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The effects of intraruminal infusions of urea, casein, glucose syrup and a mixture of casein and glucose syrup on nitrogen digestion in the rumen of cattle receiving grass-silage diets

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1. In an incomplete 5 × 5 Latin square experiment, four cattle were given grass silage in two meals per d to satisfy 1·15 maintenance energy requirements. In addition, water or casein (21 g nitrogen and 0·17 kg organic matter (OM)/d) or urea (U; 28 g N/d) or a glucose syrup (G; 0·87 kg OM/d) or casein and glucose syrup (CG; 17 g N and 0·93 kg OM/d) were infused intraruminally at a constant rate.

2. A 24 h collection of duodenal digesta was made using chromic oxide for flow estimation and ^{35}S as a marker of microbial N entering the small intestine. Samples of rumen fluid were also taken for estimation of rumen pH, and concentrations of ammonia-N and volatile fatty acids.

3. The intraruminal infusions had no significant effects on rumen pH, concentrations of volatile fatty acids or their molar proportions. Infusion of either C or U significantly ($P < 0·05$) increased rumen NH_3-N concentrations whereas infusions of either G or CG lowered rumen NH_3-N concentrations.

4. Infusions of C or U had no significant effect on the quantities of OM, acid-detergent fibre (ADF) or N constituents which entered the small intestine.

5. Infusions of G or CG increased the quantities of OM (G $P < 0·05$, CG $P < 0·01$), ADF (CG $P < 0·05$), non-NH_3-N (G $P < 0·05$, CG $P < 0·01$), amino acid N (G $P < 0·05$, CG $P < 0·01$) and microbial N (G $P < 0·05$, CG $P < 0·01$) which entered the small intestine.

6. The efficiency of rumen microbial N synthesis was unchanged by the infusion of C, U or G ($P > 0·05$) but increased significantly ($P < 0·05$) when CG were infused.

During ensilage, the soluble carbohydrates (CHO) present in grass are fermented to lactic acid and volatile fatty acids by anaerobic bacteria. Extensive proteolysis of the herbage protein also takes place chiefly as a result of the activity of plant proteases (McDonald, 1981). Thus when silage is given to ruminant livestock the major CHO substrates available for rumen fermentation are the slowly fermented plant cell walls whilst most of the nitrogenous substrates available for rumen microbial synthesis are soluble and are present in silage in the form of non-protein-nitrogen, e.g. ammonia and amino acids. The efficiency of microbial N synthesis in the rumen in animals given silage is markedly lower than the value of 32 g N/kg organic matter (OM) apparently digested in the rumen (OMADR), adopted by the Agricultural Research Council (ARC, 1984), with most values being in the range 25–30 g N/kg OMADR (for example, see Thomson *et al.* 1981; Chamberlain *et al.* 1982; Rooke *et al.* 1983*b*).

Supplementation of grass silage with barley has proved largely ineffective in stimulating the efficiency of rumen microbial N synthesis (Thomas *et al.* 1980; Rooke *et al.* 1985*a*) whereas consistent responses have been obtained by supplementing silage given to cattle with soya-bean meal (Brett *et al.* 1979; Rooke *et al.* 1983*a*, 1985*a*), although not with sheep (Siddons *et al.* 1979). The experiment reported here was designed to establish whether these responses to soya-bean meal supplementation were a response to the release in the rumen of additional NH_3-N or of amino acids and peptides; a further objective was to investigate whether a rapidly fermentable soluble CHO would prove effective in stimulating microbial

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Table 1. *The chemical composition (g/kg dry matter) of the silage*

pH	3·8
Dry matter (g/kg)*	229
Organic matter	934
Acid-detergent fibre	364
Neutral-detergent fibre	738
Water-soluble carbohydrate	61
Total nitrogen	18·4
Amino acid-N	12·5
Ammonia-N	1·2
Formic acid	22
Acetic acid	19
Lactic acid	111
Ethanol	69

* Determined by toluene distillation.

N synthesis in the rumen. Cattle fed on grass silage were supplemented with intraruminal infusions of water (W, control) or urea (U), casein (C), glucose syrup (G), or C and G. The effects of these infusions on the entry of microbial N, undegraded feed N and other constituents into the small intestine were measured.

