Ammonia Versus Urea-Treated Silages with Varying Urea in Concentrate¹

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ABSTRACT
In four factorial experiments, 96 lactating Holstein cows averaging 100 days postpartum were fed corn silage (21 to 31% dry matter) ad libitum treated with aqueous ammonia (.3 to .4%) or urea (.5 to .7%). Concentrates fed at 1 kg/3 kg milk contained 0, .7, or 1.4% urea in Experiment 1 and 0 or 1.4% in Experiments 2, 3, and 4. Following 14-day pretreatment, experimental rations were fed for 65 days in Experiment 1 and 84 days in Experiments 2, 3, and 4. Following 14-day pretreatment, experimental rations were fed for 65 days in Experiment 1 and 84 days in Experiments 2, 3, and 4. Urea in grain and urea in silage depressed intakes of silage and total dry matter. Milk persistencies were lowered only by the diet containing urea in both grain and silage. Bodyweight changes, percent milk fat, and feed efficiencies were not altered significantly by treatments.

INTRODUCTION
Addition of ammonia (NH₃) to corn silage results in higher insoluble nitrogen than addition of urea (2, 5). Studies of ¹⁵N labeled ammonia revealed that approximately 60% of the increase in insoluble nitrogen was due to incorporation of the added ammonia into the insoluble protein fraction (3). The remaining 40% increase was presumably from inhibition of plant proteolysis (1, 3).

Lactating cows fed ammonia-treated silages produced more milk than cows fed urea-treated or untreated silages (2, 5), but this finding has not always been consistent (4).

The study was to assess a nutritional difference between ammonia- and urea-treated silages by challenging cows receiving these silages with supplemental urea in concentrate. The rationale was that ammonia treatment of silage would cause greater "protein sparing" than urea treatment and would allow for feeding more urea in grain without depressing milk yields.

EXPERIMENTAL PROCEDURE
Four experiments with 96 Holstein cows were at the MSU Upper Peninsula Experiment Station at Chatham, MI during 4 consecutive yr, 1972 to 1975. Cows averaged 104 days postpartum prior to starting on experimental diets. All experiments employed a factorial design.

Factors compared were silage treatment (with .3 to .4% added ammonia vs. .5 to .7% added urea) and source of supplemental nitrogen (soybean meal vs. urea) in concentrate. In Experiment 1, urea was added to concentrate at 0, .7, and 1.4%, but in Experiments 2, 3, and 4 urea was added at 0 and 1.4% of concentrate. Ingredient and chemical composition of concentrates are in Table 1.

Silages were made by placing alternate loads of chopped corn plant into two concrete-stave silos (4.9 × 18.5 m). Urea was added to silage by spreading uniformly the needed quantity of urea on top of each wagon load of silage. Anhydrous ammonia was added by mixing one part ammonia with four parts of water (by weight) in the mixing chamber described by Boman (2) and adding to silage as it flowed from the wagon into the silo blower. Silages and concentrates were sampled weekly during feeding and analyzed for dry matter (silage at 60 C in a forced air oven for 48 h and concentrate at 100 C for 24 h) and nitrogen (Kjeldahl).

For Experiment 1, six cows were assigned to each of six diets and for Experiments 2, 3, and 4, six cows were assigned to each of six diets.

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3 Southern Piedmont Continuing Education Center, P.O. Box 148, Blackstone, VA 23824.
TABLE 1. Composition of concentrates.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Ration</th>
<th>Experiment 1</th>
<th>Experiments 2, 3, and 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Ground oats</td>
<td>14.3</td>
<td>15.5</td>
<td>16.6</td>
</tr>
<tr>
<td>Shelled corn</td>
<td>69.2</td>
<td>71.8</td>
<td>73.5</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>11.5</td>
<td>7.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Urea</td>
<td>....</td>
<td>.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Dried molasses</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Steamed bonemeal</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>....</td>
<td>....</td>
<td>....</td>
</tr>
<tr>
<td>Limestone</td>
<td>.5</td>
<td>.5</td>
<td>.5</td>
</tr>
<tr>
<td>Trace mineral salt</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Dry matter</td>
<td>85.9</td>
<td>86.4</td>
<td>86.0</td>
</tr>
<tr>
<td>Crude protein</td>
<td>15.0</td>
<td>16.0</td>
<td>15.8</td>
</tr>
</tbody>
</table>

