Effect of time of supplementary feeding on intake, apparent digestibility and rumen fermentation of grass hay by sheep

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Abstract

Effects of time of supplementation on forage intake, nutrient apparent digestibility and rumen fermentation were studied with 12 mature castrated male sheep (wethers) offered grass hay from 16.30 h to 09.30 h and supplemented with a cereal-based concentrate given at either 09.30 or 16.00 h. Voluntary intake of hay organic matter (OM) was decreased by feeding the concentrate ($P < 0.01$). Offering concentrate at 09.30 h after hay was available, increased intake of hay and total OM compared with offering it at 16.00 h before hay was available ($P < 0.05$). Daily pattern of hay intake was not changed when concentrate was offered at 09.30 h compared with feeding hay alone, but concentrate given at 16.00 h resulted in a lower hay intake between 16.30 and 18.00 h. Sheep offered concentrate at 09.30 h had higher rumen ammonia levels than those offered concentrate at 16.00 h, but there were no differences in the apparent digestibility of the nutrients, rumen pH and molar proportions of the main volatile fatty acids. There were also no differences between groups in the blood plasma concentrations of 3-hydroxybutyrate (3OHB), non-esterified fatty acids (NEFA) and glucose. It is concluded that feeding supplement after rather than before a period of intake of forage or a bout of grazing may offer a means of minimizing reduction of forage intake as a consequence of feeding concentrate.

Keywords: concentrate, digestion, eating pattern, hay, sheep.

Introduction

In situations where optimum sward conditions cannot be maintained, and the nutrient intake of animals falls below the required level, one option available is to provide supplementary feeding. Supplements are usually offered in the morning, when the animals have just completed the first grazing session. The frequency of feeding supplements has been examined in several studies (see Allden, 1981), but little is known about the effect of time of supplementation on the daily pattern of herbage intake. The normal daily pattern of grazing consists of major grazing periods beginning near dawn and again in the late afternoon, ending near sunset, with minor sessions during the remainder of the day (Arnold, 1981).

The aim of this experiment was to investigate whether the timing of feeding a concentrate supplement, in relation to whether this was preceded or followed by intake of forage, had an influence on the pattern of intake of the forage component of the diet.

To ensure control of pattern of forage availability animals were fed indoors on hay. Measurements of pattern of hay intake and of rumen pH, ammonia and volatile fatty acids and blood metabolites were carried out.

Material and methods

Animals and experimental design

Twelve mature Scottish Blackface castrated male sheep (wethers), averaging 53.9 (s.e. 6.70) kg live weight and 2.5 (s.e. 0.20) body condition score, were divided into two groups (treatments A and M) of six animals, according to live weight and body

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condition, and housed in individual pens, with no bedding material.

The experiment consisted of a pre-experimental and experimental phase each of 20 days duration; each was divided into a 10-day period to allow adaptation to the diet and a 10-day period during which measurements were carried out.

Chopped grass hay was offered *ad libitum* to all animals throughout the pre-experimental and experimental phases from 16.30 h until 08.30 h. At this time the refusals were removed and fresh hay was offered for 1 h. Thus no hay was available from 09.30 h to 16.30 h in order to promote a high rate of intake in the morning and late afternoon, to mimic the diurnal pattern of intake in grazing animals.

During the pre-experimental phase the animals were offered only hay. During the experimental phase a cereal-based concentrate supplement was offered. Half the sheep were given supplement in the morning at 09.30 h (treatment M) and half in the afternoon at 16.00 h (treatment A) at the rate of 700 g per sheep per day. Sheep consumed all of the offered concentrate within 15 min of feeding. All sheep had free access to water during the experiment.

The composition of the concentrate is shown in Table 1, while the chemical composition of the hay and concentrate is given in Table 2.

Measurements

Voluntary intake was measured during the last 10 days of each period, during which time hay was offered at an amount proportionately 0.10 to 0.15 in excess of the previous day's consumption. Samples of food offered to and refused by the animals were taken, bulked over the 10-day measurement period and stored for subsequent analysis.