EXPERIMENTAL

Animals

Four female Jersey cattle, aged between 4 and 5 years, had mean (with SE) weights of 409 (SE 21·5) kg at the beginning of the experiment. Each animal was equipped with a rumen cannula and a re-entrant cannula in the proximal duodenum (McMeniman & Armstrong, 1979).

Diets and experimental procedure

The animals were fed on grass silage throughout the experiment and in addition each animal was infused intraruminally with each of five different solutions in turn according to an incomplete 5 × 5 Latin square experimental design.

The grass silage was prepared from a first cut of predominantly perennial ryegrass (*Lolium perenne*) containing some white clover (*Trifolium repens*), harvested with a precision-chop forage harvester on 7 June 1983. The grass was wilted for 24 h and ensiled by means of an Eberhard Silopresse (Benedict Agricultural Ltd, London) with the application of an additive containing 850 g formic acid/kg (Add-F; BP Nutrition UK Ltd). The silo was opened after 210 d and from then on silage was removed at weekly intervals, weighed and stored in tightly closed plastic bags at room temperature. The composition of the silage is given in Table 1.

The silage was offered to each animal twice daily in equal amounts at 08.00 and 16.00 hours throughout the experiment. The amount of silage offered supplied sufficient metabolizable energy to provide 1·15 times the maintenance energy requirements of each animal, calculated from the live weight of the animal at the start of the experiment (Ministry of Agriculture, Fisheries and Food, 1975). In the event, it was necessary to reduce silage intake to 1·0 times maintenance energy requirements in order to avoid silage refusals when G alone or C and G together were infused (see p. 91). Water and mineralized salt licks were freely available throughout the experiment and 2 × 10 g chromic oxide impregnated paper/d was administered to each animal after each feed.

Each experimental period was 21 d long and consisted of a 14 d infusion period followed by a 7 d rest period. The five different intraruminal infusions consisted of W, C (Technical grade, Sigma Chemical Co Ltd, Poole, Dorset; 70 g C/kg infusate), U (General Purpose Reagent, BDH Ltd, Poole, Dorset; 35 g U/kg infusate), G (42DE; CPC Ltd, Trafford Park, Manchester; 530 g G/kg infusate) and C and G (35 g C and 265 g G/kg infusate; CG). G contained (g/kg total carbohydrate) glucose, 170; maltose, 130; maltotriose–maltoheptose, 420; and oligosaccharides of chain-length greater than 7, 280. The intention was to maintain infusion rates of 0·1 l/h for infusates W, C, U and G and 0·2 l/h for infusate CG; in practice there were some deviations from these rates but the exact amounts of each infusate infused were recorded daily. In addition to the nutrients included in the infusates, 2·5 mCi $Na_2{}^{35}SO_4$ were added to each infusate at 09.00 hours on day 12 of each infusion period and this infusion of ^{35}S was maintained until the completion of the 24 h collection of duodenal digesta. On the final day of each infusion period (day 14), beginning at 08.00 hours, a 24 h complete collection of duodenal digesta was made from each animal. In addition, sixteen samples of rumen fluid were obtained at 1·5-h intervals from 09.00 hours on day 14. Details of the sampling procedure and of the preparation of a duodenal microbial fraction have been given by Rooke *et al.* (1985 *b*).

Analytical procedures

The procedures used in the analysis of the silage, infusates, rumen fluid, duodenal digesta and the duodenal microbial samples have been described (Rooke *et al.* 1985*b*). Additionally, the ethanol content of the silage was determined according to Böttcher (1982) and the free glucose plus α-linked glucose polymer contents of the infusates and duodenal digesta samples were determined according to MacRae & Armstrong (1969).

Calculation of results

Flows of digesta dry matter (DM) entering the small intestine were corrected for complete recovery of Cr_2O_3 administered daily. The intake of soluble CHO was calculated as the sum of silage water-soluble CHO (determined by the anthrone method) and infused CHO (determined as free glucose plus α-linked glucose polymers); the soluble CHO content of duodenal digesta was determined as the free glucose plus α-linked glucose polymers.