a Each kilogram of concentrate was supplemented with 4400 and 2000 IU of vitamins A and D.
b Urea in concentrate.
c Percent of dry matter.

4, five cows were assigned to each of four diets. For 14 days prior to the feeding trials all cows were fed a pretreatment ration of corn silage, a 13% crude protein concentrate at 1 kg/3 kg milk, and 4.5 kg of haylage. On alternate days during pretreatment either urea-treated or ammonia-treated silages were fed at 10% in excess of appetite. During experiments, corn silages were fed at 10% in excess of appetite, and daily concentrate allotment was 1 kg/3 kg milk produced during pretreatment. Total concentrate was decreased 5% at 28-day intervals. Corn silage was the only forage in Experiment 1, but 4.5 kg of alfalfa-grass haylage were fed in Experiment 2, and 2.3 kg hay in Experiments 3 and 4. Experimental diets were fed for 65 days in Experiment 1 and for 84 days in Experiments 2, 3, and 4. The

TABLE 2. Composition of corn silages.

<table>
<thead>
<tr>
<th>Item</th>
<th>Experiment a</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silage dry matter (%)</td>
<td></td>
<td>x</td>
<td>SD</td>
<td>x</td>
<td>SD</td>
</tr>
<tr>
<td>Ammonia-treated silage</td>
<td></td>
<td>29.0</td>
<td>.9</td>
<td>20.2</td>
<td>.2</td>
</tr>
<tr>
<td>Urea-treated silage</td>
<td></td>
<td>27.1</td>
<td>.2</td>
<td>23.2</td>
<td>.3</td>
</tr>
<tr>
<td>Silage crude protein in DM (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia-treated silage</td>
<td></td>
<td>12.0</td>
<td>.02</td>
<td>19.2</td>
<td>.2</td>
</tr>
<tr>
<td>Urea-treated silage</td>
<td></td>
<td>12.0</td>
<td>.04</td>
<td>15.7</td>
<td>.2</td>
</tr>
</tbody>
</table>

a Percent ammonia added to fresh silages fed in Experiments 1, 2, 3, and 4 were .5, .7, .7, and .7; and percents urea were .5, .7, .7, and .7.
TABLE 3. Influence of nonprotein nitrogen source and percent on daily intakes of cows.

