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Influence of sward height and advancing season on rumen fermentation in Merino sheep grazing grass/white clover pasture

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Abstract

The study was carried out on a continuously stocked grass/white clover pasture, which was maintained at two sward heights: 3·5 cm (low; LSH) and 6·5 cm (high; HSH). Three oesophageal-cannulated and three other rumen-cannulated Merino sheep were allocated to each of the plots (LSH and HSH) in order to study the effects of sward height and advancing grazing season on rumen fermentation in grazing sheep. Three grazing periods (13 days) were considered: mid June, late July and early October. During each grazing period and after a preliminary period (7 days), samples of the grazed herbage and of grass hay were incubated in nylon bags in the rumen of each sheep for 0, 3, 6, 12, 24, 48, 72 and 96 h. On days 10 and 12 rumen fluid was sampled at the incubation time (11.00 h) and at 3, 6 and 12 h afterwards and pH, ammonia-nitrogen and volatile fatty acids (VFA) concentrations were determined. Sward height did not affect (P > 0·05) the degradation rate of dry matter (DM) and neutral-detergent fibre (NDF) from grazed herbage in any of the considered periods. Animals grazing LSH presented higher (P < 0·05) DM and NDF effective degradabilities (DMED and NDFED, respectively) during October but no differences were found during June and July. HSH grazing animals presented lower (P < 0·05) degradation rates of DM and NDF from grass hay during June and July than those found for LSH grazing sheep, with no differences (P > 0·05) observed during October. Sward height did not affect (P > 0·05) grass hay DMED and NDFED during July but during June and October HSH grazing sheep presented higher (P < 0·05) values. In general, DMED and NDFED from grazed herbage increased with advancing season, the lowest ((P < 0·05) value being observed during June. Rumen ammonia-nitrogen concentrations were higher during October than during June and July for both sward heights but values were higher than 200 mg/l at any sampling time during all grazing seasons. Rumen pH values were within the range considered adequate for maintaining a normal cellulolytic activity at most of the sampling times, with the exception of sheep grazing LSH during October. Rumen VFA concentrations were within the range reported for other grazing studies and only a few differences between sward heights were found. Differences in rumen parameters are discussed in relation to both chemical composition of grazed herbage and pattern of intake.

Keywords: *grazing time, rumen fermentation, sheep, sward height.*

Introduction

In the drier areas of many countries in the world, irrigation has been used for many years to increase productivity of pastures. As a general rule, grass/legume mixtures are favoured for irrigated pastures (Church, 1991). Optimal combinations of grass and legume are more difficult to maintain than pure stands of legumes or grasses but also present some advantages. A number of benefits from the use of grass/clover swards have been proposed: for example white clover presents a high nutritive value for ruminants and also has a potential benefit in the biological fixation of atmospheric nitrogen (N) by *Rhizobium* bacteria in root nodules (Church, 1991).

Sheep production based on grazing systems could be an alternative to agricultural production on irrigated areas in Spain and other Mediterranean countries, in which agriculture has led to surplus production (Valdés *et al.*, 1995). Ingestive behaviour and hence

herbage intake of grazing animals is strongly influenced by sward structure, which is a function of height, bulk density, mass, botanical composition and distribution of morphological components within the canopy (Gong *et al.*, 1996). However, under uniform sward conditions, this complex can be reduced to two key components: sward height and bulk density (Gong *et al.*, 1996). Grazing behaviour also influences rumen function through diet selectivity, particle size breakdown and hydration of ingested food. On the other hand, the ruminal conditions determine the rate of fermentation and the fractional rate of passage in relation to the rumen volume, both being important factors in the regulation of voluntary intake in forage-fed ruminants (Van Soest, 1994). The study of factors influencing rumen fermentation and thus herbage intake, provides basic information for developing appropriate grazing systems. Moreover, estimation of seasonal changes in rumen fermentation is one approach to determine when deficiencies in diet quality and rumen activity might be corrected through supplementation (Beever *et al.*, 1986).

To our knowledge no data about rumen fermentation from controlled grazing experiments are available for continuously stocked grass/white clover irrigated pastures. Therefore, our objective was to evaluate rumen fermentation patterns of Merino sheep grazing grass/white clover pasture at two sward heights and, in addition, to monitor changes in rumen parameters over a grazing season.

Material and methods

Study area treatments and sampling periods

Grazing trials were conducted at the Estación Agrícola Experimental of Consejo Superior de Investigaciones Científicas (CSIC) located at León in north-west Spain (latitude 42° 35' N; longitude 5° 43' E). The experiment was carried out over 5 months, from mid June to early October, on a 7-year-old pasture sown with ryegrass (*Lolium perenne*), tall fescue (*Festuca arundinacea*) and white clover (*Trifolium repens*) in a proportion of 20, 15 and 1 kg/ha, respectively. The two sward heights imposed were 3·5 (LSH) and 6·5 cm (HSH). The field was divided in four plots of 0·15 ha, two being randomly assigned to one of the two treatments and the other two being grazed by sheep in the non-experimental periods. Every year each plot received 45 kg/ha of each N, P and K, and 300 kg/ha of 33% NH_4NO_3. Each plot was irrigated every 9 days for 24 h throughout the experiment.