Statistical analysis

Analysis of variance was carried out on the results according to an incomplete Latin square design using a least-squares procedure. Two sets of experimental values were missing from the results due to the removal of two different animals from two different experimental periods for reasons not connected with the diets being fed, i.e. leakage of digesta from the duodenal cannula in one case and accidental temporary disconnection of the duodenal cannula and loss of digesta in the other case. Differences between each infusion and the control (water) infusion were determined using Dunnett's test (Dunnett, 1955).

RESULTS

Infusing different nutrients had no significant effects on mean rumen pH, concentrations of volatile fatty acids or molar proportions of individual fatty acids (Table 2). Infusing either C or U significantly ($P < 0·05$) increased rumen NH_3-N concentrations when compared with the infusion of W alone. In addition, although the differences were not significant, infusion of CG together or of G alone reduced NH_3-N concentrations in comparison with the W infusion, with the lowest mean values for NH_3-N being observed when G alone was infused.

The changes in rumen NH_3-N concentrations throughout the day are shown in Fig. 1.

Table 2. *Mean values for pH and for the concentrations of ammonia-nitrogen (mg/l) and volatile fatty acids (mmol/l) in the rumen fluid of cattle given diets of grass silage and five different intraruminal infusions*†

(The molar proportions of individual fatty acids (mmol acid/mol total volatile fatty acids) are also given)

	Infusions						Statistical significance of infusions§	
	W	C	U	G	CG	SE‡	U	C
pH	6·8	6·8	6·8	6·8	6·7	0·02	NS	NS
NH_3-N	51	98	82	28	39	11·1	*	*
Volatile fatty acids								
Total	67·3	67·3	65·3	71·4	66·0	2·96	NS	NS
Acetic	682	678	661	687	666	7·6	NS	NS
Propionic	177	177	178	179	187	7·5	NS	NS
iso-Butyric	13	13	16	10	9	1·0	NS	NS
n-Butyric	82	83	83	86	96	3·9	NS	NS
iso-Valeric	30	31	41	22	22	4·2	NS	NS
n-Valeric	17	18	21	16	19	0·7	NS	NS

W, water; C, casein; U, urea; G, glucose syrup; CG, casein plus glucose syrup; NS, not significant.
* $P < 0·05$.
† For details, see p. 91.
‡ SE of mean with 6 df for four observations, G and CG three observations only.
§ No significant effects were observed for infusions G and CG.

The significant increase observed in NH_3-N concentrations (Table 2) when C or U were infused was apparent at all sampling times as were the reductions in NH_3-N concentrations observed when G alone or G plus C were infused. Indeed, when G alone was infused mean NH_3-N concentrations observed between 22.30 and 06.00 hours were less than 5 mg NH_3-N/l.

The daily intakes of OM, soluble CHO and acid-detergent fibre (ADF) by the cattle, and the quantities of OM, soluble CHO and ADF entering the small intestine are shown in Table 3. Infusion of C or U had no significant effects on the quantities of OM, soluble CHO or of ADF entering the small intestine daily.

However, infusion of G or of G and C resulted in increases in the quantities of OM (G, $P < 0·05$; CG, $P < 0·01$), soluble CHO (G, $P < 0·01$; CG, $P < 0·01$) and of ADF (G, not significant; CG, $P < 0·05$) entering the small intestine. The increase in the amounts of soluble CHO entering the small intestine daily were quantitatively small; indeed, when expressed as a proportion of the total soluble CHO intake, proportionately less soluble CHO entered the small intestine daily when G was infused alone or together with C. However, expressed as a proportion of total OM and ADF intake, the increases in OM (CG, $P < 0·05$) and ADF (G, $P < 0·05$; CG, $P < 0·01$) entering the small intestine when G or G and C were infused were significant; the increase in OM when G alone was infused was not significant. Thus, inclusion of C in the G infusion, gave rise to greater increases in the quantities of OM and ADF entering the small intestine than were observed with G alone.

