AMMONIATION OF CORN STOVER STACKS TO IMPROVE FEED VALUE

C. K. Sankat1 and W. K. Bilanski

1Department of Mechanical Engineering, University of the West Indies, St. Augustine, Trinidad and 2School of Engineering, University of Guelph, Guelph, Ontario N1G 2W1

Received 15 January 1979


Stacks of corn stover made with a high density McKee Stacker and with an average dry matter weight of 1206 kg were harvested on the farm and individually covered with plastic sheets. Anhydrous NH₃ from an ammonia tank-wagon was then injected into the stacks at 2%, 3%, and 4% levels of ammoniation (on a dry matter basis). Significant improvements in both the crude protein content of the corn stover and in vitro digestibility of dry matter were obtained after 30 days of treatment at all three levels of ammoniation.

INTRODUCTION

Corn stover, comprising leaves, stalks, husks and cobs, is the residue of the corn plant after grain harvest and is abundant in Ontario. As shown in Table I, it has an approximate dry matter digestibility of 55% and a crude protein content of 4.5% (Daynard and Mowat 1976). Its use as an animal feed has been limited in the past because of this low digestibility and poor nutritional value. However, because ruminant animals are uniquely adapted to utilize the cellulose in high fibre forages, the potential use of corn stover as an animal feed is under investigation and consideration.

To improve the nutritive value, digestibility and keeping quality of roughages, their treatment with alkalies has been reported. Experiments with NaOH-treated straw have shown an increase in the in vitro digestibility of organic matter ranging from about 49% in untreated straw to 70% in straw treated with 5% NaOH (by weight) (Rexen and Moller 1974). Experiments with rice straw treated with 5.2% NH₃ (by weight), and 22.8% water for 30 days at room temperature, showed an enzymatic digestibility (TSAE) increase from 29% to 62% and a nitrogen content increase from 0.56% to 1.32% (Waiss et al. 1972).

Ammonia treatment of straw (either aqua-ammonia or anhydrous ammonia) therefore has an advantage over NaOH treatment in that considerable amounts of nitrogen can be incorporated into the treated straw in a form which can be used as a source of nonprotein nitrogen by ruminant animals. It has the disadvantage that the improvement in in vitro digestibility is not as great as when stronger bases, such as sodium hydroxide, are used (Coxworth 1976). However, in actual feeding trials, this difference is not pronounced.

The primary objectives of this research were to evaluate a method of ammoniating stacks of corn stover on the field and, in particular, to measure the changes in the crude protein content and in vitro digestibility of dry matter (IVDDM) of the ammoniated corn stover with various levels of ammoniation and treatment time.

MATERIALS AND METHODS

Stacks of corn stover were harvested in the fall of 1976 at the Arkell Research Station, Guelph, Ontario, utilizing a McKee Bros. High Density Stacker. The stacks were 2.13 m wide × 3.04 m long × 2.13 m high and an estimated weight of 1722 kg (at 30% moisture content) was calculated after the random weighing of three stacks.

Twelve stacks were individually covered the following spring (21 Apr.) with 6-mil black polyethylene plastic sheets, which were commercially available in 12.2 × 20.5-m rolls. The stacks were made air-tight using sand to seal the plastic in contact with the ground (Fig. 1). Before covering, grab samples of corn stover were taken from the top, middle and bottom sections of each stack for individual moisture and nutritional analysis. In two stacks, thermocouples were inserted at centers and after ammoniation, temperatures were monitored continuously for the first 24 h using a recorder, and subsequently at daily intervals using a portable temperature indicator.

Ammoniation was performed by direct injection of anhydrous ammonia taken from an ammonia tank wagon. The ammonia discharge (kg NH₃/s) from the tank was previously calibrated by weighing the tank wagon before and after ammoniation. The ammonia was applied to the stacks through a flexible hose from the tank to the center of the bottom section of each stack (Fig. 2) by a tapered metal pipe, which was plunged into the stacks. The desired weight of ammonia was applied to the stacks initially by timing the duration of ammonia injection, and more precisely by weighing the tank wagon before and after ammoniation. After ammoniation, the metal pipe was removed from stack and the hole in the plastic covering sealed with a polyethylene contact tape.