This study forms part of a larger grazing experiment. Plots were continuously grazed by non-experimental sheep throughout the experiment to achieve the two target sward heights. Experimental animals were moved to the plots at the beginning of each experimental period. Sward surface height was measured three times weekly using the Hill Farming Research Organization sward stick (Barthram, 1986). Forty measurements were taken at random in each plot. Non-experimental Merino sheep were used on a 'put and take' basis throughout the experiment to control sward heights on the two plots. More details about pasture conditions and herbage mass are given by Mantecón *et al.* (1995).

Three experimental periods were conducted during the grazing season: June 10 to 22 (mid June), July 22 to August 4 (late July) and September 28 to October 10 (early October).

Animals and experimental procedure

Six oesophageal-cannulated Merino sheep (average initial body weight (BW) 43·7 (s.e. 1·60) kg) and six rumen-cannulated Merino sheep (average initial BW 38·9 (s.e. 0·44) kg) were used. All animals were healthy and between 2 and 3 years old. Throughout the experiment, sheep were given free access to water, shade and trace mineral salts. Animals were weighed at the beginning and end of each sampling period at about 11.00 h. Sheep were assigned randomly to either low (LSH; 3·5 cm) or high sward height (HSH; 6·5 cm) and remained on the same treatment (three oesophageal-cannulated and three rumen-cannulated sheep in each treatment) across sampling periods.

Sampling periods consisted of a 7-day adaptation phase and a 6-day collection period. On day 8 of each period three oesophageal-cannulated sheep were used in each plot to collect forage samples representative of the diet. Animals were fasted for 12 h overnight prior to collection of extrusa samples. At about 08.00 h the plug of the oesophageal-cannula was removed, plastic bags were attached to the neck and the sheep allowed to graze until the bags were filled (about 30 min). After collection, samples were examined for contamination by regurgitated material, any contaminated portion was discarded and samples were composited within sward heights across sheep. The fistulated sheep were administered salts and water, the plug was reinserted and sheep were allowed to graze normally in the assigned plots for the remainder of the day. A portion of the samples used for chemical analyses was deep frozen (–20°C) and freeze-dried. The rest of the sample was used to measure its rumen degradation using the nylon bag technique (Ørskov *et al.*, 1980). About 30 g of sample was weighed without further manipulation into nylon bags, which were incubated in the rumen of each rumen-cannulated sheep for 3,

6, 12, 24, 48, 72 and 96 h. One bag was incubated per time interval per sheep beginning at about 11.00 h. As soon as the bags were removed from the rumen, they were washed thoroughly under running cold water for 2 min and then washed in the cold rinse cycle (20 min) of a washing machine. A further two bags per grazed herbage sample received this washing treatment alone (zero-time washout value). Dry matter (DM) disappearance was measured from the loss in weight after oven drying at 60°C for 48 h and the residues were analysed for neutral-detergent fibre (NDF) to estimate the loss of fibre.

In order to evaluate the rumen activity over the grazing periods, samples of a grass hay (crude protein (CP): 86 g, NDF: 693 g, acid-detergent fibre (ADF): 345 g and lignin: 56 g/kg DM) and filter paper were also incubated in the rumen of the sheep. Samples of grass hay were ground using a hammer-mill fitted with a 2-mm screen and about 5 g were weighed into nylon bags, which were incubated in the rumen of each sheep for 0, 3, 6, 12, 24, 48, 72 and 96 h as above described for grazed samples. Filter paper was cut into square pieces (0·5 × 0·5 cm) and about 3 g were weighed into nylon bags, which were incubated for periods of 12, 24, 48, 72 and 96 h. Once the bags were removed from the rumen, they were washed and dried following the procedure described above. Residues from incubation of hay were analysed for NDF to estimate the loss of fibre.

On days 10 and 12 rumen fluid samples were obtained from each sheep through the rumen cannula at 11.00, 14.00, 17.00 and 23.00 h. Rumen fluid was strained through four layers of cheese-cloth, its pH determined immediately and duplicate samples were taken for volatile fatty acid (VFA) and ammonia analyses. One ml of rumen fluid was added to 1 ml of deproteinizing solution (0·10 of metaphosphoric acid and 0·0006 crotonic acid; w/v) for VFA determination. Twenty ml of rumen fluid were acidified with 20 ml 0·5 mol/l HCl for ammonia determination. Samples were stored at –20°C until analyses were undertaken.