The quantities of total N (TN) and of amino acid-N (AAN) ingested as silage TN and AAN and infused intraruminally are shown in Table 4, as are the quantities of non-NH_3-N (NAN) and AAN entering the small intestine. Increasing TN intake by infusing U or C,

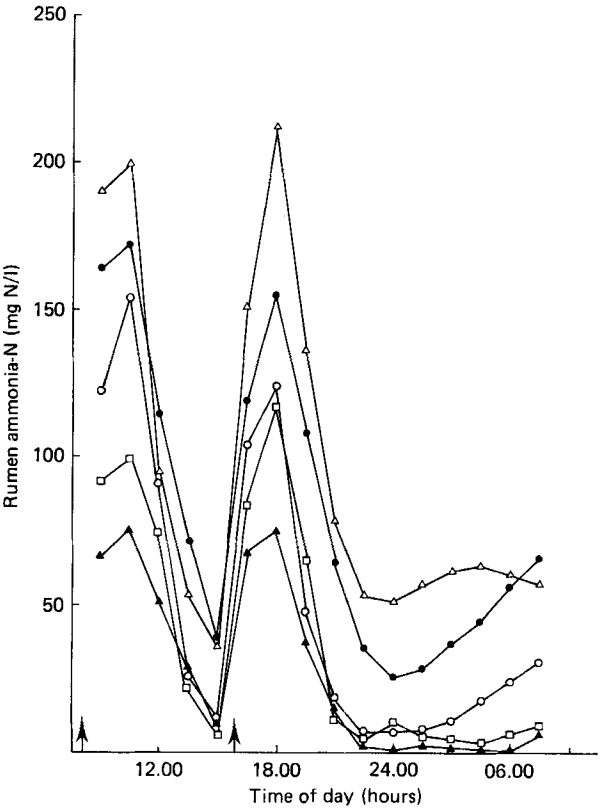

Fig. 1. Daily variations in rumen ammonia-nitrogen concentrations of cattle given grass-silage diets in two meals per d (↓ times of feeding) supplemented with intraruminal infusions of water (○), casein (●), urea (△), glucose syrup (▲) or casein and glucose syrup (□). For details, see p. 91. Mean values for four observations are given for water, casein and urea infusions and for three observations for glucose syrup and casein and glucose syrup infusions.

and AAN intake by infusing C, did not significantly change the quantities of NAN or AAN entering the small intestine as compared with the infusion of W. Thus, when expressed as a proportion of TN intake, significantly smaller amounts of NAN entered the small intestine (g/g N intake) when U ($P < 0{\cdot}05$) was infused. Infusion of G increased the quantities of NAN and AAN entering the small intestine when expressed either as g/d (NAN and AAN, $P < 0{\cdot}05$) or g/g N (or AAN) intake (NAN, $P < 0{\cdot}01$; AAN, $P < 0{\cdot}05$). Addition of C to the G infusion resulted in increases in the quantities of NAN and AAN entering the small intestine when compared with the W infusion (g NAN or AAN/d, $P < 0{\cdot}01$; g/g N (or AAN) intake, NAN, $P < 0{\cdot}01$; AAN, $P < 0{\cdot}05$) which were markedly greater in magnitude than those observed when G alone was infused.

Table 5 shows the quantities of microbial N and undegraded feed (plus endogenous) N entering the small intestine. Infusing U or C did not significantly change the quantities of microbial N or of feed N which entered the small intestine as compared with the quantities entering the small intestine when W was infused. There were no significant changes in the apparent efficiency of microbial N synthesis when U or C were infused. The apparent degradability of feed N was significantly increased when C ($P < 0{\cdot}05$) but not U was infused.

