EFFECTS OF NITROGEN SUPPLEMENTS ON INTAKE AND UTILIZATION OF LOW QUALITY FORAGES

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SUMMARY

Experiments conducted by the authors and their colleagues in the previous five years are summarized. It is concluded that dietary requirements for rumen-degradable nitrogen (RDN) can be supplied entirely as non-protein nitrogen (NPN). Also, that supplements of 'NPN and proteins are equally effective in stimulating forage intake, when intake of RDN in the forage is low, provided that intake of NPN is not too infrequent. When intake of NPN is too'infrequent, such as when grazing animals have access to urea/molasses blocks or licks, protein supplements are likely to be more effective as slow-release sources of RDN.

When RDN is non-limiting, protein supplements have negligible effects on forage intake, and occasional positive effects on liveweight gain (two out of four experiments). When protein supplements do have a positive effect on liveweight gain it is likely that this is attributable to an increase in the proportion of nutrients absorbed'as essential amino acids.

INTRODUCTION

Edibility and the digestible energy content of low quality forages may be increased by:-

1) treatment of the forages by chemical and/or physical processes
2) provision of supplementary nutrients.

The two approaches often are complementary, as, treatments which increase intake or digestibility may generate a need for additional nutrients to supply the needs of rumen bacteria as well as of the host animal. In this paper, we have considered nitrogen (N) requirements of rumen bacteria and of the animal, in animals fed untreated and chemically-treated forages of low nutritive value. The reason for considering both bacterial and animal requirements in a symposium on by-pass protein is because all proteins contain rumen-degradable and by-pass fractions, the relative significance of which is likely to vary with the circumstances in which it is fed. Thus, effects of protein supplements may be attributed to one or more of the following factors:-

1) slow release of N in the rumen
2) increase in the proportion of nutrients absorbed as essential amino acids
3) supplementary energy, including gluconeogenesis
4) stimulatory effects on intake.

NITROGEN REQUIREMENTS OF RUMEN BACTERIA

These are supplied to the animal as RDN which may be protein and/or NPN. RDN is absorbed by rumen bacteria as ammonia, peptides and amino acids. Peptides and amino acids contribute 200-400 mg/g N incorporated into microbial cells in the rumen (Pilgrim *et al.* 1970; Nolan and Leng 1972; Nolan *et al.* 1976) and *in vitro* studies indicated that the optimum value for NPN to amino acid N for microbial growth was 75:25 (Maeng *et al.* 1976). This suggests the possibility that availability of amino acid N

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in the rumen could limit efficiency of bacterial protein synthesis when animals are fed forages of low protein content. This possibility was investigated in experiments summarized in Table 1.

TABLE 1 Effects of supplements of urea (U), casein (C) and HCHO-casein (TC) on efficiency of bacterial protein synthesis (g N/kg organic matter apparently digested in the stomach)

Ref. No.	Animals No.	Animals Species	Forage (g N/kg DM)	Supplements (g N/d) U	C	TC	Rumen NH_3 (mM/l)	Bacterial protein synthesis (g N/kg OM) (SEM)
1	5	Cattle	Oaten chaff	0	0	0	2	22
			7.7	22	0	0	5	21
				0	22	0	5	19
				0	11	11	2	17
				0	0	22	2	16
								(3.4)
2	4	Cattle	Wheat straw	30	0	0	10	31
			5.0	30	40	0	18	24
				30	0	40	14	26
								(2.5)
3	8	Sheep	NaOH-washed	5.2	0	0	4	16
			wheat straw	4.4	0.8	0	4	17
			1.7	3.6	1.6	0	3	18
				0	5.2	0	3	19
								(1.1)

((1) Redman et al. 1980; (2) Sriskandarajah et al. 1980; (3) Leibholz and Kellaway 1979)

N supplements in Expts 1, 2' and 3 (Table 1) were fed eight times daily, twice daily and sprayed onto the forage in the respective experiments. HCHO-casein was found to be partly degraded in the rumen so that in effect it acted as a slow-release source of amino acids in the rumen. Efficiencies of bacterial protein synthesis with supplementsof casein and HCHO-casein were no higher than with a supplement of urea. It may be concluded that requirements of RDN for low quality forages can be supplied as urea. Requirements for pre-formed amino acids probably are supplied by endogenous proteins (MacRae and Reeds 1980), much of which may be accounted for as sloughed epithelial cells from the rumen wall (Kennedy and Milligan 1980).