Analytical procedures

DM was determined by drying at 100°C until constant weight. Ash was determined by ashing samples in a muffle furnace at 500 to 505°C. N was determined according to Association of Official Analytical Chemists (AOAC, 1990). NDF, ADF and lignin analyses were carried out according to Goering and Van Soest (1970) Ammonia-N concentration was determined using an auto-analyser (Kjeltec Auto 1030 Tecator) as described by McDonald *et al.* (1960). VFAs were determined in centrifuged samples (1 ml) by gas chromatography following the procedure described by Ranilla *et al.* (1997).

Calculations and statistical analyses

The values for disappearance of DM and NDF from grazed herbage and grass hay were fitted to the exponential models $y = a + b\,(1 - e^{(-ct)})$ and $y = a + b\,(1 - e^{-c(t-lag)})$, respectively. In both models c represents the rate of degradation and $a + b$ is the potential degradability. Data were fitted with time using the NLIN procedure of the Statistical Analysis Systems Institute (SAS, 1997). Effective degradability (ED) was estimated in each sheep by using the parameters a, b, c and lag and assuming a rumen particulate outflow rate of 0·03 per h according to the equation: $ED = a + (b \times c/(c + k_p))\, e^{(-kp \times lag)}$. A lag time value of 0 was assumed for the calculation of DM effective degradability (DMED).

In situ data were analysed by variance analysis as a split-plot design with sward height as the main-plot treatment and sampling period as the subplot treatment (Steel and Torrie, 1980). Effects for treatment (sward height), sampling period, treatment × sampling period and sheep within treatment were included in the model. Treatment effects were tested using sheep within treatment as the error term. The interaction treatment × sampling period and the main effect of sampling period were tested using residual error. When a significant ($P < 0·05$) treatment × sampling period interaction was detected, data were analysed within sampling period.

Rumen pH, ammonia-N and VFA data (average values of two sampling days) were analysed as a split-split-plot design (Steel and Torrie, 1980) with sampling time and the interactions treatment × sampling period × sampling time and treatment × sampling time added to the model. When significant ($P < 0·05$) interactions were detected, which precluded pooling pH, VFA and ammonia-N data across sampling time and sampling period, these variables were analysed for each individual sampling period and sampling time.

The method of least significant difference was used to separate treatment means when a significant ($P < 0·05$) F-test for treatment was detected. The GLM procedure of SAS (1997) was used for all statistical analyses.

Results

The target sward heights were generally achieved in all sampling periods, although HSH was systematically lower than designated. Mean sward heights were similar ($P > 0·05$) in all sampling

periods for both LSH (mean values of 3·63, 3·43 and 3·53 for June, July and October, respectively) and HSH (mean values of 6·30, 6·20 and 6·37 for June, July and October, respectively) treatments. Animals remained healthy throughout the experimental periods and no variations in their BW were observed.

Drastic changes in daily temperatures were registered during the experimental periods (Figure 1), with minimum and maximum temperatures ranging from 6 to 24°C, from 13 to 33°C and from 5 to 16°C for June, July and October, respectively. No rain was recorded in any of the sampling periods.

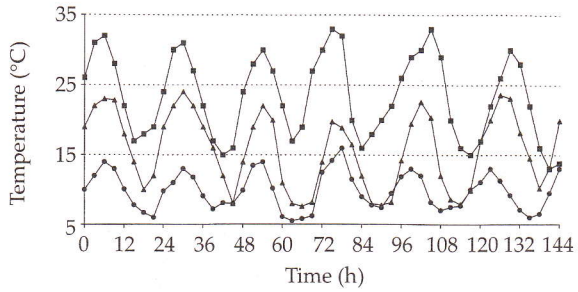

Figure 1 Daily evolution of temperature after beginning the *in situ* incubations (11.00 h): ▲ = June; ■ = July; ● = October.

Table 1 *Chemical composition (g/kg dry matter) of grazed herbage as affected by sward height (low (LSH) and high (HSH)) and grazing season in Merino sheep grazing grass/white clover pasture*

Item and sward height	Sampling period: Mid June	Late July	Early October
Organic matter			
LSH	890	893	872
HSH	911	857	865
Crude protein			
LSH	124	210	285
HSH	127	208	243
Neutral-detergent fibre			
LSH	715	523	442
HSH	720	535	479
Acid-detergent fibre			
LSH	348	243	171
HSH	377	253	224
Cellulose			
LSH	289	205	142
HSH	312	216	188
Hemicellulose			
LSH	363	280	271
HSH	343	282	255
Acid-detergent lignin			
LSH	59·1	37·5	28·6
HSH	64·5	37·3	36·0

Chemical composition of grazed herbage is shown in Table 1. CP content increased from June through October for both sward heights, whereas NDF, ADF and lignin contents followed the reverse order. CP and NDF contents of grazed herbage were similar for both sward heights during June and July; during