Table 3. *The mean quantities (kg/24 h) of organic matter (OM), soluble carbohydrate (CHO) and acid-detergent fibre (ADF) consumed by the cattle, infused intraruminally and entering the small intestine*

(The quantities of OM, soluble CHO and ADF entering the small intestine daily are also expressed as a proportion (g/g) of OM, soluble CHO or ADF intake)

	Infusion†						Statistical significance of infusions§	
	W	C	U	G	CG	SE‡	G	CG
OM intake from								
Silage	4·78	4·77	4·94	4·29	4·40	—	—	—
Infusion	—	0·17	0·06	0·87	0·93	—	—	—
Total	4·78	4·94	5·00	5·16	5·33	—	—	—
Soluble CHO intake from								
Silage	0·32	0·28	0·28	0·25	0·29	—	—	—
Infusion	—	—	—	0·75	0·64	—	—	—
Total	0·32	0·28	0·28	1·00	0·93	—	—	—
ADF intake from								
Silage	1·84	1·87	1·79	1·67	1·68	—	—	—
Entering small intestine OM:								
kg/24 h	1·66	1·80	1·76	1·99	2·42	0·080	*	**
g/g intake	0·35	0·36	0·38	0·39	0·46	0·023	NS	*
Soluble CHO:								
kg/24 h	0·04	0·05	0·04	0·08	0·09	0·003	**	**
g/g intake	0·12	0·18	0·14	0·08	0·10	0·023	NS	NS
ADF:								
kg/24 h	0·30	0·31	0·32	0·35	0·41	0·018	NS	*
g/g intake	0·16	0·17	0·18	0·21	0·24	0·011	*	**

W, water; C, casein; U, urea; G, glucose syrup; CG, casein plus glucose syrup; NS, not significant.
* $P < 0·05$, ** $P < 0·01$.
† For details, see p. 91.
‡ SE of mean with 6 df for four observations, G and CG three observations only.
§ No significant effects were observed for U and C infusions.

Infusion of G significantly ($P < 0·05$) increased the microbial N entering the small intestine, compared with when W was infused. However, the increase in the efficiency of microbial N synthesis when G was infused was not significant. Addition of C to G resulted in increases in microbial N entering the small intestine ($P < 0·01$) and in the efficiency of microbial N synthesis ($P < 0·05$) compared with W, which again were markedly greater than the increases observed when G alone was infused. The infusion of G alone or in conjunction with C did not significantly alter the quantities of feed (plus endogenous) N entering the small intestine or the apparent degradability of feed N.

DISCUSSION

Digestion of silage

When silage was given alone the efficiency of microbial N synthesis in the rumen observed in this experiment 22 g N/kg OMADR was within the range of values previously observed with cattle (20–30 g N/kg OMADR; Brett *et al.* 1979; Thomson *et al.* 1981; Rooke *et al.* 1982, 1983*a*, *b*, 1985*a*). The extensive fermentation of OM within the rumen and the marked diurnal fluctuations in rumen NH_3-N concentrations as a result of twice-daily feeding were

Table 4. *The mean quantities of total (TN) and amino acid-nitrogen (AAN) consumed (g/24 h) by the cattle, infused intraruminally and the quantities (g/24 h) of non-ammonia-N (NAN) and AAN entering the small intestine*

(The quantities of NAN and AAN entering the small intestine daily are also expressed as a proportion of the quantity of TN or AAN ingested)

	Infusion†						Statistical significance of infusions§		
	W	C	U	G	CG	SE‡	U	G	CG
TN intake from									
Silage	94	95	90	86	86	—	—	—	—
Infusion	—	21	28	—	17	—	—	—	—
Total	94	116	119	86	103	—	—	—	—
AAN intake from									
Silage	64	62	61	57	57	—	—	—	—
Infusion	—	18	—	—	14	—	—	—	—
Total	64	80	61	57	71	—	—	—	—
NAN entering small intestine									
g/24 h	89	94	91	106	139	4·1	NS	*	**
g/g TN intake	0·94	0·81	0·76	1·24	1·35	0·050	*	**	**
AAN entering small intestine									
g/24 h	61	68	63	75	94	2·7	NS	*	**
g/g AAN intake	0·97	0·85	1·04	1·32	1·33	0·064	NS	*	*

W, water; C, casein; U, urea; G, glucose syrup; CG, casein plus glucose syrup; NS, not significant.
* $P < 0·05$, ** $P < 0·01$.
† For details, see p. 91.
‡ SE of mean with 6 df for four observations, G and CG three observations only.
§ No significant effects were observed for C infusion.

also in line with previous observations. The low efficiencies of rumen microbial N synthesis when ruminants were fed on silage have been variously related (1) to low yields of ATP/kg OMADR because of the presence of fermentation end-products in the silage OM (Thomas, 1982), (2) to poor synchronization of the rates of N and energy release from silage leading to a low efficiency of N capture by the rumen micro-organisms and consequent losses of NH_3 across the rumen wall (Siddons *et al.* 1985) or (3) to the form in which rumen-degradable N is present in silage, i.e. as amino acids and NH_3 (Rooke *et al.* 1985*a*).