On 2 days consecutively in each measurement period the pattern of hay intake was measured by weighing refusals at 18.00, 21.00, 24.00, 03.00, 06.00, 08.30 and 09.30 h.

In order to measure the apparent digestibility of the total diet, a total collection of faeces was made for the last 8 days of each experimental period, when the sheep were equipped with faecal collection bags. A representative sample of faeces was taken daily, dried at 60°C in a forced-air oven and stored for subsequent analysis.

On the last day of the second period, rumen fluid samples were obtained at 12.00, 18.00, 24.00 and 06.00 h using a stomach tube. Care was taken to avoid excessive contamination with saliva, and

Table 1 Composition of concentrate (g/kg fresh weight)

Barley	419.1
Malt culms	208.0
Rapeseed meal	100.0
Condensed molasses solubles (0.2 molasses)	70.0
Dark grains	68.0
Dry fat (0.5 lipid)	50.0
Fish meal	50.0
Fat protector	10.0
Limestone	9.6
Salt	9.2
Calcined magnesite	3.2
Minerals/vitamins	2.5
Dibasic calcium phosphate	0.4

Table 2 Chemical composition of grass hay and concentrate

	Hay	Concentrate
Dry matter (DM; g/kg)	838	925
Composition of DM (g/kg)		
Organic matter (OM)	927	909
Crude protein (CP)	105	196
Starch	†	246
Sugar	†	53
Neutral-detergent fibre	626	267
Acid-detergent fibre	386	135

† Not available.

samples were large enough to minimize any potential effect of contamination. The pH of the sample was measured immediately following collection and the sample was then strained through four layers of cheesecloth, acidified with 0.5 mol/l sulphuric acid and frozen until analysis for volatile fatty acids (VFA) and ammonia.

Blood samples were collected into heparinized tubes by jugular venipuncture at 12.00, 15.00, 18.00, 21.00, 24.00, 03.00, 06.00 and 09.00 h on 2 days consecutively in the second period. Following centrifugation plasma was removed and stored at -20°C until determination of 3-hydroxybutyrate (3OHB), non-esterified fatty acids (NEFA) and glucose.

Chemical analyses

Dry matter (DM) concentration of foods, refusals and faeces was determined by drying samples to constant weight at 100°C and organic matter (OM) calculated as weight lost during ashing at 550°C. Nitrogen (N) concentration was determined by a macro-Kjeldahl method. Neutral-detergent fibre (NDF) and acid-detergent fibre (ADF) were determined using the method of Goering and Van Soest (1970). Rumen fluid ammonia was determined as described by Whitehead, Cooke and Chapman (1967) and VFA by

gas chromatography (Ottenstein and Bartley, 1971). Blood samples were analysed for 3OHb using the method described by Zivin and Snarr (1973); for glucose using a modification of the method described by Richardson (1977); and for NEFA using a kit (NEFA C kit, Wako Chemicals GmbH, Germany).

Statistical analysis

Intake and apparent digestibility data were analysed by analysis of variance, with intake in period 1 as a covariate using the ANOVA procedure of the Statistical Analysis Systems Institute (SAS, 1982). Ruminal fermentation parameters and blood metabolites were analysed by ANOVA (SAS, 1982) with time of concentrate feeding as the main effect.

Results

Voluntary intake of hay DM was lower when concentrate was given in the experimental phase than when no concentrate was offered in the pre-experimental phase (1026 v. 772 (s.e. 34.1) g/day; $P < 0.001$). Table 3 shows the voluntary intake of hay when the sheep were given the concentrate at 09.30 h (M) or at 16.00 h (A).

Table 3 Effects of time of supplementation on voluntary intake of hay

	Time of supplementation†		
	M	A	s.e.
Hay intake			
Organic matter intake (g/day)	860	686*	55.7
Crude protein intake(g/day)	108	80*	6.5

† M: concentrate given at 09.30 h; A: concentrate given at 16.00 h.