Table 2 *Influence of sward height (low (LSH) and high (HSH)) and advancing season on* in situ *degradation of dry matter and neutral-detergent fibre from grazed herbage in sheep grazing grass/white clover pasture*

Item and treatment	Sampling period: Mid June	Late July	Early October	s.e.d.
Dry matter (DM)				
c (per h)				
LSH	0·0462[a]	0·0918[b]	0·1083[b]	0·00693
HSH	0·0438[a]	0·0921[b]	0·0920[b]	0·00673
s.e.d.	0·00541	0·00805	0·01101	
a + *b* (g/kg)				
LSH	754[a]	884[b]	904[b]	13·4
HSH	799[a]	883[b]	885[b]	8·9
Significance	*		*	
s.e.d.	12·1	10·1	6·1	
Effective degradability (DMED; g/kg)				
LSH	588[a]	762[b]	822[c]	14·8
HSH	605[a]	786[b]	782[b]	11·9
Significance			*	
s.e.d.	17·1	9·3	9·5	
Neutral-detergent fibre (NDF)				
c (per h)				
LSH	0·0487[a]	0·1057[b]	0·1315[c]	0·00840
HSH	0·0456[a]	0·1270[b]	0·1070[b]	0·01225
Significance			†	
s.e.d.	0·00899	0·0136	0·0107	
a + *b* (g/kg)				
LSH	731[a]	846[b]	849[c]	12·6
HSH	765[a]	827[b]	806[ab]	21·3
Significance	*			
s.e.d.	7·8	11·8	24·4	
Effective degradability (NDFED; g/kg)				
LSH	529[a]	675[b]	739[c]	18·6
HSH	536[a]	686[b]	661[b]	18·3
Significance		†	*	
s.e.d.	20·3	13·2	20·9	

[a,b,c] Means in a row with a different superscript differ significantly ($P < 0·05$).
† $P < 0·1$.

October, however, the diet of LSH grazing animals contained a higher content of CP and a lower content of NDF compared with that for HSH grazing sheep.

Treatment × sampling period interactions ($P < 0.05$) were detected when *in situ* data for DM and NDF of grazed herbage and grass hay were analysed. Therefore, data from each sampling period were analysed separately to determine the effect of sward height on rumen degradation of grazed herbage (Table 2) and grass hay (Table 3). Sward height did not affect ($P > 0.05$) either the rates of degradation or the effective degradability of the DM and NDF of the grazed herbage in any of the sampling periods considered, except during October, when DMED and NDFED were higher ($P < 0.05$) for LSH compared with HSH. In relation to the sampling period, fractional rates of degradation and potential and effective degradabilities of DM and NDF were lowest ($P < 0.05$) during June for both sward heights.

HSH grazing sheep had lower ($P < 0.05$) rates of degradation of DM and NDF of grass hay than LSH grazing sheep during June and July but no significant differences ($P > 0.05$) were detected during October (Table 3). Both DMED and NDFED were higher ($P < 0.05$) for HSH than for LSH during June and October, with no significant differences during July. Grazing period did not affect ($P > 0.05$)

Table 3 *Influence of sward height (low (LSH) and high (HSH)) and advancing season on* in situ *degradation of dry matter and neutral-detergent fibre from grass hay incubated in the rumen of sheep grazing grass/white clover pasture*

Item and treatment	Sampling period: Mid June	Late July	Early October	s.e.d.
Dry matter (DM)				
c (per h)				
LSH	0·0519[a]	0·0473[b]	0·0346[a]	0·00277
HSH	0·0444	0·0404	0·0409	0·00168
Significance	*	*		
s.e.d.	0·00177	0·00250	0·00314	
a + *b* (g/kg)				
LSH	671	675	699	10·4
HSH	755[a]	714[a]	743[b]	8·3
Significance	*	*		
s.e.d.	19·5	10·9	21·8	
Effective degradability (DMED; g/kg)				
LSH	511[b]	501[b]	479[a]	6·4
HSH	551[c]	510[a]	528[b]	2·7
Significance	*		*	
s.e.d.	10·7	9·4	15·1	
Neutral-detergent fibre (NDF) *c* (per h)				
LSH	0·0322[b]	0·0312[b]	0·0245[a]	0·00140
HSH	0·0269	0·0248	0·0277	0·00155
Significance	**	*		
s.e.d.	0·00111	0·00143	0·00227	
a + *b* (g/kg)				
LSH	613	630	640	16·4
HSH	740	708	702	18·9
Significance	**	**		
s.e.d.	23·1	10·6	32·3	
Effective degradability (NDFED; g/kg)				
LSH	357[b]	352[b]	303[a]	9·0
HSH	415[b]	368[a]	367[a]	3·4
Significance	*		*	
s.e.d.	14·1	11·5	20·4	

[a,b] Means in a row with a different superscript differ significantly ($P < 0.05$).

