Ammonium Hydroxide Treatment of Wheat Straw

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Story in Brief

Chopped wheat straw, containing increasing amounts of added water was treated with a constant level of ammonia (3.3 percent of straw dry matter) as ammonium hydroxide, and stored for 1 to 60 days before determing *in vitro* dry matter digestibility (IVDMD), nitrogen content and fiber-bound nitrogen (ADF-N) versus free ammonia nitrogen (NH_3-N) of the treated sample. The overall improvement (e.g., mean of all day × moisture treatment combinations) in IVDMD of treated versus untreated straw was about 33 percent, whereas nitrogen content of treated straw was increased from 4.6 percent crude protein to 11.0 percent crude protein. Fiber-bound nitrogen and NH_3-N accounted for 12.6 and 43.4 percent of the retained nitrogen, respectively, when averaged across all day × moisture treatment combinations. The ammonium hydroxide treatment increased straw digestibility by (1) directly decreasing the total cell wall fiber (NDF) and hemicellulose fractions (perhaps by solubilization effects), and (2) increasing the digestibility of the NDF, hemicellulose and cellulose fiber fractions.

Introduction

An estimated 1 ton of wheat straw is available as a potential feedstuff for each acre of wheat that yields 20 to 25 bushels of grain. Both the digestibility and crude protein content of wheat straw are generally low. Chemical treatment of crop residues with various alkalis, such as sodium hydroxide, calcium hydroxide and potassium hydroxide, has increased digestibility and often has increased voluntary intake and animal performance. Ammonium hydroxide (NH_4OH) has the potential of (1) reducing the chemical cost of treatment, and (2) increasing the crude protein content of the treated straw.

The objectives of these studies were to determine (1) the effect of length of time (days post-treatment) and water content of wheat straw on *in vitro* dry matter digestibility (IVDMD) and nitrogen retention of NH_4OH-treated straw, (2) the relative amounts of nitrogen retained as fiber-bound nitrogen versus free ammonia nitrogen (NH_3-N), and (3) the changes in digestibility of various fiber fractions of straw due to NH_4OH treatment.

Experimental Procedures

Experiment I.

Water was added to chopped wheat straw to result in final levels of about 10, 20, 30, 40 and 50 percent of dry matter. Ammonium hydroxide was then sprayed on the straw at a level that resulted in 3.3 percent ammonia (NH_3) being added on a dry matter basis. The treated straw was sealed in double plastic bags, and stored at room temperature for 10, 20, 30, 40 or 50 days before being frozen and ground with dry ice to pass through a 1 mm screen. Dry matter, total nitrogen and IVDMD were measured. Total nitrogen was analyzed by the Kjeldahl procedure and IVDMD by the Tilley and Terry procedure with urea (0.5 g/liter) added to the buffered rumen fluid and a 24 hr pepsin digestion phase. Also, dry matter, total nitrogen, fiber-bound nitrogen (ADF-N), and free ammonia-nitrogen (NH_3-N) were measured on the treated straw samples after they had been spread in a pan and aerated for 24 hr at room temperature. Free ammonia-nitrogen was analyzed by the magnesium oxide distillation step of the Kjeldahl procedure.

Changes in the digestibility of various fiber fractions as a result of NH_4OH-treatment were determined by analyzing the untreated straw and 3 treated straw samples for neutral-detergent fiber (NDF), acid-detergent fiber (ADF), acid-detergent lignin (ADL) and cellulose both *before* and *after* running IVDMDs on the samples. The 3 treated straw samples that were chosen were among those that had the highest IVDMDs after NH_4OH treatment.

The data were analyzed by regression analysis for a 5×5 factorial arrangement of treatments in a completely randomized design with two replications.

Experiment II.

Chopped wheat straw was treated the same as described for Experiment I in regard to ammonia and water level with the exception that a straw sample with no added water and ammonia was carried through each of the storage times. Storage times were 1, 5, 10, 20, 40 and 60 days. Treated samples were analyzed for IVDMD and total nitrogen after aeration as described for Experiment I. The data were analyzed by regression analysis for a 6×6 factorial arrangement of treatments in a completely randomized design with two replications.

Results and Discussion

Digestibility and total nitrogen content of straw

Both IVDMD (digestibility) and total nitrogen content of wheat straw were significantly increased by NH_4OH-treatment ($P<.01$). Although number of days post-treatment ($P<.05$) and moisture level ($P<.0001$) had significant linear effects on both digestibility and total nitrogen content,

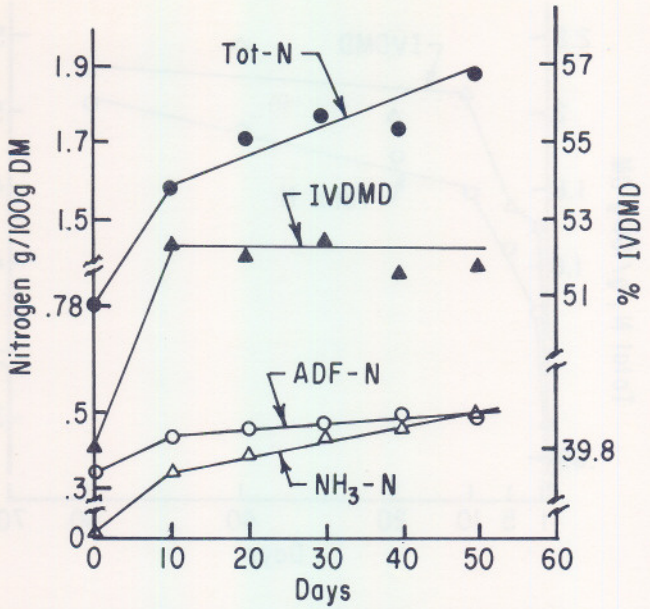

Figure 1. Nitrogen and IVDMD response to days post-treatment (Experiment 1)