Table 4 Effect of time of supplementation on diurnal pattern of hay intake (g dry matter)

Time	Time of supplementation†		
	M	A	s.e.
16.30-18.00	514	299**	28.5
18.00-21.00	221	192	20.1
21.00-24.00	144	142	14.5
24.00-03.00	118	148	13.2
03.00-06.00	94	80	8.0
06.00-08.30	67	82	7.3
08.30-09.30	108	108	13.1

† M: concentrate given at 09.30 h; A: concentrate given at 16.00 h.

The sheep on treatment A had lower intakes of hay OM than those on treatment M ($P < 0.05$). Time of supplementation had no significant effect on the apparent digestibility of OM in the total diet (0.712 v. 0.696 (s.e. 0.0084), $P > 0.05$ for M and A treatments respectively) or on digestion of NDF or ADF.

The diurnal pattern of hay DM intake is shown in Table 4. Feeding the concentrate in the afternoon reduced hay DM intake by 215 g between 16.30 and 18.00 h compared with feeding the concentrate in the morning ($P < 0.01$). However, there were no differences in DM intake between the treatments at other times of the day.

Figure 1 shows the effect of time of supplementation on rumen pH and ammonia concentrations. Samples obtained at 12.00 h from treatment A had a significantly higher ruminal pH (7.23 v. 6.79; $P < 0.001$) and a significantly lower ammonia concentration (112 v. 149 mg/l; $P < 0.05$) than those from treatment M. There were no significant differences between groups in these parameters at other sampling times.

Time of supplementation failed to change significantly molar proportions of acetate (70.8 (s.e. 0.45) mol/l) and propionate (17.2 (s.e. 0.34) mol/l) at any sampling times. However, molar proportions of butyrate and valerate were lower in the samples obtained at 12.00 h from treatment A than those from treatment M (Figure 2; $P < 0.05$). The concentration of isoacids was lower in treatment A at 06.00 h ($P < 0.05$) and at 12.00 h ($P < 0.001$).

Figure 1 Rumen pH and ammonia concentrations at different times of day for sheep given supplement in the morning (●—●) or afternoon (▲—▲).

Figure 2 Rumen butyrate, valerate and iso-acid concentrations at different times of day for sheep given supplement in the morning (●—●) or afternoon (▲—▲).

Plasma concentrations of NEFA, glucose and 3OHB are shown in Figure 3. After the feeding of the supplement concentrations of glucose and 3OHB rose while concentrations of NEFA fell. This resulted in differing diurnal patterns for these blood metabolites between the two treatments.

Figure 3 Plasma concentrations of non-esterified fatty acid (NEFA), glucose and 3-hydroxybutyrate (3OHB) at different times of day for sheep given supplement in the morning (●—●) or afternoon (▲—▲).

Discussion

The diurnal pattern of hay intake is shown more clearly when the hay-DM intake in each of the measured time intervals is expressed as a proportion of the daily intake (Figure 4). The highest proportion of hay intake occurred between 16.30 and 18.00 h with a steady decline from 18.00 to 08.30 h and a slight increase from 08.30 to 09.30 h.

The method of feeding hay was partly successful in mimicking the diurnal pattern of intake seen in grazing animals (Arnold, 1981). It promoted a high proportion of the total daily intake in late afternoon, but there was only a small increase in the proportion of intake occurring between 08.30 and 09.30 h.

The pattern of hay intake differed between the A and M treatments. The proportion of daily intake

between 16.30 and 18.00 h was lower when animals were offered the concentrate in the afternoon (0.25 *v.* 0.41 for the A and M treatments respectively). This may have been due to the high ruminal digesta fill in the A sheep in this period; animals consumed 700 g concentrate within 15 min of feeding and, as a consequence, may not have been able to achieve a high subsequent intake of hay.

Overall, animals given concentrate in the morning had a significantly higher total intake of digestible OM (881 and 1041 g/day ($P < 0.05$) for the A and M groups, respectively). Similar results were reported by Howard, Muntifering, Howard and Hayek (1992), who found that offering supplement to hay-fed sheep at 08.00 h resulted in a higher total DM intake than offering supplement at 15.00 h.