Table 4 *Influence of sward height (low (LSH) and high (HSH)) and advancing season on* in situ *disappearance (g/kg) of filter paper incubated in the rumen of sheep grazing grass/white clover pasture for periods of time of 12, 24, 48, 72 and 96 h*

Incubation time (h) and treatment	Sampling period: Mid June	Late July	Early October	s.e.d.
12				
LSH	169[b]	161[b]	74·1[a]	21·4
HSH	190	173	176	37·5
Significance			**	
s.e.d.	27·5	32·8	20·8	
24				
LSH	406[b]	352[b]	223[a]	24·5
HSH	499[b]	354[a]	359[a]	22·6
Significance			**	
s.e.d.	35·1	18·1	15·9	
48				
LSH	520	575	555	38·6
HSH	681	626	646	61·9
Significance	†			
s.e.d.	70·0	29·3	50·1	
72				
LSH	708	732	745	37·8
HSH	856[b]	764[a]	822[ab]	29·7
Significance	*			
s.e.d.	45·5	45·3	50·6	
96				
LSH	900	905	859	40·9
HSH	967	917	939	30·6
Significance			†	
s.e.d.	48·0	18·5	36·2	

[a,b] Means in a row with a different superscript differ significantly ($P < 0.05$).
† $P < 0.1$.

DM and NDF fractional rates of degradation in animals grazing HSH. On the contrary, DM and NDF fractional rates of degradation were lowest ($P < 0{\cdot}05$) during October in animals grazing LSH, with no significant differences between June and July.

In general, there were only few differences between treatments in the filter paper disappearance (Table 4). During October filter paper disappearance after 12 and 24 h of incubation was higher ($P < 0{\cdot}05$) for HSH than for LSH sheep. However, no differences ($P > 0{\cdot}05$) between treatments were observed during June and July at any incubation time (with the exception of 72 h during June).

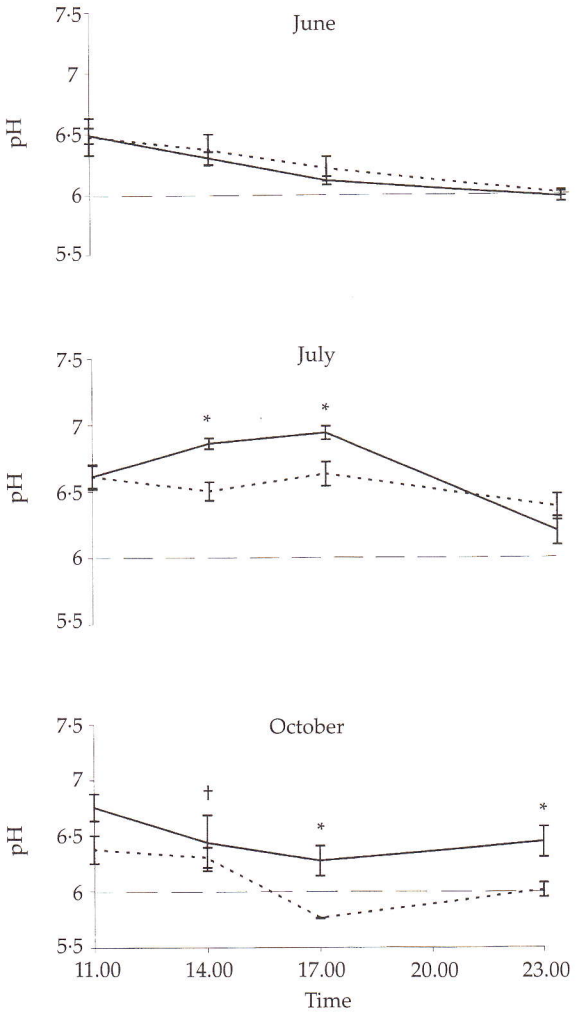

Figure 2 Influence of sward height (low (LSH; ------) and high (HSH; ———)) and advancing season on pH in the rumen of sheep grazing grass/white clover pasture (†: $P<0{\cdot}10$).