Optimum levels of urea supplementation were investigated in the experiment, summarized in Table 2, in which urea was sprayed onto the forage. Responses in terms of N flow to the abomasum and efficiency of bacterial'protein synthesis indicated an optimum of about 28 g urea/kg straw which corresponded with an ammonia concentration in the rumen of 20 mM/l. This was in marked contrast to observations of Roffler and Satter (1975) that there was zero utilization of NPN when rumen NH3 was >3.6 mM/l. Roy et al. (1977) suggested an RDN requirement of 1.25 g/MJ ME which is in broad agreement with the observations in Table 2.

Efficiency of urea utilization is increased with frequency of ingestion (Romera et al. 1976) , the most efficient utilizationbeing obtain-

TABLE 2 Effects of incremental levels of urea supplementation on efficiency of bacterial protein synthesis (g N/kg organic matter apparently digested in the stomach) in cattle fed NaOH-treated wheat straw (4.0 g N/kg DM)

	Urea in diet (g/kg straw)				SEM
	10	19	28	37	
N intake (g/d)	52	81	104	138	4.6
N flow to abomasum (g/d)	80	91	100	105	5.9
Rumen NH_3 (mM/l)	5	16	20	23	2.1
Bacterial protein synthesis (g N/kg OM)	21	23	28	29	1.7
RDN/MJ ME	0.6	1.1	1.5	2.1	

(Leibholz and Kellaway, 1980)

ed by spraying it onto the forage. When-this is not possible it would be expected that dietary proteins which are degraded slowly in the rumen would be a more effective source of ammonia than urea which is degraded very rapidly. This has been shown to be the reason why protein supplements sometimes have greater effects than urea supplements on digestibility and intake of low quality forages (Siebert et al. 1976).

Efficiency of bacterial protein synthesis in the rumen varies considerably within and between experiments (Tables 1 and 2) for reasons which are not always apparent. Availability of energy in the rumen could be a limiting factor on low quality roughage diets. When starch or sucrose were sprayed onto paspalum hay, efficiency of bacterial protein synthesis was not increased, although there were significant increases in DM intake, N flow to the abomasum and N balance (Table 3).

TABLE 3 Effects of urea and energy supplements on efficiency of bacterial protein synthesis (g N/kg organic matter apparently digested in the stomach), DM intake and N flows in sheep fed paspalum hay (6.2 g N/kg DM)

Urea N (g/d)	0	8.0	9.5	9.9	
Starch (g/d)	0	0	103	0	SEM
Sucrose (g/d)	0	0	0	107	
Forage DM intake (g/d)	744	853	919	947	27.6
N intake (g/d)	6.4	14.3	15.9	16.6	0.90
N flow to abomasum (g/d)	8.9	12.4	14.2	15.7	0.91
Bacterial protein synthesis (g N/kg OM)	18	24	26	26	2.5
Rumen NH_3 (mM/l)	2	9	5	4	0.5
N balance (g/d)	-1.0	1.1	4.0	3.4	0.62

(Jane Leibholz and R.C. Kellaway - unpublished)

These observations suggest that energy supplements increased total bacterial N synthesis without changing efficiency of synthesis. Rumen NH_3 concentrations were lower with urea and energy supplements than with urea alone, which indicates more effective utilization of NH_3 when energy was freely available. Clearly, interpretation of rumen NH_3 concentrations is not simple in that low concentrations could indicate low rates of production and utilization, or high rates of production and utilization. . Distinction between these alternatives can be made only by reference to total bacterial flows from the stomach. It is possible that when rumen NH_3 concentrations are low, due to high rates of production and utilization (urea + energy supplements in Table 3), efficiency of synthesis and total production of bacterial protein could be increased by additional RDN supplementation.

