RELATIVE VALUES OF UREA AND PROTEIN AS NITROGEN SUPPLEMENTS FOR A LOW-QUALITY ROUGHAGE

J. A. HEMSLEY*

Summary

Wheaten straw diets were supplemented with urea or protein (casein or gluten) and offered ad libitum to sheep. Intakes and digestibilities of the diets were similar irrespective of the nitrogen source. The breakdown of cotton thread suspended in the rumen for 48 h was substantially increased when protein was substituted in the diets. Despite this increase in cellulolytic activity in the rumen there was little change in the digestion of roughage-cellulose. Ruminal concentrations of isobutyric, isovaleric and n-valeric acids were also increased by substitution of urea with protein. Ruminal ammonia and precipitable protein concentrations were similar with all diets, indicating a substantial breakdown of both casein and gluten in the rumen. The factors which limit roughage intake and utilization are discussed.

I. INTRODUCTION

Protein deficiency of mature roughages can be overcome by supplementation with nitrogen derived from protein and non-protein sources. However, in addition to nitrogen, proteins provide metabolites to which rumen micro-organisms can respond. In the experiments reported, the possible influence of such substances on ruminal digestion was examined. To eliminate possible mineral deficiencies, a complete mineral mixture was added to all the diets. In the first experiment, casein and urea were compared as supplements to a wheaten straw diet. Casein is readily fermented in the rumen and some of its constituent amino acids are converted to higher volatile fatty acids (higher VFA) (Dehority et al. 1958) which are necessary for the growth of some rumen microbes (Allison 1965). Branched- and straight-chain higher VFA added to some diets have stimulated roughage and fibre digestion (Hemsley and Moir 1963; Cline, Garrigus and Hatfield 1966).

In the second experiment, wheat gluten, a protein that was expected to resist ruminal fermentation (Lewis 1961), was used to examine the possible effect on food intake of a direct improvement in the animals’ protein status (Egan 1965).

II. EXPERIMENTAL

Four Merino wethers fitted with rumen cannulae were used in two experiments. Two diets were given in Experiment 1 and these consisted of wheaten straw (90 or 84% by weight), urea (3 or 0%), casein (0 or 9%), minerals (3%), and molasses (4%). In Experiment 2, the diets were similar in composition to those used in Experiment 1 but the straw was derived from a different source and casein was replaced by wheat gluten (0 or 10%); all diets had similar nitrogen contents (c 1.6% N) and were offered ad libitum for 18 days.

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The straw was milled through a 1.6 cm screen and the molasses assisted the supplements to adhere to the straw. Measurement of food intake, faecal and urine output were made between the eleventh and seventeenth days. During this period, a cotton thread was suspended for 48 h in the rumen and its extent of breakdown was used as an estimate of ruminal cellulolytic activity. Samples of rumen contents were taken on the eighteenth day, 6 h after fresh food was offered, and analysed for ammonia, nitrogen precipitated by trichloroacetic acid (TCA-nitrogen), and VFA (Hemsley 1964). Nitrogen was estimated by a Kjeldahl procedure, and cellulose by the method of Donefer, Crampton, and Lloyd (1960).

III. RESULTS

The substitution of dietary urea with protein and its effect on food intake, digestion, nitrogen balance, and rumen constituents are shown in Table 1.

Food intakes, digestibilities and nitrogen balances were similar for both the urea and the protein diets. Cotton thread while suspended in the rumen was broken down more rapidly with those containing protein than with those containing urea, but this had no effect on roughage-cellulose digestion. Ammonia-nitrogen and TCA-nitrogen concentrations in rumen fluid were similar for both the urea and protein diets. Higher VFA (isobutyric, isovaleric, and n-valeric acids) concentrations in rumen fluid were all higher in the diets containing protein.

IV. DISCUSSION

Protein supplements to wheaten straw conferred little additional benefit to the animal compared to that obtained with urea. The intakes and digestion of roughage and the retention of nitrogen were similar in both the urea and protein diets (Table 1a). Since ammonia-nitrogen and TCA-nitrogen levels in the rumen (Table 1b) were similar for diets containing either urea or protein, it was probable that both protein sources were extensively degraded in the rumen. Subsequent work (Hemsley, unpublished) has confirmed that a wheat gluten from another source was degraded almost as completely as casein by rumen microorganisms in vitro. As much as 80% of the gluten-nitrogen was recovered as ammonia-nitrogen after incubation with rumen contents for 24 h. Further evidence that gluten was extensively degraded was indicated by the substantial increases in ruminal concentrations of isobutyric, isovaleric and n-valeric acids (Table 1b) which are formed during amino acid fermentation (Dehority et al. 1958).