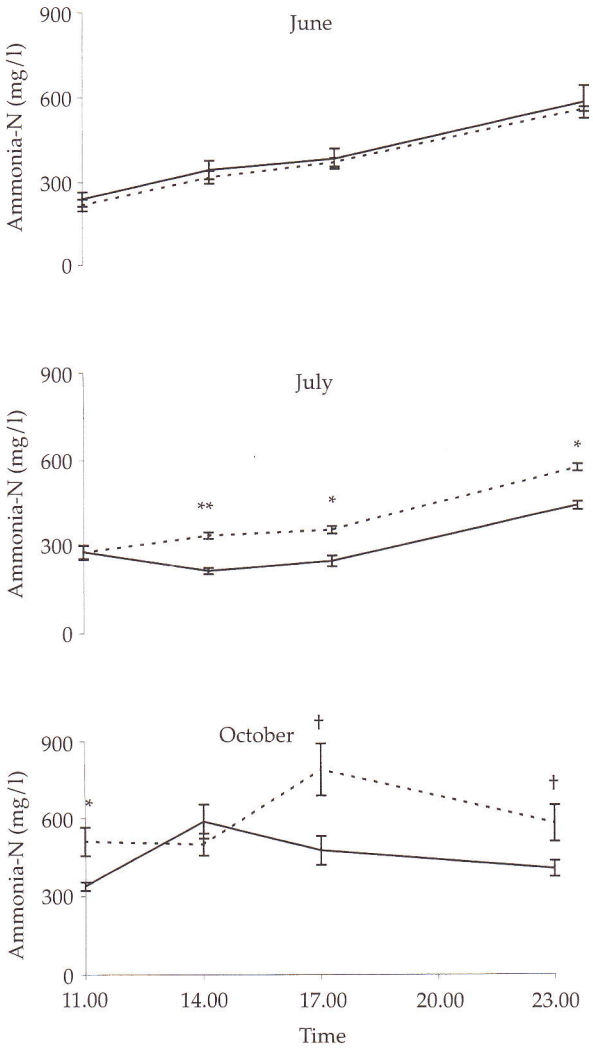

Figure 3 Influence of sward height (low (LSH; ------) and high (HSH; ———), and advancing season on ammonia-N concentrations in the rumen of sheep grazing grass/white clover pasture (†: $P<0{\cdot}10$).

As there were significant ($P < 0{\cdot}05$) treatment × sampling period × sampling time interactions for pH, ammonia-N and VFA concentrations, mean treatment values for these parameters at each sampling time are given in Figures 2, 3, 4 and 5. Sward height had no effect ($P > 0{\cdot}05$) on rumen pH, ammonia-N and VFA concentrations during June at any sampling time. During July, HSH grazing sheep presented higher ($P < 0{\cdot}05$) pH values and lower ($P < 0{\cdot}05$) ammonia-N and VFA concentrations at 14.00 and 17.00 h sampling. During October, HSH

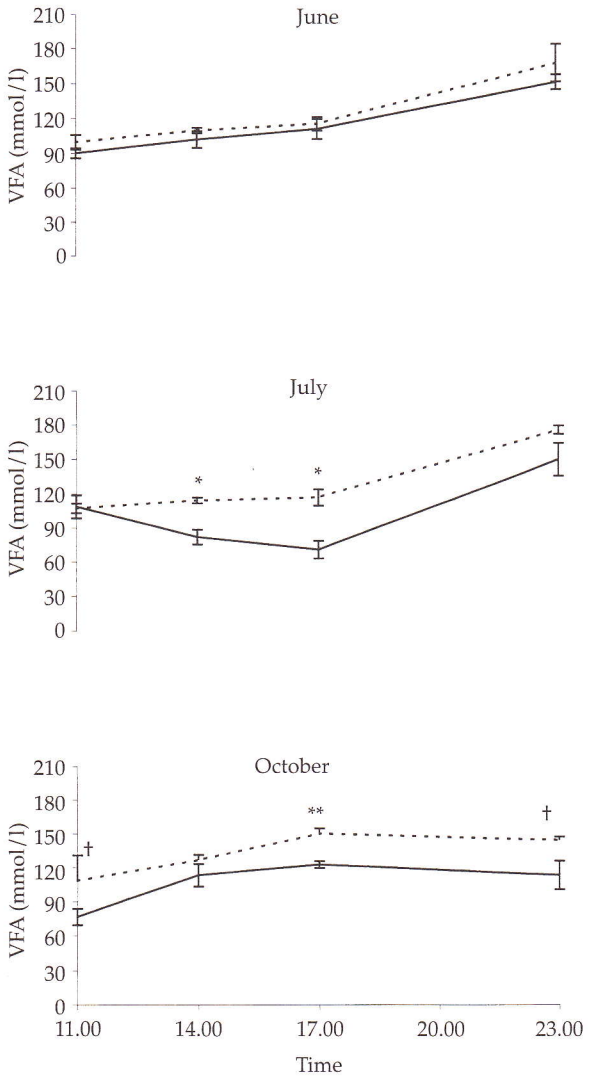

Figure 4 Influence of sward height (low (LSH; - - - - - -) and high (HSH; ———)) and advancing season on volatile fatty acids (VFA) concentrations in the rumen of sheep grazing grass/white clover pasture (†: $P<0{\cdot}10$).

grazing sheep also presented higher pH values at 17.00 and 23.00 h and tended ($P<0{\cdot}10$) to present lower ammonia-N and VFA concentrations at these sampling times.