Stacks were treated in four groups with 24.9 kg, 36.6 kg and 47.6 kg ± 1.1 kg of ammonia, representing 2%, 3% and 4% levels (on a dry matter basis) of ammoniation, respectively. All stacks were treated within a 24-h period. One stack from each level of ammoniation was opened after 10, 20, 30, and 40 days, respectively. The stacks were allowed to aerate for a further 10 days to dispel excess and undesirable free ammonia. Grab samples of corn stover were again removed from the top, middle and bottom sections of each stack for nutritional analysis.

Analysis of the total Kjeldahl (NH₃ nitrogen and organic nitrogen) nitrogen on all the samples of corn stover was

<table>
<thead>
<tr>
<th>Stover composition</th>
<th>% of dry weight</th>
<th>% dry matter digestibility</th>
<th>% crude protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaves</td>
<td>25</td>
<td>55</td>
<td>7</td>
</tr>
<tr>
<td>Stalks</td>
<td>35</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>Husks, shank</td>
<td>20</td>
<td>65</td>
<td>3</td>
</tr>
<tr>
<td>Cob</td>
<td>20</td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>55</td>
<td>4.5</td>
</tr>
</tbody>
</table>
**Figure 1.** Covered corn stover stacks at the Arkell Research Station.

**Figure 2.** Probe for ammonia injection into the stack.

### TABLE II. INCREASES IN THE CRUDE PROTEIN CONTENT OF AMMONIATED CORN STOVER

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Position in the stack</th>
<th>Overall mean % increase$\dagger$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top</td>
<td>Middle</td>
</tr>
<tr>
<td>10</td>
<td>8.0</td>
<td>7.9</td>
</tr>
<tr>
<td>20</td>
<td>7.9</td>
<td>7.7</td>
</tr>
<tr>
<td>30</td>
<td>7.1</td>
<td>9.1</td>
</tr>
<tr>
<td>40</td>
<td>8.8</td>
<td>10.8</td>
</tr>
</tbody>
</table>

### TABLE III. INCREASES IN IN VITRO DIGESTIBILITY OF DRY MATTER OF AMMONIATED CORN STOVER

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Position in the stack</th>
<th>Overall mean % increase$\dagger$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top</td>
<td>Middle</td>
</tr>
<tr>
<td>10</td>
<td>57.4</td>
<td>57.8</td>
</tr>
<tr>
<td>20</td>
<td>59.4</td>
<td>53.8</td>
</tr>
<tr>
<td>30</td>
<td>59.8</td>
<td>61.6</td>
</tr>
<tr>
<td>40</td>
<td>56.5</td>
<td>61.0</td>
</tr>
</tbody>
</table>

$\dagger$Mean values from duplicate nitrogen analysis.

$\dagger$Based on the average value of 5.3% (dry matter basis) for untreated corn stover.

$\dagger$Level of ammoniation based on the dry matter weight (1205 kg) of the stacks.

The mean moisture content of the 12 stacks prior to treatment was 22.4% with a standard deviation of 13.9%. This variability can be attributed to the time of treatment, as the spring thaw resulted in considerable wetting of some stacks, especially the bottom sections in contact with the ground. The average temperature on the farm (calculated from daily maximum and minimum temperatures) for the duration of the experiment was 13°C, and daily temperatures indicated a statistically warming trend as the experiment proceeded. The temperature in the center of the treated stacks in which thermocouples were located increased from 21°C to a maximum of 78°C within 2 h of ammoniation, but dropped to 29°C after 24 h. This immediate rise in temperature could be due mainly to the exothermic reaction between NH₃ and H₂O. By the 6th day of treatment, stack temperatures had fallen to the temperature of the surroundings. On ammoniation, the color of the corn stover changed from golden yellow to dark brown.

**OBSERVATIONS**

The mean moisture content of the 12 stacks prior to treatment was 22.4% with a standard deviation of 13.9%. This variability can be attributed to the time of treatment, as the spring thaw resulted in considerable wetting of some stacks, especially the bottom sections in contact with the ground. The average temperature on the farm (calculated from daily maximum and minimum temperatures) for the duration of the experiment was 13°C, and daily temperatures indicated a statistically warming trend as the experiment proceeded. The temperature in the center of the treated stacks in which thermocouples were located increased from 21°C to a maximum of 78°C within 2 h of ammoniation, but dropped to 29°C after 24 h. This immediate rise in temperature could be due mainly to the exothermic reaction between NH₃ and H₂O. By the 6th day of treatment, stack temperatures had fallen to the temperature of the surroundings. On ammoniation, the color of the corn stover changed from golden yellow to dark brown.
RESULTS AND DISCUSSION

Analysis of the 36 samples of corn stover taken from the 12 stacks prior to ammoniation showed a mean crude protein content of 5.3% on a dry matter basis, with a standard deviation of 0.8% and an in vitro digestibility of dry matter of 51% with a standard deviation of 3.4%. On this control basis, and from similar nutritional analyses of the corn stover samples taken from the 12 stacks after ammoniation, percentage increase in the crude protein content and in vitro digestibility were calculated. These results are shown in Tables II and III.

