# Influence of Ammonia Concentration on Microbial Protein Synthesis in the Rumen

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## Story in Brief

The influence of ruminal ammonia supply on microbial protein synthesis was studied using four Angus steers (1080 lb) with ruminal and duodenal cannulas fed a concentrate based diet supplemented with 0, 1, 2 or 3 percent crude protein equivalent from non-protein nitrogen. Ruminal ammonia concentration values ranged from 1.2 to 13.1 mg ammonia nitrogen/dl rumen fluid. Efficiency of microbial protein synthesis appeared to be depressed at the lower ruminal ammonia concentrations. A compilation of this and another related study demonstrated no significant effect of ammonia concentration on efficiency of microbial protein synthesis at ruminal ammonia concentrations ranging from 1.2 to 22.1 mg/dl. Organic matter (OM) digestion in the rumen tended to increase ($P < .08$) as ruminal ammonia concentrations increased. For digestion of a high concentrate diet, ruminal ammonia levels above 3 mg/dl appear adequate for efficient protein synthesis by ruminal microbes but higher levels may increase digestion of organic matter in the rumen and total tract.

## Introduction

Slow release urea compounds were devised to match the supply of ammonia with the rate of digestion to maximize microbial protein synthesis and avoid ammonia deficiencies for microbes in the rumen. Such work is based on the suggestions that ruminal ammonia levels less than 3 to 5 mg/dl rumen fluid are inadequate for most efficient protein synthesis by ruminal microbes. Ammonia levels in the rumen below 3 mg/dl are frequently observed with cattle grazing native range in the winter and, in some cases, with feedlot cattle. When urea is added to a diet, it is generally beneficial only when digestibility or feed intake or both increase. These findings plus inconsistent responses to slow release urea compounds suggest that factors other than a direct effect of ammonia on efficiency of microbial protein synthesis are responsible for observed benefits to NPN supplementation. The objective of this study was to determine if ruminal ammonia supply influences organic matter digestion and efficiency of microbial protein synthesis in the rumen.

## Materials and Methods

Four Angus steers (1080 lb) fitted with ruminal and duodenal cannulas were fed a ground corn diet supplemented with 0, 1, 2 or 3 percent crude protein equivalent from non-protein nitrogen (NPN; Table 1). A mixture of am-

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**Table 1. Ration composition**

| Item | Diets | | | |
|---|---|---|---|---|
| | % Supplemental CPE | | | |
| | 0 | 1 | 2 | 3 |
| | % of diet DM | | | |
| Ground corn | 60.4 | 61.2 | 61.4 | 61.5 |
| Cottonseed hulls | 15.1 | 15.1 | 15.1 | 15.1 |
| Molasses | .45 | .45 | .45 | .45 |
| Chromic oxide | .22 | .22 | .22 | .22 |
| Supplement | 23.8 | 23.0 | 22.8 | 22.7 |
| Ammonium acetate | 0 | .53 | 1.05 | 1.57 |
| Urea | 0 | .14 | .28 | .41 |
| Ground corn | 20.8 | 19.4 | 18.6 | 17.8 |
| Dicalcium phosphate | .55 | .53 | .53 | .53 |
| Limestone | .95 | .91 | .91 | .90 |
| Trace mineralized salt | .47 | .45 | .45 | .44 |
| $NaSO_4$ | .47 | .45 | .45 | .44 |
| KCl | .56 | .54 | .54 | .54 |
| Vitamin A | .01 | .01 | .01 | .01 |
| Vitamin D | .002 | .002 | .002 | .002 |
| Crude protein, % of DM | 8.3 | 9.3 | 10.5 | 11.5 |

monium acetate and urea was used to avoid the elevation in ruminal pH often seen with urea supplementation. In this manner, ruminal ammonia levels could be altered without causing major changes in ruminal pH. Diets were fed in a 4 x 4 Latin square design, every 6 hr at a daily intake level of 1.2 percent of body weight. Chromic oxide was included as an indigestible marker.

After consuming the diet for 5 days, fecal and duodenal samples were collected twice daily (am and pm) for 3 days. Samples were composited, dried and ground for analysis. Daily duodenal purine flow was used as an indicator of microbial N production.

On the fourth day of sampling, rumen fluid was collected for ammonia and pH measurement and determination of purine to nitrogen ratio in isolated bacteria.

## Results and Discussion

Ruminal ammonia-N levels increased in response to added increments of NPN (Table 2). Individual values ranged from 1.2 to 13.1 mg ammonia-N/dl rumen fluid. Ruminal pH values on each diet were not increased with added NPN which should help avoid confounding of pH with ruminal ammonia effects.