NITROGEN REQUIREMENTS OF THE ANIMAL

Ørskov (1977) calculated that microbial protein supplies, about 0.5 g N/MJ ME, which is sufficient to support growth rates of cattle up to 0.5 and 1.0 kg/d for 'animals of 200 and 250 kg live weight respectively, and growth rates of lambs up to 200 and 350 g/d for animals of 35 and 40 kg live weight respectively. Energy intakes from low quality forages would mostly restrict growth rates below these levels, so that digestible by-pass protein should not often be the primary factor limiting growth on these diets. However, responses to feeding supplements of digestible by-pass protein to animals eating low quality forages have been measured in terms of intake and liveweight gain.

Responses which have been measured at the University of Sydney are summarized in Tables 4 and 5, and these include two experiments carried out in collaboration with the University of New England. Responses to N supplements when the control diet was clearly deficient in N are summarized in Table 4; weighted (for animal numbers) mean responses were +15% for forage intake and +243 g/d liveweight change ('cattle).

TABLE 4 Summary of responses to single nitrogen supplements of urea (U) and meat meal (M) given to cattle and sheep fed low quality forages in pens

Ref. No.	Animals: No.	Animals: Initial live weight (kg)	Forage (g N/kg DM)	Supplement (g N/d)		Rumen NH_3 (mM/l)	Forage intake (g/d) (SEM)	Live-weight change (g/d) (SEM)
1	10	Cattle	Paspalum	-	-	-	5420	-30
	10	210	6.3	M	30	-	5470	30
							(180)	(31.7)
2	8	Cattle	Paspalum	-	-	-	5118	42
	8	200	6.2	M	30	-	6134	315
							(190)	(14.0)
3	6	Sheep	Paspalum	-	-	2	744	-38
	6	40	6.2	U	8	9	870	49
							(30.7)	(21.5)
4	6	Sheep	Paspalum	-	-	-	764	
	6	40	6.2	U	8	-	913	
							(20.9)	

TABLE 4 (continued)

Ref. No.	Animals No.	Initial live weight (kg)	Forage (g N/kg DM)	Supplement (g N/d)		Rumen NH_3 (mM/l)	Forage intake (g/d) (SEM)	Live-weight change (g/d) (SEM)
5	8	Cattle	Oaten chaff	-	-	2	5510	356
	8	288	7.7	U	50	5	6720	798
							(218.0)	(68.7)

Weighted response:-	Forage intake No.	Forage intake %	Liveweight change No.	Liveweight change g/d
N supplements - No N supplement	76	15	52 (cattle)	243

((1) - (3) Jane Leibholz and R.C. Kellaway - unpublished; (4) Leibholz, Jane (1981); (5) Redman et al. (1980))

TABLE 5 Summary of responses to alternative, additive and incremental supplements of urea (U), meat meal (M), casein (C), HCHO-casein (TC), cottonseed meal (CSM), and barley cracked (CB), whole (WB), extruded (EB) or NH_3-treated (NB) given. to cattle fed low quality forages in pens

Ref. No.	Cattle No.	Initial live weight (kg)	Forage (g N/kg DM)	Supplement (g N/d)		Rumen NH (mM/l)	Forage intake (g/d) (SEM)	Live-weight change (g/d) (SEM)
1	8	166	Paspalum	U	35	-	3620	471
	8		"	U+M	35+30	-	3730	474
	8		NaOH-treated	U	35	-	4180	547
	8		paspalum	U+M	35+30	-	3930	524
			9.4				(170)	(75.7)
2	6	310	Paspalum	U	60		7600	-
	6		9.4	U+M	60+40		7700	-
							(113)	
3	8	288	Oaten chaff	U	50	5	6720	798
	8		7.7	C	50	5	6700	843
	8			C+TC	25+25	2	6960	842
	8			TC	50	2	6690	805
							(218.0)	(68.7)
4	4	185	Wheat straw	U	33	10	2873	-
	4		5.0	U+C	29+30	18	3319	-
	4			U+TC	30+37	14	3442	-
							(174.7)	

TABLE 5 (continued)