Figure 4 Proportion of total daily intake of hay consumed in different time intervals for sheep fed in the morning or afternoon. Within time intervals different letters indicate significant differences ($P < 0.05$).

It might be expected that animals given the concentrate after hay (M group) and in which digestion was spread out over a longer time interval (in which no food was available), would utilize absorbed nutrients more efficiently since substrates would be available more continuously (Milligan, 1971). Some authors (Palmquist, Smith and Ronning, 1964; French and Kennelly, 1990) have reported improved daily gains and food conversion efficiencies when patterns of food administration similar to that used for the M group were used. However the short duration of the experiment precludes any conclusions being made on likely effects on live-weight gain.

In agreement with the results of Howard *et al.* (1992), time of supplementation had no effect on the mean value of ruminal pH, but in both groups ruminal pH decreased after feeding the concentrate. However it was always higher than 6.5, the critical level below which cellulolytic activity is depressed (Stewart, 1977). Kaufmann (1976) reported that a satisfactory regulation of rumen pH is achieved with a minimum proportion of 0.40 roughage in the diet and in this experiment the ratio hay:concentrate of the diet (DM basis) ranged from 56:44 to 69:31.

Although the difference was only significant at 12.00 h ruminal ammonia concentration was higher in sheep given concentrate in the morning compared with those given concentrate in the afternoon. This may have been due to the higher intake of hay and therefore total crude protein intake for the M group than for the A group. It might be expected that the increased ammonia concentrations would promote more extensive microbial growth and forage degradation (DeCurto, Cochran, Harmon, Beharka, Jacques, Towne and Vazant, 1990) in the M group. The exact nature of the response will depend on the concentration and degradability of protein in both the forage and concentrate. Although not significant ($P = 0.20$) apparent digestibility of cell wall (NDF) tended to be higher for the M group (0.663) than for the A group (0.633). It is possible that there were differences in the ruminal NDF digestion, but postruminal digestion may have prevented their detection. Howard *et al.* (1992) reported that offering supplement to hay-fed sheep at 08.00 h resulted in a higher digestion of ADF than offering supplement at 15.00 h, but time of supplementation had no effect on digestion of NDF.

In both groups of animals molar proportions of acetate were decreased and molar proportions of propionate and butyrate were increased after feeding the concentrate. The method of obtaining rumen samples in this experiment prevented frequent measurement to obtain an accurate assessment of the pattern of rumen molar proportions of VFA with the two times of supplementation used.

In agreement with the results reported by Sutton, Hart, Broster, Elliott and Schuller (1986), both glucose and 3OHB concentrations in the plasma increased after feeding the concentrate (Figure 3), the increase being similar for both treatments. Plasma NEFA concentrations decreased after feeding the concentrate, probably as a consequence of a reduction in lipolysis owing to an increase in energy supply from the products of digestion (Annison, 1960). Günzel and Giesecke (1974) reported that in sheep offered good quality hay *ad libitum* twice daily, plasma NEFA concentrations showed a definite pattern of diurnal variation, with the highest mean NEFA concentration before the morning feed and the lowest 4 h after it. In our experiment also the highest NEFA concentration was, for both groups, before feeding the concentrate and the lowest 4 to 6 h after.

In conclusion, feeding concentrate at 09.30 h instead of 16.00 h resulted in a higher total intake of OM i.e. total OM intake was higher when concentrates were given after rather than before a period of ingestion of hay. This suggests that feeding supplement after rather than before a major grazing bout may be an

effective means of minimizing reduction in forage intake as a consequence of feeding concentrate. However, care must be exercised in extrapolating beyond pen-feeding situations, as grazing animals may respond to time of supplementation by altered ingestive behaviour (Howard *et al.*, 1992). Therefore, further studies are necessary on the relationship between time of supplementation and diurnal pattern of herbage intake before general recommendations can be devised.

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