Organic matter intake (Table 3) was slightly lower on the 0 and 3 percent diets due to feed refusal by one animal. Ruminal digestion of OM was not changed greatly by added NPN, though in this trial, added NPN tended to reduce ruminal digestion (Table 3). This was recovered post-ruminally so that digestion in the total tract was influenced little by added NPN. Flow of liquid

**Table 2. Ruminal parameters**

| Item | Diets | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| Ammonia-N, mg/dl | 2.7[c] | 3.7[c] | 5.8[b] | 9.2[a] |
| pH | 6.40[ab] | 6.43[a] | 6.16[c] | 6.20[bc] |

[abc]Means in a row with different superscripts differ statistically ($P < .05$).

to the small intestine tended to increase with added NPN, possibly due to a stimulatory effect on salivary flow.

Total N leaving the rumen daily was in excess of N intake on all four diets (Table 4). This is due to substantial use of N recycled to the rumen with low feed N intakes and high energy diets. Digestibility of N tended to decrease as total N intake decreased, probably a result of dilution of metabolic fecal N loss. For comparison, digestibilities for N, calculated from the standard relationship (percent digestible protein = .9 x percent crude protein -3) are also presented in Table 4. This close check of values shows that protein level changes apparent digestibility. Efficiency of microbial protein synthesis tended to be depressed at the lowest ruminal ammonia levels with the low N diet ($P < .10$). Even though ruminal OM digestion was slightly higher on this diet, total microbial N production tended to be less than with the other three diets. Digestion of starch in the rumen and post-ruminally was relatively unchanged by ruminal ammonia supply (Table 5).

**Table 3. Organic matter**

| Item | Diets | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| Intake, g/day | 5046 | 5353 | 5337 | 5193 |
| Leaving abomasum, g/day | | | | |
| Total | 2461 | 3140 | 2867 | 2735 |
| Non-microbial | 1851 | 2431 | 2156 | 1985 |
| Chyme, liter/day | 41.7 | 48.2 | 44.0 | 49.5 |
| Ruminal digestion, % | | | | |
| Unadjusted | 51.6 | 41.5 | 46.4 | 47.0 |
| Adjusted[c] | 63.8 | 54.8 | 59.7 | 61.3 |
| Ruminal digestion, % of total | 66.8 | 52.9 | 57.6 | 63.3 |
| Feces, g/day | 1148 | 1167 | 1076 | 1358 |
| Post-ruminal digestion, % of input | 52.3 | 61.3 | 60.0 | 50.3 |
| Total tract digestion, % | 77.1[ab] | 78.2[a] | 79.9[a] | 73.7[b] |

[ab]Means in a row with different superscripts differ statistically ($P < .05$).
[c]Adjusted for microbial organic matter.

**Table 4. Nitrogen**

| Item | Diets 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Intake, g/day | 70[c] | 85[b] | 95[a] | 102[a] |
| Ruminal $NH_3$-N, mg/dl | 2.7[c] | 3.7[c] | 5.8[b] | 9.2[a] |
| Leaving abomasum, g/day | | | | |
| Total N | 88 | 110 | 108 | 109 |
| Microbial N | 39 | 50 | 52 | 51 |
| Non-ammonia, non-microbial | 46 | 56 | 52 | 53 |
| Ruminal digestion, % | | | | |
| Unadjusted | -25.9 | - 28.8 | - 12.7 | - 7.2 |
| Adjusted[f] | 35.0 | 35.2 | 46.0 | 48.3 |
| Microbial efficiency, g microbial N/kg OM truly digested in rumen | 12.3[d] | 17.6[e] | 16.7[e] | 16.1[e] |
| Ruminal digestion, % of total | -55.8 | - 49.5 | - 21.9 | - 14.7 |
| Feces, g/day | 35 | 36 | 37 | 38 |
| Post-ruminal digestion, % of input | 59.6 | 65.9 | 65.2 | 63.4 |
| Total tract digestion, % | 49.4[b] | 57.4[ab] | 60.7[a] | 62.1[a] |
| Expected total digestion[g], % | 53.8 | 57.7 | 61.4 | 63.9 |

[abc]Means in a row with different superscripts differ statistically (P<.05).
[de]Means in a row with different superscripts differ statistically (P<.10).
[f]Adjusted for microbial and ammonia nitrogen.
[g]Calculated from percent digestible protein = .9 (percent crude protein) -3.

**Table 5. Starch**

| Item | Diets 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Intake, g/day | 3119 | 3308 | 3271 | 3200 |
| Leaving abomasum, g/day | 780 | 1203 | 968 | 785 |
| Apparent ruminal digestion, % | 75.3 | 63.8 | 70.8 | 75.3 |
| Ruminal digestion, % of total | 77.0 | 66.2 | 72.2 | 79.0 |
| Feces, g/day | 72[b] | 132[ab] | 65[b] | 148[a] |
| Post-ruminal digestion, % of input | 90.7[a] | 89.1[ab] | 91.5[a] | 81.4[b] |
| Total tract digestion, % | 97.7[a] | 95.9[ab] | 98.0[a] | 95.3[b] |

[ab]Means in a row with different superscripts differ statistically (P<.05).