Ref. No.	Cattle No.	Cattle Initial live weight (kg)	Forage (g N/kg DM)	Supplement (g N/d)		Rumen NH_3 (mM/l)	Forage intake (g/d) (SEM)	Live weight change (g/d) (SEM)
5	8	209	Wheat straw	U	37	9	2830	-189
	8		5.0	U+C	37+38	13	3000	-108
	8			U+C+TC	37+27+14	11	2650	- 82
	8			U+C+TC	37+11+33	8	3310	102
	8			U+TC	37+47	8	3320	42
							(164.8)	(57.2)
6	6	340	NaOH-treated	U	27	5	6490	-
	6		wheat straw	U	58	16	6820	-
	6		4.0	U	90	20	6760	-
	6			U	121	23	6910	-
							(202)	
7	10	280	Wheat straw	U	40	18	4530	- 6
	10			U+CSM	40+32	22	4710	189
	10		NaOH-treated	U	60	18	6580	334
	10		wheat straw	U+CSM	60+32	15	6560	495
			4.0				(205)	(40.1)
8	9	250	NaOH-treated	U+CSM	98+49		7350	891
	9		wheat straw	U+EB	101+12		7523	784
	9		5.0	U+CB	99+11		7414	761
	9			U+NB	94+13		7039	657
	9			U+WB	95+10		7103	639
							(172.1)	(44.6)

Weighted responses:-	Forage intake No.	Forage intake (%)	Liveweight change No.	Liveweight change (g/d)
(Urea + N supplements) - Urea	168	3.7	128	106
TC - C	40	4.9	32	56
(U+CSM) - [(U+EB) + (U+CB)]	27	-1.6	27	109
(U+CSM) - [(U+NB) + (U+WB)]	27	3.9	27	192

((1), (2) Jane Leibholz and R.C. Kellaway - unpublished; (3) Redman et al. 1980; (4) Sriskandarajah et al. 1980; (5) N. Sriskandarajah, R.C. Kellaway and Jane Leibholz - unpublished; (6) Leibholz and Kellaway 1980; (7) N. Sriskandarajah, R.C. Kellaway, T.J. Kempton, R.A. Leng and Jane Leibholz - unpublished; (8) J. Spragg, R.C. Kellaway, T.J. Kempton, R.A. Leng and Jane Leibholz - unpublished)

Responses to N supplements given in addition to urea were not significant ($P>0.05$) in respect of forage intake in any of the six relevant experiments in Table 5, the weighted mean response being +3.7%. Responses in respect to liveweight change were significant ($P<0.05$) in two out of four relevant experiments, the weighted mean response being 106 g/d, These findings agree with those of Smith et al. (1980) that growth responses to protein supplements occur when the supplement has no effect on forage intake.

Protein supplements provide additional energy which may be the primary reason for responses in liveweight gain in some experiments. However, in the experiment by Spragg et al. (unpublished, Table 5), where ME intakes from supplements would have been similar, the higher liveweight gain by animals given cottonseed meal suggests that the response was attributable to a higher proportion of nutrients absorbed as essential amino acids. Evidence presented in Table 1 indicates that it was unlikely for additional amino acids to have come from microbial sources when cottonseed meal was fed. Instead, additional amino acids, are likely to have come. from by-pass protein, as it was found that 0.6 of cottonseed meal N was degraded slowly, half-life in the rumen being 24 h (N. Sriskandarajah and R.C. Kellaway - unpublished). The apparent growth response to by-pass protein in the experiment by Spragg et al. (loc. cit.) suggests that recommendations by the Agricultural Research Council (1980), that no undegraded dietary protein is required for steers of 250 kg live weight eating low to medium quality diets and growing up to 1 kg/d, may require reappraisal.

CONCLUSIONS

Dietary requirements for RDN can be supplied entirely as NPN. Supplements of NPN and proteins are equally effective in stimulating forage intake, when intake of RDN in the forage is low, provided that intake of NPN is not too infrequent. When intake of NPN is too infrequent, protein supplements are likely to be more effective as slow-release sources of RDN.

When RDN is non-limiting, protein supplements have negligible effects on forage intake, and occasional positive effects on liveweight gain, apparently through an increase in the proportion of nutrients absorbed as essential amino acids.

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