Discussion

The chemical composition of the diet grazed by sheep varied with grazing season in both sward heights. Similar increases in CP content and decreases in NDF content of grazed herbage with advancing season have been reported by Valdés *et al.* (1995) for an irrigated grass/white clover pasture continuously stocked from May to November. These changes in the chemical composition of the diet are the consequence of changes in both the quality of the herbage on offer and in the herbage selection made by the sheep themselves. In a study conducted on the same plots used here, Mantecón *et al.* (1995) reported an increase in the proportion of white clover in the pasture and in the herbage regrowth produced as grazing period advanced, both of them being consequent with the changes observed in the chemical composition.

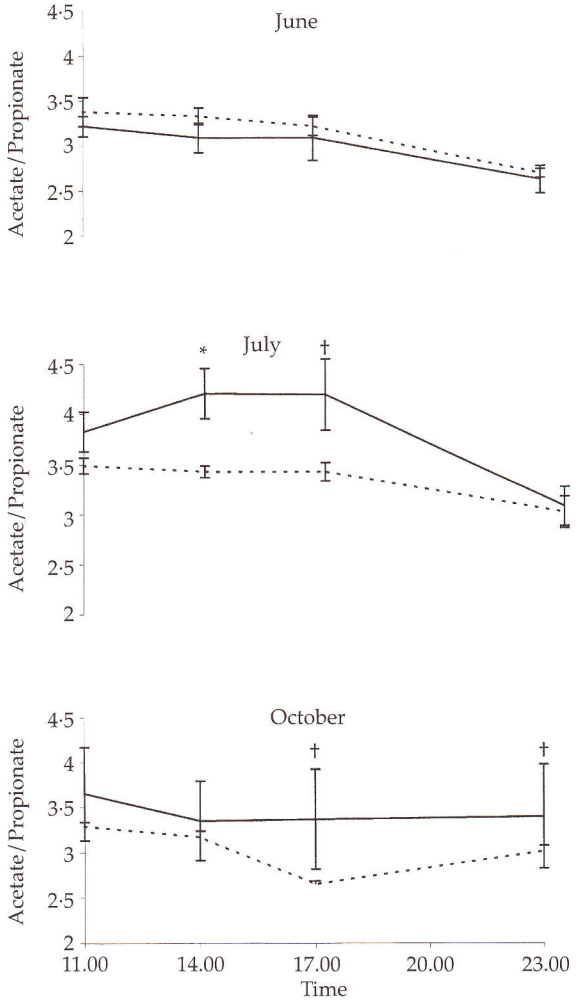

Figure 5 Influence of sward height (low (LSH; - - - - - -)and high (HSH; ———)) and advancing season on the acetate/propionate ratio in the rumen of sheep grazing grass/white clover pasture (†: $P<0{\cdot}10$).

Chemical composition of foods determines their rumen degradation. Thus, the lower DM rate of degradation from grazed herbage observed during June (compared with July and October) for both sward heights is probably the consequence of its higher cell wall content. Cell content is rapidly fermented, whereas rate of degradation of cell wall depends on its physico-chemical characteristics (Van Soest, 1994). June-grazed herbage presented a higher cell wall lignification, which could explain its lower NDF potential degradability, as lignin is the major component of the cell wall that is recognized as a limiting factor of the rumen degradation of cell wall polysaccharides (Van Soest, 1994).

It is noticeable that despite the lack of apparent differences in the chemical composition of the grazed herbage between LSH and HSH treatments during June, HSH herbage presented a higher potential degradability of both DM and NDF. The rumen is a very complex system, which is not only influenced by the food itself but also by the animal and its environment (Van Soest, 1994). It would be possible that the physico-chemical conditions (other than the parameters considered in this study) in the rumen of HSH grazing sheep correspond to a more regular fermentation pattern than those in LSH grazing sheep. This concept is supported by both the increased NDFED of grass hay and the higher filter paper disappearance after 72 h of incubation observed in HSH sheep. Moreover, the urinary excretion of allantoin was higher in sheep grazing HSH than in those grazing LSH (unpublished results), which also could be indicative of a higher microbial synthesis. However, there were no differences between sward heights in any of the considered rumen parameters and minimum pH values were in the limit of those causing severe depression in fibre digestion.