Despite the lack of response in food intake and digestion to the replacement of urea with the protein supplements, there was a significant increase in cellulolytic activity in the rumen when protein was substituted for urea. The breakdown of cotton thread during 48 h in the rumen increased from approximately 50% with the urea diets to over 90% with the diets containing protein. The rate of cotton thread breakdown was positively correlated with the ruminal concentrations of higher VFA. However, in previous experiments with diets based on wheaten straw (Hemsley 1964, see Table 1 a), the addition of higher VFA to diets containing urea did not appreciably increase intake or cotton thread breakdown in the rumen. This contrasts with responses in intake to higher VFA observed.
<table>
<thead>
<tr>
<th>Dietary Supplements (% of DM)</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Data from Hemsley (1964)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urea 3%</td>
<td>Casein 9%</td>
<td>Urea 3%</td>
</tr>
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<td></td>
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<tr>
<td>(a) Intake, Digestibility and Nitrogen Balance Data</td>
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<tr>
<td>DM intake (g/day)</td>
<td>450 ± 34</td>
<td>590 ± 40</td>
<td>670 ± 29</td>
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<tr>
<td>Straw intake (g DM/day)</td>
<td>410 ± 29</td>
<td>500 ± 33</td>
<td>600 ± 24</td>
</tr>
<tr>
<td>DM digested (g/day)</td>
<td>210 ± 22</td>
<td>310 ± 25</td>
<td>320 ± 19</td>
</tr>
<tr>
<td>DM digestibility (%)</td>
<td>47 ± 1</td>
<td>52 ± 1</td>
<td>48 ± 1</td>
</tr>
<tr>
<td>Cellulose digested (g/day)</td>
<td>110 ± 9</td>
<td>140 ± 10</td>
<td>130 ± 7</td>
</tr>
<tr>
<td>Cellulose digestibility (%)</td>
<td>59 ± 1</td>
<td>60 ± 1</td>
<td>52 ± 1</td>
</tr>
<tr>
<td>Crude fibre digested (g/day)</td>
<td>100 ± 8</td>
<td>120 ± 9</td>
<td>122 ± 7</td>
</tr>
<tr>
<td>Crude fibre digestibility (%)</td>
<td>56 ± 1</td>
<td>58 ± 1</td>
<td>51 ± 1</td>
</tr>
<tr>
<td>Cotton thread breakdown (%)</td>
<td>52 ± 9*</td>
<td>84 ± 10*</td>
<td>55 ± 7*</td>
</tr>
<tr>
<td>Nitrogen intake (g/day)</td>
<td>7.2 ± 0.3</td>
<td>8.2 ± 0.5</td>
<td>11.3 ± 0.5</td>
</tr>
<tr>
<td>Nitrogen balance (g/day)</td>
<td>-0.6 ± 0.5</td>
<td>-0.8 ± 0.5</td>
<td>-0.6 ± 0.5</td>
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<tr>
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<tr>
<td>(b) Ruminal Nitrogen and VFA Data</td>
<td></td>
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<tr>
<td>Ammonia-nitrogen (mg/100 ml)</td>
<td>23 ± 3</td>
<td>21 ± 3</td>
<td>22 ± 2</td>
</tr>
<tr>
<td>TCA-nitrogen (mg/100 ml)</td>
<td>22 ± 3</td>
<td>26 ± 3</td>
<td>19 ± 2</td>
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<tr>
<td>Isobutyric acid (m-equiv./l.)</td>
<td>0.2 ± 0.1*</td>
<td>1.8 ± 0.1*</td>
<td>0.1 ± 0.1*</td>
</tr>
<tr>
<td>Isovaleric acid (m-equiv./l.)</td>
<td>0.1 ± 0.2*</td>
<td>2.2 ± 0.2*</td>
<td>0.1 ± 0.1*</td>
</tr>
<tr>
<td>n-Valeric acid (m-equiv./l.)</td>
<td>0.2 ± 0.2*</td>
<td>2.1 ± 0.2*</td>
<td>0.4 ± 0.2*</td>
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*Significant differences between diets (P < 0.05).
in earlier studies with oat hay (Hemsley and Moir 1963) and with responses in digestibility of purified diets and in urea-nitrogen retention by sheep (Cline,
Garrigus, and Hatfield 1966).

Sheep have the capacity to digest at least 400-500 g cellulose per day (Hems-
ley 1966). However, in these experiments only 100-150 g cellulose were digested
daily, despite an apparently active cellulolytic ruminal population. It was prob-
able that a high proportion of the roughage-cellulose was relatively unavailable
for rumen microbial attack and that the ability of the sheep to remove undigested
food particles from the rumen substantially limited the intake of additional rough-
age. The problem thus becomes one of improving the availability of energy-
yielding substrates in roughages rather than providing nutrients other than energy
to stimulate rumen microbial activity. If a situation arose where energy sub-
strates were not limiting in the rumen then the effect of protein on cellulolytic
activity observed in these experiments could possibly be expressed as an increase
in food intake. The influence of lignification on energy-substrate availability in
the rumen is well known and is probably the single most important factor limit-
ing the productive use of mature roughages by ruminants.

It is unlikely that wheaten straw would supply sufficient nutrients to satisfy
rumen microbial requirements. However, in the present study, the intakes and
digestion of this roughage supplemented with nitrogen and a complete mineral
mixture were little affected by replacing dietary urea-nitrogen with protein-nitro-
gen. Both the low intakes of roughage and the apparent extensive degradation
of both casein and gluten in the rumen probably contributed to the inability of
the sheep to maintain positive nitrogen balances.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

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