THE EFFECT OF GLUCOSE INFUSION ON NITROGEN UTILIZATION IN SHEEP GIVEN ROUGHAGE DIETS

H. SOETANTO*, K. BOODHOO+, and N.P. McMENIMAN*

Summary

Nitrogen utilization in sheep fed barley straw diets supplemented with urea to meet RDN requirements was studied in two experiments during which they were or were not infused intra-abomasally with water, or 50 g anhydrous glucose, or intra-ruminally with 60 g sodium propionate per day. Although the responses were not consistent it appeared that nitrogen retention was higher when either glucose or propionate was supplied indicating a competition for amino acids between protein synthesis and gluconeogenesis. The results also suggested that previous treatment with either glucose or propionate had a carry-over effect on nitrogen balance.

I. INTRODUCTION

The role of glucose in ruminant metabolism has been the subject of a number of studies during the past 20 years (see Lindsay 1959). While it is true that glucose is an essential metabolite for a number of tissues, in particular the red blood cells and the brain, glucose insufficiency is more likely to limit production in animals with a high metabolic demand for glucose, i.e. lactating or fast-growing animals. Leng et al. (1978) and Girdler et al. (1986) provided supplementary glucose or its precursors to growing lambs and concluded that these metabolites were limiting production. McRae and Lobley (1982) and Preston and Leng (1987) have suggested that the low productivity of roughage-fed ruminants is associated with an insufficient supply of glucose for the production of NADPH. NADPH is required for the formation of long-chain fatty acids from acetic acid which is produced abundantly with high-roughage diets. Although direct proof of this hypothesis is still required, McRae et al. (1985) provided indirect but supportive evidence when they showed that metabolisable energy in spring-harvested grass was utilized more efficiently by sheep than that in the same sward harvested in the autumn.

To obtain more information on this topic, nitrogen balance studies were conducted with sheep fed barley straw diets with and without the provision of glucose and/or propionate.

II. MATERIALS AND METHODS

(a) Animals and diets

In experiment 1 five mixed breed ewes (2-3 year old; mean live weight (LW) 29.9 $\pm$ 2.8 kg), each fitted with a rumen and abomasal cannula, were placed in individual metabolism cages and fed ad libitum from a continous feeder with a barley straw diet that had been sprayed with sufficient urea to provide the rumen digestible nitrogen (RDN) requirements (ARC 1980). They were also provided with 20 g mineral mix. The sheep were adapted to this diet over 4 weeks. For the following 7 days (period 1 = P1) total collections of faeces and urine were carried out to allow for the subsequent calculation of nitrogen balance. For the following 3-week period (P2) the sheep were fed the basal diet and were given 50 g/day glucose by abomasal infusion. The nitrogen balance of each sheep was determined during the last week of this period. Following P2, the sheep were fed with the basal diet as in P1 for 3 weeks and nitrogen balance

*Dept. of Farm Animal Medicine and Production, University of Queensland, Qld. 4072

+Present address: 16 Mauritius Street, Port Louis, Mauritius

was again determined during the last week. On the last day of P1 and P2 rumen fluid samples were obtained from each sheep.

In experiment 2, seven mixed-sex sheep (mean LW 31.0 $\pm$ 7.2 kg; 1-3 year old) were allocated to three groups: viz. control (C), three sheep infused intra-ruminally with 11 g urea in 200 ml of water to provide RDN requirements plus 200 ml water/day infused intra-abomasally; glucose (G), two sheep infused intra-ruminally with urea as for C and 50 g glucose dissolved in 200 ml of water infused into the abomasum; and propionate (P), two sheep infused as for group C except that 60 g sodium propionate was dissolved in the rumen infusate. The basal diet fed to all sheep was ad libitum barley straw, 20 g/day mineral mix and a negligible amount of molasses. This diet was offered in two equal amounts at 1000 h and 1600 h. After 3 weeks on this feeding and infusion regime a 10 day nitrogen balance was carried out (P1). The sheep were then reallocated to the treatments described above and adapted to the new feeding and infusion regimes for a week and then subjected to a 10 day total collection for faeces and urine (P2). One animal (sheep no. 7) that was in the P group died between P1 and P2 and a spare animal was substituted. The allocation of animals to treatments and period was as follows:

			Animal number and treatment		
			C	G	P
P1 :	day 1-21:	adaptation period	1,2,3	4,5	6,7
	day 22-32:	nitrogen balance study			
	day 32 :	sampling of rumen fluid			
P2 :	day 33-40:	adaptation period	4,5,6	7,3	1,2
	day 41-51:	nitrogen balance study			
	day 51 :	sampling of rumen fluid			

Rumen fluid was obtained from each sheep 2 hours before and 2, 4 and 6 hours after the morning feeding for subsequent rumen ammonia and volatile fatty acid (VFA) determinations.

(b) Analytical and statistical methods

The dry matter (DM) and organic matter (OM) content of feed, feed refusals and faeces samples were obtained by heating them at 80^{o}C for 36 h and then ashing them at 550^{o}C for 4 h. The nitrogen (N) content of samples was determined by Kjeldahl digestion and distillation. Rumen ammonia concentrations were obtained by distillation and titration. VFA were analysed by gas liquid chromatography. Differences between treatments and experimental period were compared by analysis of variance. In experiment 2 however, no statistical comparison was made between P1 and P2.