In situ degradation depends not only on the characteristics of foods but also on the activity of rumen micro-organisms. As the same grass hay was incubated in the rumen of sheep during all grazing periods, differences observed in its degradation should be due to changes in the rumen population and/or its activity. According to Stewart (1977), a decrease in rumen pH to near or below 6·0, as found at 17.00 and 23.00 h in the rumen of LSH grazing sheep during October, causes severe inhibition in fibre digestion. This could explain the lower NDFED from grass hay found during October in LSH grazing sheep compared with those on the HSH grazing treatment. In fact, the pH in the rumen of HSH grazing sheep did not drop below 6·27 (average value), thus maintaining appropriate values for a normal cellulolytic activity. The higher filter paper disappearance observed in these animals after 12 and 24 h of incubation, as well as the trend to a higher acetate/propionate (Ac/Pr) ratio in their rumen fluid found at 17.00 and 23.00 h, also reflect improved fibre digestion in HSH compared with LSH grazing sheep during October.

Daily variations in rumen parameters (pH, VFA and ammonia-N concentrations) are directly related to the pattern of intake (Arnold, 1981). Pattern of intake in grazing animals is affected by a great number of factors intrinsic to the animal and also by factors external to the animal (e.g. weather, forage quantity and forage quality). Grazing behaviour was not recorded in our study, but the daily evolution of the rumen parameters supports the observations made by other authors (Arnold, 1981; Berggren-Thomas and Hohenboken, 1986). During July the rumen pH values were higher than 6·50 at 11.00, 14.00 and 17.00 h, suggesting that no major grazing periods took place over this period of time, probably due to the high temperatures (in general higher than 25°C). In fact, it was noticed that at 14.00 and 17.00 h sheep sought shade and no regular grazing was observed. Rumen pH values dropped (and VFA and ammonia-N concentrations increased) at 23.00 h, suggesting that a major grazing period took place before this sampling time. It is noticeable that, in general, pH values at 14.00 and 17.00 h were higher during July than during October for both sward heights. Arnold (1981) reported that when daily maximum temperatures are lower than 15°C (as during October), little night grazing is done, but when they are high (>25°C), night grazing varies from 0 to proportionately 0·7 of total grazing time. Our results are consistent with this observation.

The differences observed between swards height in ammonia-N concentrations during July and October are consistent with the ones observed for rumen pH values and VFA cocentrations. LSH grazing sheep presented higher ammonia-N concentrations at certain sampling times, which probably reflect their more regular pattern of grazing. When the herbage is short, sheep can eat less per bite and the frequency of grazing is usually increased (Arnold, 1981). In agreement with our results, many studies have reported increases in rumen ammonia-N concentrations when herbage N content increases (Beever *et al.*, 1986; Cruickshank *et al.*, 1992; García *et al.*, 1994). Similar rumen ammonia-N values to those obtained here were reported by Cruickshank *et al.* (1992) for lambs and by Beever *et al.* (1986) for cattle, both species grazing white clover and ryegrass. Rumen ammonia-N concentrations were greater than the 50 mg/l concentration suggested by Satter and

Slyter (1974) as optimal for efficiency of microbial growth and also higher than the 200 mg/l found by Mehrez *et al.* (1977) as optimal for the maximum rate of organic matter degradation. Thus, it can be assumed that ammonia-N concentrations were not limiting the growth of ruminal micro-organisms for both sward heights over all grazing periods. However, the high ammonia-N concentrations observed for both height swards during October could be indicative of substantial losses of dietary N before the small intestine, as suggested by Beever *et al.* (1986). These authors reported that the high levels of ammonia-N found in the rumen of cattle grazing white clover (values similar to the ones found in our study during October) were due to the readily soluble nature of the N constituents of the herbage, which gave rise to a supply of degraded N (ammonia-N in particular), in excess of the capacity of the rumen micro-organisms to assimilate the N into microbial mass. Under these rumen conditions, the supply of a complementary food (with a high energy content, but low in rumen degradable N) would help to maximize microbial synthesis.

Differences observed in VFA concentrations among grazing periods are, in general, the result of changes in grazing patterns over the experimental periods. The values observed in our study were within reported ranges for other pastures (García *et al.*, 1994; Olson *et al.*, 1994). During October, rumen VFA concentrations were higher in LSH grazing sheep compared with those on the HSH grazing treatment, which corresponds to the lower pH and the higher degradation rate of fibre from grazed herbage observed in LSH grazing group. Despite changes in grazed herbage quality, only few differences were detected for the ratio Ac/Pr in rumen fluid, which were in the range reported in the literature for forage-fed ruminants (Van Soest, 1994).

In conclusion, the rumen parameters would suggest differences in rumen fermentation due to both sward height and grazing season at some times of the day. However, the VFA and the ammonia-N concentrations were in all animals adequate for the growth of the rumen microbes. The high levels of ammonia-N found in the rumen, specially during July and October, suggest an excess of rumen degradable protein intake. Complementation with energy foods could make more efficient use of the protein in the herbage. Nevertheless, it must be taken into account that these suggestions are made for optimizing rumen fermentation. In order to take decisions for grazing management practice, herbage intake by the animals and animal performance (among other factors) must be considered.

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