Infusion of casein or urea

Previous experiments (Brett *et al.* 1979; Rooke *et al.* 1983*a*, 1985*a*) showed that the stimulation in the efficiency of rumen microbial N synthesis observed when silage was supplemented with soya-bean meal was associated with increases in rumen NH_3-N concentrations such that the values of less than 50 mg N/l observed between feeds when soya-bean meal was not present were elevated above 50 mg N/l when the meal was included in the diet. In the present experiment, U or C were continuously infused intraruminally in an attempt to clarify the basis of the stimulation of rumen microbial N synthesis obtained with soya-bean-meal supplementation. U was infused to determine whether the stimulation resulted from an improved synchronization of the rates of release in the rumen of NH_3 and energy, whereas C was infused to determine whether the supply of amino acids and peptides from degraded protein-N was important. As expected U and C improved N supply to the

Table 5. *Mean quantities (g/24 h) of microbial total nitrogen (TN) entering the small intestine and the apparent efficiency of microbial N synthesis in the rumen (g N/kg organic matter apparently digested in the rumen)*

(Also shown are values for the apparent quantities (g/24 h) of feed non-ammonia-N (NAN) entering the small intestine, together with values for the apparent degradability of feed TN within the rumen)

	Infusion†						Statistical significance of infusions§		
	W	C	U	G	CG	SE‡	C	G	CG
Microbial TN entering small intestine	63	75	68	81	109	4·5	NS	*	**
Efficiency of microbial TN synthesis	22	25	25	27	38	2·7	NS	NS	*
Feed N entering small intestine‖	22	19	24	23	28	2·4	NS	NS	NS
Apparent feed TN degradability	0·76	0·83	0·80	0·73	0·72	0·019	*	NS	NS

W, water; C, casein; U, urea; G, glucose syrup; CG, casein plus glucose syrup; NS, not significant.
* $P < 0·05$, ** $P < 0·01$.
† For details, see p. 91.
‡ SE of mean with 6 df for four observations, G and CG three observations only.
§ No significant effects of U infusion.
‖ Includes endogenous N secretions. Values for degradability of feed N calculated from the difference between TN intake and duodenal (NAN − microbial TN).

rumen micro-organisms as both infusions elevated rumen NH_3-N concentrations over the 24 h sampling period (see Fig. 1). However, only small and non-significant increases in the quantity of microbial N synthesized and in the efficiency of microbial N synthesis in the rumen were observed. These results indicate that it was not a shortage of rumen NH_3-N *per se* that was limiting the efficiency of rumen microbial synthesis when silage was fed. Furthermore, the failure of C to stimulate microbial N synthesis suggested that a supply of additional AAN or peptide-N was not an important limiting factor. The present experiment did not, therefore, provide any explanation for the stimulation of microbial N synthesis by soya-bean meal observed previously.

Infusion of G

Infusion of G alone reduced rumen NH_3-N concentrations throughout the 24 h sampling period to such an extent that between 24.00 and 06.00 hours rumen NH_3-N concentrations were frequently below the limits of detection of the assay procedure used (< 2 mg N/l). Thus, G reduced NH_3-N concentrations markedly in agreement with Syrjala (1972) and the recent observations of Chamberlain *et al.* (1985). Rumen NH_3-N concentrations were also lower than those in experiments where silage was supplemented with barley (Rooke *et al.* 1985*a*), again in agreement with the results of Syrjala (1972) and Chamberlain *et al.* (1985) where direct comparisons between starch and sucrose in reducing NH_3-N concentrations were made. The observed reduction in rumen NH_3-N concentration was accompanied by a 1·2-fold increase in the quantities of NAN which entered the small intestine daily, in agreement with the results of Gill & Ulyatt (1977). As suggested by Gill & Ulyatt (1977), the increase in the quantities of NAN which entered the small intestine was mediated entirely by an increase in the quantities of microbial N synthesized within the rumen.