<table>
<thead>
<tr>
<th>Item</th>
<th>Ammonia</th>
<th>Urea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>Low</td>
</tr>
<tr>
<td>Silage DM (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment 1 (1972, 6 cows/treatment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silage DM (kg)</td>
<td>13.48</td>
<td>12.03</td>
</tr>
<tr>
<td>Grain DM (kg)</td>
<td>6.31</td>
<td>6.42</td>
</tr>
<tr>
<td>Total DM (kg)</td>
<td>19.79</td>
<td>18.45</td>
</tr>
<tr>
<td>Total DM (% BW)</td>
<td>3.23</td>
<td>3.26</td>
</tr>
<tr>
<td>Total CP (kg)</td>
<td>2.57</td>
<td>2.47</td>
</tr>
<tr>
<td>CP from NPN (% of total)</td>
<td>20.9</td>
<td>24.6</td>
</tr>
<tr>
<td>Experiment 2 (1973, 5 cows/treatment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silage DM (kg)</td>
<td>7.44</td>
<td></td>
</tr>
<tr>
<td>Grain DM (kg)</td>
<td>7.45</td>
<td></td>
</tr>
<tr>
<td>Total DM (kg)</td>
<td>16.84</td>
<td></td>
</tr>
<tr>
<td>Total DM (% BW)</td>
<td>2.89</td>
<td></td>
</tr>
<tr>
<td>Total CP (kg)</td>
<td>2.71</td>
<td></td>
</tr>
<tr>
<td>CP from NPN (% of total)</td>
<td>30.8</td>
<td></td>
</tr>
<tr>
<td>Experiment 3 (1974, 5 cows/treatment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silage DM (kg)</td>
<td>11.44</td>
<td></td>
</tr>
<tr>
<td>Grain DM (kg)</td>
<td>7.06</td>
<td></td>
</tr>
<tr>
<td>Total DM (kg)</td>
<td>20.32</td>
<td></td>
</tr>
<tr>
<td>Total DM (% BW)</td>
<td>3.43</td>
<td></td>
</tr>
<tr>
<td>Total CP (kg)</td>
<td>2.85</td>
<td></td>
</tr>
<tr>
<td>CP from NPN (% of total)</td>
<td>24.8</td>
<td></td>
</tr>
<tr>
<td>Experiment 4 (1975, 5 cows/treatment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silage DM (kg)</td>
<td>10.45</td>
<td></td>
</tr>
<tr>
<td>Grain DM (kg)</td>
<td>7.09</td>
<td></td>
</tr>
<tr>
<td>Total DM (kg)</td>
<td>19.35</td>
<td></td>
</tr>
<tr>
<td>Total DM (% BW)</td>
<td>3.16</td>
<td></td>
</tr>
<tr>
<td>Total CP (kg)</td>
<td>2.75</td>
<td></td>
</tr>
<tr>
<td>CP from NPN (% of total)</td>
<td>24.6</td>
<td></td>
</tr>
</tbody>
</table>

aAbbreviations: NPN, nonprotein nitrogen; DM, dry matter; BW, body weight.
bNone, low, and high refer to 0, 17, and 1.4% urea in respective concentrate mixtures.
cFor silage DM and total DM, ammonia silage vs. urea silage (P<.05).
dFor silage DM and total DM, none vs. high grain (P<.1).

shorter time in Experiment 1 was due to a limitation in silage.

Feed intakes and milk weights were determined daily. Milk fat was analyzed monthly by the Babcock method, and cows were weighed for 2 consecutive days 7 days after the beginning and at the end of experiments.

