appear to conflict with the data of Milne et al. (1978), obtained with high-quality dried grass and low-quality hill forages, who reported that deer digested fibre less efficiently than sheep, and was associated with a faster rumen FOR of Ru-phen in deer. Our data support the findings of Fennessy et al. (1980) with deer in New Zealand fed either meadow hay or a pelleted cereal/lucerne diet, which showed that deer digest fibre better than sheep.

The greater superiority of goats in digesting fibre than sheep, especially lignin, which is the least digestible component of fibre, was observed both in summer and in winter. Two reasons can be advanced for the superior apparent fibre digestibility

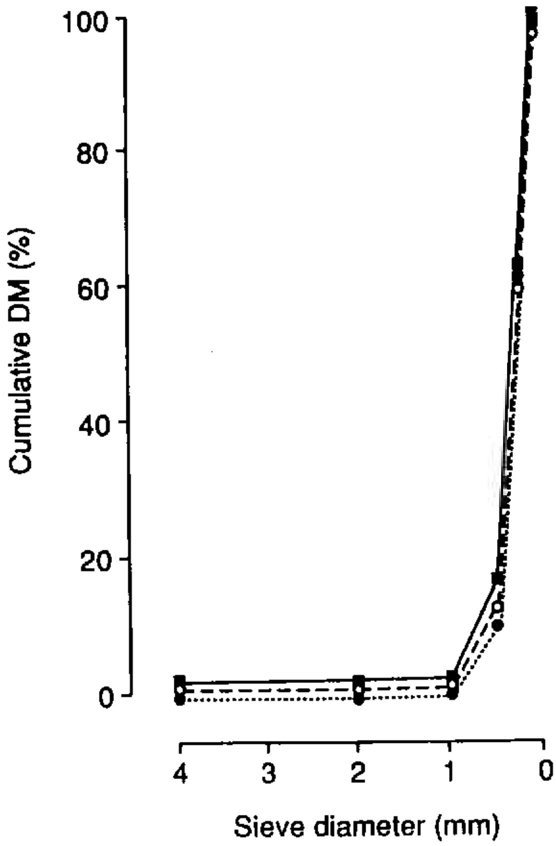

Fig. 1 Cumulative dry matter (DM) distribution of faecal samples from deer (■), goats (●), and sheep (○).

Table 7 Particle size distribution (% particulate dry matter (DM) retained on sieve size) in the rumen digesta and faeces of deer, goats, and sheep fed on lucerne hay ad libitum in winter.

Sieve size	Deer	Goats	Sheep	SEM
Rumen digesta				
0	7.1	2.9	8.5	0.73
2.0	8.4	3.9	6.4	0.44
1.0	17.1	8.5	11.2	0.68
0.5	18.8	17.0	16.3	0.43
0.25	19.1	28.5	23.6	0.56
< 0.251	29.5	39.4	34.1	1.24
< 1.0	67.4	84.9	74.0	1.45
> 1.0	32.6	15.1	26.0	1.45
Faeces				
4.0	–	–	–	
2.0	0.2	0.1	0.1	0.03
1.0	1.0	0.2	0.4	0.10
0.5	15.2	9.3	11.6	0.78
0.25	45.5	51.0	46.9	1.02
< 0.25[a]	38.1	39.5	41.0	0.74
< 1.0	98.8	99.7	99.4	0.09
1.0	1.22	0.27	0.59	0.094

[a]Initial sample dry weight – sum of recovered particulate DM fractions.

of goats. First there is a greater proportion of small particles in the rumen contents of goats, and consequently a larger surface area for the attachment of microorganisms, and microbial attack (Hungate 1966; Akin 1976; Cheng et al. 1977). Goats chew better the medium-quality forage diet used in the present experiment, and break it down to finer particles than sheep (Domingue et al. 1991a). Second, the recycling of N into the rumen, either by salivary N secretion or diffusion across the rumen is greater in goats than in sheep (Domingue et al. 1991c).

Evolutionary significance of differences in gastro-instestinal tract function

Based upon anatomical and morphological criteria, Hoffman (1985) classified the domestic sheep as a true grazer and the red deer as an intermediate between a true grazer and a concentrate selector. The high rumen water FOR and high rumen DM% observed in the present study in red deer may be part of a mechanism that they have evolved to handle concentrate-type diets which have a high content of cell solubles (i.e., carbohydrate and protein), with the soluble components being rapidly washed out of the rumen and into the intestines, where they can be digested more efficiently, whereas the fibre component is retained for rumen fermentation. This could have considerable significance in the development of new feeding strategies for farmed red deer, as they may be able to utilise forages with a high content of soluble carbohydrate and protein more efficiently than sheep and cattle, whereas the goat with its superior fibre digestion is best able to utilise low-quality diets.

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