Chamberlain *et al.* (1985) have also suggested that the reduction in NH_3-N concentrations mediated by sucrose supplementation reflected increased microbial N synthesis within the rumen. The results from the present experiment, therefore, have confirmed experimentally the suggestions made by Gill & Ulyatt (1977) and by Chamberlain *et al.* (1985).

The increase in the quantities of microbial N entering the small intestine when G was infused was accompanied by only a small increase in the efficiency of rumen microbial N synthesis (22–27 g N/kg OMADR). Since the mean rumen NH_3-N concentration when G was infused was only 28 mg N/l it is probable that NH_3 supply was limiting microbial N synthesis (see Miller, 1982). Addition of C to the G infusate resulted in the mean rumen NH_3-N concentration increasing from 28 to 39 mg N/l with corresponding increases in both the quantities of microbial N synthesized and the efficiency of synthesis. Thus the supply of N or amino acids to the micro-organisms was apparently limiting microbial N synthesis when G alone was infused; whether infusion of U would have been as effective as C is currently under investigation.

Thomson *et al.* (1981) calculated values for the ratio of rumen-degradable CHO (DC):degradable N (DN) in calves fed on grass silages and found that an increase in the ratio from 18 to 32 was associated with an increase in the apparent efficiency of capture of degraded N in the rumen from 65 to 95% and an increase in efficiency of microbial N synthesis from 24 to 29 g N/kg OMADR. In agreement with Thomson *et al.* (1981) infusion of G increased DC:DN from 49 when W was infused to 57, the apparent efficiency of capture of degraded N in the rumen from 88 to 129% and the efficiency of microbial N synthesis from 22 to 27 g N/kg OMADR. In contrast, however, addition of C to G reduced DC:DN from 57 (G) to 46 (CG) yet the apparent efficiency of capture of degraded N increased from 129 to 145% and the efficiency of microbial N synthesis from 27 to 38 g N/kg OMADR. This contrasting observation probably reflects the improved synchronization of supply of energy and of N for microbial synthesis and in part the well-documented synergistic effect of supplying a mixture of structural and non-structural CHO in the diet on the efficiency of rumen microbial N synthesis (e.g. Offer *et al.* 1978; Mathers & Miller, 1981).

Calculation of DC:DN also demonstrates the improved capture of degraded N within the rumen resulting from the infusion of G alone or in conjunction with C, such that a net loss of N between the mouth and small intestine of 1·0 g N/kg OM intake when silage was given alone was translated into net gains of 3·9 and 6·8 g N/kg OM intake when G or G and C were infused intraruminally. The change from net loss to a net gain of N across the forestomachs as a result of CHO infusion is in agreement with the concepts (Kennedy & Milligan, 1980) that (1) the transfer of endogenous urea to the rumen is inversely related to the rumen NH_3-N concentration, and (2) that the addition of sucrose to the diet markedly increases the clearance of plasma U to the rumen. The additional net gain of N across the forestomachs observed when C and G were infused might be caused by increased plasma U concentrations as a result of catabolism of additional quantities of amino acids absorbed from the small intestine.

The results from the present experiment have shown that in agreement with other workers (Syrjala, 1972; Gill & Ulyatt, 1977; Chamberlain *et al.* 1985) the utilization of silage N for rumen microbial N synthesis is markedly improved by the provision of soluble CHO for rumen fermentation. However, the practical advantages in improving animal performance through the use of soluble CHO may be limited to some extent by the reduction in the extent of fibre digestion which occurred within the rumen when soluble CHO was infused in the present experiment and the likely reductions in voluntary food intake of the silage caused by this inhibition of fibre digestion. In the present experiment, silage intake had to be reduced to avoid refusals when G was infused. Similarly, when England & Gill (1985) gave

increasing amounts of sucrose to calves as a supplement to *ad lib.* silage, a progressive reduction in both the apparent digestibility of silage cellulose and in silage intake was observed.

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