These data (with six observations for crude protein content and in vitro digestibility, respectively, and for each stack) were examined statistically by analysis of variance, using the F-test. From this the following conclusions were made:

1. At any level of ammoniation the duration of treatment very significantly affected both the crude protein content and in vitro digestibility of the corn stover.

2. In general, different levels of ammoniation (2%, 3% or 4%) did not significantly affect the crude protein content of the corn stover.

3. There were no significant differences in the percentage increases in in vitro digestibility between 3% and 4% NH₃-treated corn stover. However, stacks treated with 2% NH₃ showed a significantly smaller improvement in digestibility compared to those treated with the higher levels of ammonia.

4. Individual stacks of corn stover were, in general, uniformly ammoniated. Some variation of the in vitro digestibility and particularly the crude protein content within individual stacks (as seen in Tables II and III) could be attributed to the variation in the moisture content of the corn stover. As stated earlier, the moisture content at the bottom of the stacks was, in general, higher than the average moisture content. As ammonia has a special absorption affinity for the aqueous fraction of the corn stover (Lancaster et al. 1974), an increase in the amount of ammonia retained is expected, primarily as NH₃ nitrogen.

The above-mentioned conclusions are also apparent from Figs. 3 and 4. These were obtained from a least-squares analysis, using the data of Tables II and III. The model equation used was

\[ Y = A(1 - e^{Bt}) \]

where

\[ Y = \% \text{ increase in crude protein, or } \% \text{ increase in in vitro digestibility of dry matter} \]

\[ t = \text{treatment time in days} \]

\[ A,B = \text{parameters describing the response to a particular level of ammoniation.} \]

Table IV shows the parameters \( A \) and \( B \) of Eq. 1 which were used to plot Figs. 3 and 4.

The data obtained from these experiments are consistent with previously reported information on the ammoniation of low quality forages. Oji et al. (1977) reported a 94% improvement in the crude protein content of corn stover and a 15% improvement in the apparent digestibility of dry matter when corn stover was treated with 3% aqua-ammonia for 30 days at room temperature. Sundstol et al. (1978) reported that there is little improvement in the digestibility of roughages treated with NH₃ levels greater than 3–4%, and that for treatment temperatures between 5 and 15°C, a treatment time of 4–8 wk was adequate.

On the basis of the weight of nitrogen applied initially to the corn stover as anhydrous ammonia, 48% was recovered as crude protein in the 2% NH₃ treatment, 33% in the 3% NH₃ treatment and 28% in the 4% NH₃ treatment. From the nitrogen analysis of the ammoniated corn stover samples, ammonia nitrogen averaged 31%, the rest being in a more tightly bound, organic form.
CONCLUSION

When NH₃ is applied to a low quality forage such as corn stover, both the crude protein content and in vitro digestibility of dry matter are increased. A simple method of ammoniating large stacks of corn stover on the farm has been described and evaluated. A 3% level (on a dry matter basis) of anhydrous ammonia treatment appears adequate. At such a level, and under Ontario spring conditions, the crude protein content of corn stover increased from a level of 5.3% to a level of 10% (89% improvement) and the in vitro digestibility of dry matter increased from a level of 51% to a level of 62% (21% improvement) after 30 days of treatment on the field.

ACKNOWLEDGMENTS

The authors would like to thank the Canadian International Development Agency (CIDA) for their financial support of this project, and both McKee Bros. of Elmira, Ontario, and CIL of London, Ontario, for their material support.

We also thank Dr. D. N. Mowat (Department of Animal and Poultry Science) and Dr. J. E. Winch (Department of Crop Science) of the Ontario Agricultural College, University of Guelph for their technical assistance.


Figure 4. Percentage increases in the in vitro digestibility of corn stover with time and level of ammoniation.