RESULTS AND DISCUSSION

Feeds

Dry matter (DM) in corn silages ranged from 20 to 31% but was similar for silages within each experiment (Table 2). Crude protein (of DM) of the treated silages ranged from 12 to 19% and was similar within experiments except for Experiment 2 where ammonia-treated silage contained considerably more crude protein than urea-treated silage. Similar amounts of nitrogen were added to ammonia- and urea-treated silages in Experiment 2, but the lower percent dry matter of ammonia-treated silage caused a higher percent crude protein per unit dry matter. Crude protein of concentrates ranged from 13.3 to 16.0%.
TABLE 4. Influence of nonprotein nitrogen source and percent on milk yields and persistencies of dairy cows.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Pretreatment (kg/day)</th>
<th>Treatment (kg/day)</th>
<th>Persistency (%)</th>
<th>Ammonia</th>
<th>Urea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Noneb</td>
<td>Low</td>
</tr>
<tr>
<td>Experiment 1 (1972, 6 cows/treatment)</td>
<td>22.6</td>
<td>22.9</td>
<td>23.1</td>
<td>22.6</td>
<td>23.7</td>
</tr>
<tr>
<td>Pretreatment (kg/day)</td>
<td>21.5</td>
<td>22.0</td>
<td>22.3</td>
<td>20.8</td>
<td>22.8</td>
</tr>
<tr>
<td>Treatment (kg/day)</td>
<td>95.0</td>
<td>96.1</td>
<td>97.1</td>
<td>87.1</td>
<td>85.0</td>
</tr>
<tr>
<td>Persistency (%)</td>
<td>92.1</td>
<td>97.4</td>
<td>87.1</td>
<td>3.72</td>
<td></td>
</tr>
<tr>
<td>Experiment 2 (1973, 5 cows/treatment)</td>
<td>22.4</td>
<td>23.2</td>
<td>22.8</td>
<td>23.7</td>
<td></td>
</tr>
<tr>
<td>Pretreatment (kg/day)</td>
<td>22.4</td>
<td>23.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment (kg/day)</td>
<td>18.8</td>
<td>19.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistency (%)</td>
<td>84.1</td>
<td>83.8</td>
<td>87.3</td>
<td>85.0</td>
<td>2.93</td>
</tr>
<tr>
<td>Experiment 3 (1974, 5 cows/treatment)</td>
<td>25.7</td>
<td>26.0</td>
<td>25.9</td>
<td>25.7</td>
<td></td>
</tr>
<tr>
<td>Pretreatment (kg/day)</td>
<td>22.1</td>
<td>20.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment (kg/day)</td>
<td>86.9</td>
<td>79.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistency (%)</td>
<td>85.2</td>
<td>75.1</td>
<td>2.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment 4 (1975, 5 cows/treatment)</td>
<td>25.3</td>
<td>24.4</td>
<td>25.1</td>
<td>23.9</td>
<td></td>
</tr>
<tr>
<td>Pretreatment (kg/day)</td>
<td>21.2</td>
<td>20.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment (kg/day)</td>
<td>84.1</td>
<td>84.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistency (%)</td>
<td>84.4</td>
<td>83.0</td>
<td>1.70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

aPersistency: 100 × treatment/pretreatment.
bNone, low, and high refer to 0, .7, and 1.4% urea in respective concentrate mixtures.
cAmmonia silage vs. urea silage (P<.25).
dNone vs. high (P<.05).

Animal Response

Intakes of dry matter and crude protein are in Table 3. More ammonia- than urea-treated silage was consumed in Experiment 1 (P<.05), but differences were not significant for other experiments. With ammonia-treated silage, cows fed 1.4% urea in concentrate ate 14% less silage dry matter than those fed no urea in concentrate, but the difference due to urea in concentrate was only 5% for cows fed urea-treated silages. Intakes of total dry matter followed trends similar to those for silage dry matter because concentrates and hay were fed in fixed amounts. Intakes of crude protein varied between diets within experiments because of differences in silage consumption. However, mean intakes across all treatments approximately equaled National Research Council allowances (6). Total nitrogen as nonprotein nitrogen (NPN) varied from 19 to 40% and was generally in excess of the maximum recommended by NRC (6) in diets where urea was added to concentrate.

In Experiments 1 and 3 there was a trend towards higher persistency of milk production (P<.25) for cows fed ammonia- compared to urea-treated silages (Table 4). Only for Experiment 3 did urea in grain significantly (P<.05) decrease persistency of milk yields.

Pooled silage and total intakes of dry matter (Table 5) were higher (P<.10) for ammonia-than for urea-treated silages and were decreased (P<.05) by adding urea to concentrate. The amount of urea fed to cows receiving urea-treated silage and urea in concentrate was similar to that which depressed intake in the report of Van Horn et al. (7).

In six of eight treatment comparisons (Table 4), addition of 1.4% urea to concentrate resulted in lower milk persistencies than when no urea was added. This decrease was significant (P<.05) for pooled results. The combination of urea in silage and urea in concentrate reduced milk persistencies compared to either silage fed with control concentrate, whereas urea in concentrate fed with ammonia silage caused only slight decreases.

TABLE 5. Influence of nonprotein nitrogen source and percent on performance of dairy cows (pooled data)\(^a\).