Individual values of ruminal ammonia concentration from this and another related study were compared with microbial efficiency (Figure 1) and ruminal OM digestion (Figure 2) to expand the number of observations. Microbial efficiency was not significantly altered by ruminal ammonia concentration (Figure 1) although variation was large. Ruminal OM digestion tended to be stimulated ($P < .08$) with ruminal ammonia concentrations greater than about 8-10 mg/dl (Figure 2). Results from this study indicate that ruminal ammonia concentrations in excess of 3 mg/dl are adequate to maximize efficiency of microbial protein sysnthesis. However, this level may be inadequate to maximize OM digestion in the rumen.

## Literature Cited

Weakley, D. C. and F. N. Owens. 1983. Okla. Agr. Exp. Sta. Res. Rep. MP-114:34.

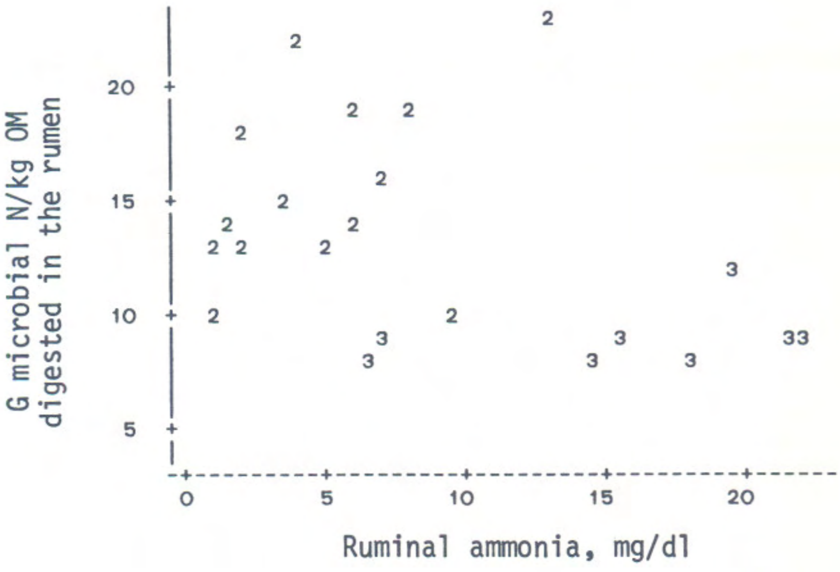


**Figure 1. Influence of ruminal ammonia on efficiency of microbial protein synthesis in 2 experiments[a].**

[a]No relationship ($P > .25$).
[2]Present study.
[3]Weakley and Owens, 1983.

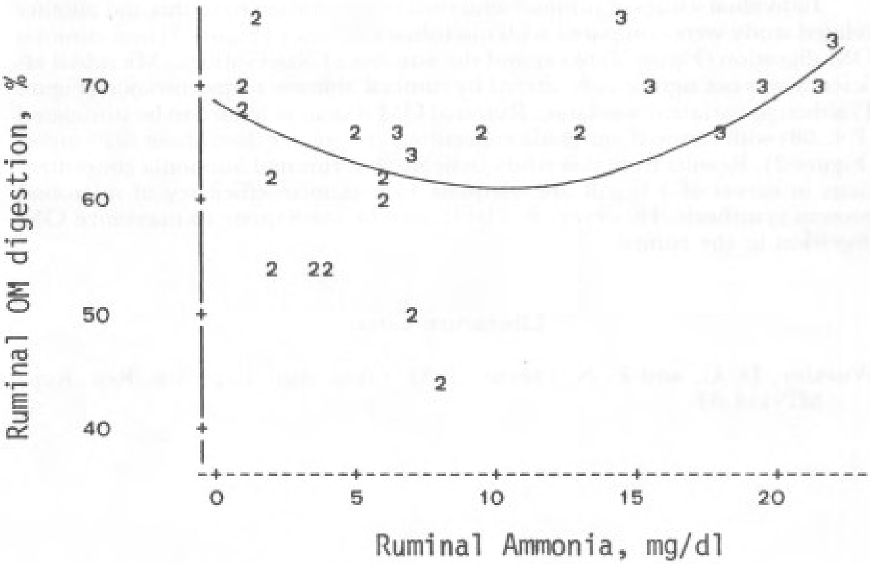


**Figure 2. Influence of ruminal ammonia on ruminal organic matter digestibility in 2 experiments[a].**

[a]Quadratically related ($P < .08$).
[2]Data of present study.
[3]Data of Weakley and Owens, 1983.