III. RESULTS

The nitrogen content of the urea-treated barley straw used in experiment 1 was 11.2, 10.9 and 11.8 g/kg DM for P1, P2 and P3. The ash content was constant at 69 g/kg DM. In experiment 2 the nitrogen and ash contents of the barley straw were 2.74 g/kg DM and 122 g/kg DM.

Tables 1 and 2 show the main effects of glucose and propionate infusion on the parameters measured in experiments 1 and 2. In general, the infusion of glucose or propionate had no significant effect ($P > 0.05$) on feed intake or digestibility except that in P2 of experiment 2 the OMI was depressed when glucose was infused. In experiment 1 nitrogen balance improved, but not significantly, when glucose was infused (P1 vs P2) but in experiment 2 propionate infusion improved N balance during P1 and glucose infusion improved it during P2. In experiment 2 the control sheep in P2 which had been given glucose or propionate in P1 had higher N balances than the control sheep in P1.

The mean concentration of rumen ammonia in both experiments 1 and 2 was above the suggested minimum requirement (> 50 mgN/l) and no significant differences ($P > 0.05$) were found due to treatments.

In experiment 2 the infusion of propionate altered the proportions of acetic and propionic acid in the rumen fluid but these changes were not significant in P2 (Table 2).

Table 1. Mean values for parameters measured in experiment 1.

Parameter	Period 1	Period 2	Period 3	SEM
Feed intake				
Organic matter (g/d/kgLW)	14.8	14.5	14.7	0.20
Nitrogen (mg/d/kgLW)	181.0a	175.0a	194.0b	17.9
Digestibility of OM (%)	42.1	44.6	40.7	1.21
N excretion (mg/d/kgLW)				
Faeces	101	94	94	26.3
Urine	109	97	113	58.9
N balance (mg/d/kgLW)	-30	-15	-12	6.4
Rumen ammonia (mgN/l)	62	65	nd	3.8

Values in the same row followed by different letters are significantly different, $P < 0.05$; SEM = standard error of the mean; nd = not determined.

Table 2. Mean values for parameters measured in experiment 2.

	Period 1				Period 2				
	C	G	P	SEM	GC	PC	CG	CP	SEM
Feed intake (g/d/kgLW)									
Organic matter	13.6	13.5	13.7	1.0	14.7a	13.9a	11.5b	13.7	0.48
Nitrogen	0.23	0.20	0.22	0.032	0.20	0.20	0.23	0.21	0.047
Digestibility of OM (%)	38.1	36.9	40.1	1.90	43.0	46.6	46.7	40.3	2.80
DOMI (g/d/kgLW)	5.2	5.0	5.5	0.53	6.4	6.5	5.4	5.5	0.40
N excretion (mg/d/kgLW)									
Faeces	86	95	89	6.6	90	85	82	91	10.40
Urine	154	98	90	27.8	73	75	80	75	28.10
N balance (mg/d/kgLW)	-7.6a	4.7a	44.5b	7.89	40.1a	43.5a	93.3b	43.1a	9.80
Rumen ammonia (mgN/l)	101	80	50	48.1	70	66	95	72	43.3
Total VFA (mM/l)	106	107	117	27.1	78	96	76	92	10.6
Proportion (%)									
Acetic acid	75a	77a	57b	2.4	75	74	73	55	5.7
Propionic acid	18a	16a	40b	1.4	19	19	19	40	6.7
Butyric acid	7	6	3	0.9	6	6	7	5	1.1

C = control; G = glucose; P = propionate; GC = control preceded by glucose treatment in previous period; PC = control preceded by propionate treatment in previous period; CG and CP glucose and propionate respectively preceded by control during previous period. Values in the same row and within the same period that are followed by different letters are significantly different, $P < 0.05$.

IV. DISCUSSION

The indication from the present studies was that both glucose and propionate infusions improved the nitrogen balance of sheep fed barley straw. This suggests that in the sheep fed barley straw alone, amino acids were being diverted to glucose production at the expense of maintenance or synthesis of body proteins.

In experiment 2, the data indicated that animals that were fed the basal diet following a period when they were infused with glucose or propionate retained more nitrogen than similarly fed sheep that were not previously infused with glucose or propionate (Tables 1 and 2). Similar findings have been reported by Girdler et al. (1986). They found in studies of sheep that were receiving their nutrients by intra-gastric infusions, that the N retention of animals that were deprived of glucose but had previously been infused with 52 g glucose/day was higher than in sheep that had not previously been infused with glucose. In both instances referred to above, it appears that following periods of supply of glucogenic substances there is a carry-over effect on N balances.

As was expected, propionate infusions altered the acetate:propionate ratio in rumen liquor. However, as the concentration of propionate in rumen fluid is not necessarily correlated with its production (Van der Walt 1977) and many factors are involved with its absorption and metabolism, it is not possible to quantitatively estimate the contribution that propionate made to glucose production in the experiment reported here. Other studies have noted that propionate infusion resulted in varying proportions of infused propionate being converted to glucose in lactating animals (e.g. Frobish and Davis 1977) and in sheep fed wheat straw plus protein meal (Cronje 1987). To obtain more information on the contribution of propionate to glucose production in roughage-fed animals, a study utilising steers infused with graded levels of propionate is currently being carried out in our laboratory.

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