<table>
<thead>
<tr>
<th>Item</th>
<th>Ammonia</th>
<th>Urea</th>
<th>Significant effects (P&lt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None(^b)</td>
<td>High</td>
<td>None</td>
</tr>
<tr>
<td>Intake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silage DM (kg/day)</td>
<td>10.85</td>
<td>9.53</td>
<td>9.76</td>
</tr>
<tr>
<td>Total DM (kg/day)</td>
<td>19.11</td>
<td>17.80</td>
<td>17.98</td>
</tr>
<tr>
<td>Total DM (% BW)</td>
<td>3.18</td>
<td>3.03</td>
<td>3.10</td>
</tr>
<tr>
<td>Total CP (kg/day)</td>
<td>2.71</td>
<td>2.56</td>
<td>2.54</td>
</tr>
<tr>
<td>CP from NPN (% of CP)</td>
<td>25.1</td>
<td>34.0</td>
<td>23.1</td>
</tr>
<tr>
<td>Milk yields</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretreatment (kg/day)</td>
<td>23.9</td>
<td>24.1</td>
<td>24.0</td>
</tr>
<tr>
<td>Treatment (kg/day)</td>
<td>20.9</td>
<td>20.7</td>
<td>20.8</td>
</tr>
<tr>
<td>Persistency (%)(^d)</td>
<td>87.9</td>
<td>86.7</td>
<td>87.5</td>
</tr>
<tr>
<td>Persistency (%)(^e)</td>
<td>86.3</td>
<td>85.3</td>
<td>84.7</td>
</tr>
<tr>
<td>Milk fat (%)</td>
<td>3.95</td>
<td>3.75</td>
<td>3.90</td>
</tr>
<tr>
<td>Weight change (kg/day)</td>
<td>.17</td>
<td>.33</td>
<td>.33</td>
</tr>
<tr>
<td>Feed efficiency (milk/DM)</td>
<td>1.17</td>
<td>1.24</td>
<td>1.23</td>
</tr>
</tbody>
</table>

\(^a\)All means in this table except those explained by footnote \(e\) are pooled for 21 cows per diet (6 from Experiment 1 and 5 each from Experiments 2, 3, and 4).

\(^b\)None and high refer to 0 and 1.4\% urea in respective concentrate mixtures. The .7\% urea was omitted from pooled data because this diet was used only in Experiment 1.

\(^c\)Nonsignificant (P>.15).

\(^d\)Persistency = (treatment/pretreatment) × 100.

\(^e\)Persistencies pooled for last 5 wk of treatment for Experiment 1 and the last 8 wk for Experiments 3 and 4 (16 cows/treatment). Data from Experiment 2 are not included because of the much higher concentration of nitrogen in ammonia-treated than urea-treated silage.

Examination of data by 28 days revealed that for Experiments 1, 3, and 4, differences between silages became greater as treatment progressed. Data from Experiment 2 were excluded from this comparison, because of the abnormally high percent of ammonia added to silage (dry matter). Persistencies of milk production for the last 37 days of treatment in Experiment 1 and the last 56 days in Experiments 3 and 4 showed that the diet containing urea in silage and concentrate was significantly poorer (P<.05) for maintaining milk yields than the three other treatments.

Pooled data for efficiency of conversion of feed dry matter to milk, bodyweight changes, and percent fat in milk showed no significant differences between treatments.

The percent of total nitrogen consumed as NPN for the respective treatments (from left to right in Table 5) averaged 25, 34, 23, and 33. These percentages were equivalent to 227, 335, 193, and 325 g urea per day. Decreased milk yields have been reported on similar rations when intake of NPN exceeded about 220 g urea.

or urea equivalent per day (7). Because of the decreased milk persistency on the diet containing urea in grain and urea in silage compared to urea in grain and ammonia in silage, we suggest that ammonia treatment of silage allows for higher intakes of NPN without decreasing milk production than when urea is added. This difference in response of ammonia and urea in silage at high NPN intakes was probably due to a sparing action of ammonia on corn plant protein (1, 3).

REFERENCES