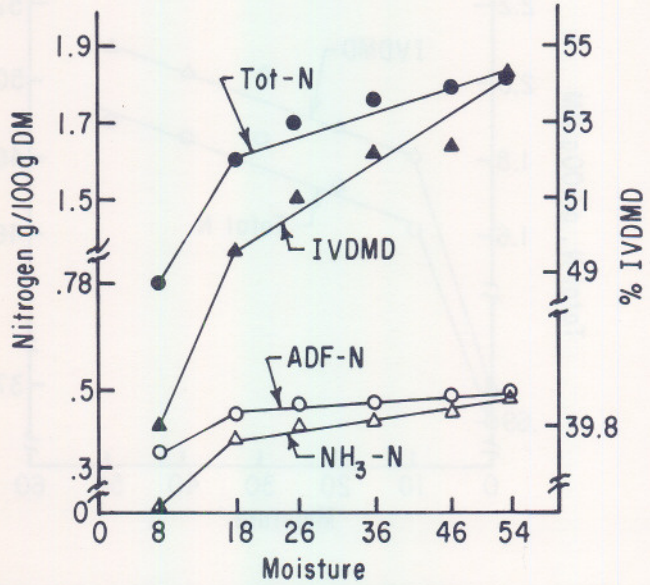

Figure 2. Nitrogen and IVDMD response to straw moisture level (Experiment 1)

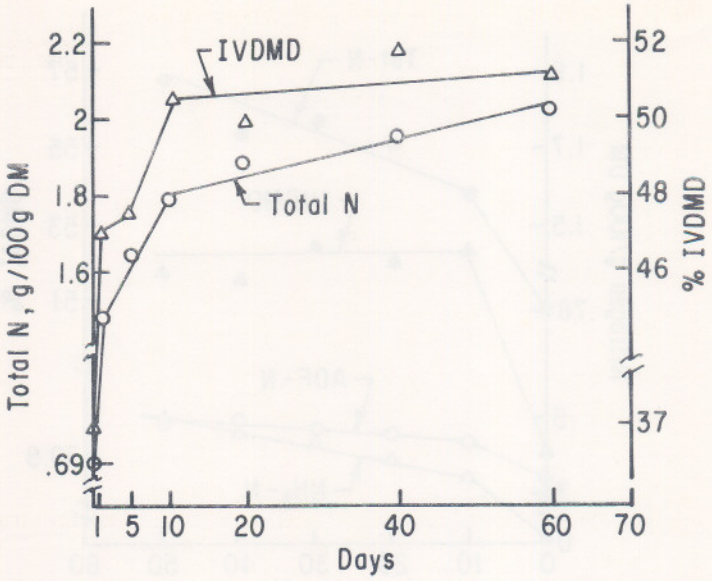

Figure 3. Nitrogen and IVDMD response to days post-treatment (Experiment 2)

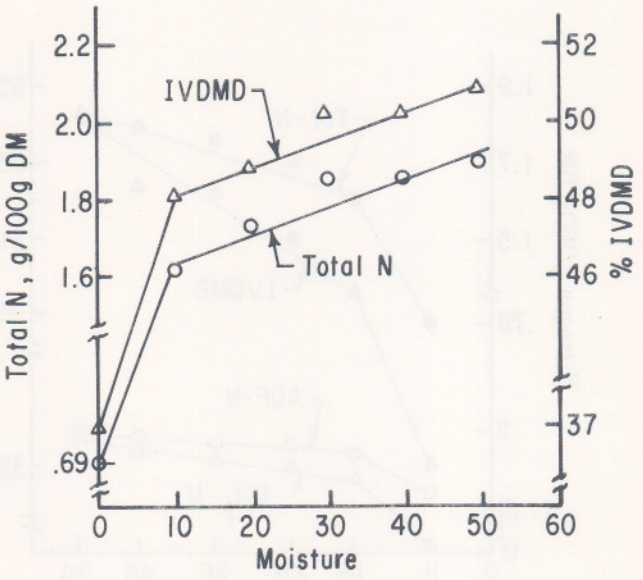

Figure 4. Nitrogen and IVDMD response to straw moisture level (Experiment 2)

Table 1. IVDMD and Total N content in wheat straw

	IVDMD (%)		Total N Content (g/100 g DM)	
Experiment No.:	I	II	I	II
Untreated straw	39.8	36.8	.78	.69
Treated straw[a]	52	49.64	1.73	1.79
% increase over untreated straw	30.6	34.9	122	159
Treated straw[b]	53.5[c]	52.4[d]	1.90[e]	2.13[f]
% increase over untreated straw	34.4	42.4	144	209

[a]Overall means of all day × moisture treatment combinations.
[b]Treated straw samples which showed maximum or near maximum increase in IVDMD or total nitrogen content.
[c]10 days × 54 percent moisture.
[d]10 days × 50 percent moisture.
[e]50 days × 54 percent moisture.
[f]60 days × 50 percent moisture.

Table 2. Total nitrogen, ADF-N and NH_3–N in treated wheat straw

	Untreated straw	Treated[a] straw	Treated[b] straw
Total N added g/100 g DM straw	----	2.72	----
Total N content g/100 g DM	.78	1.73	1.90
Total N retention, % of added	----	34.9	41.2
ADF–N			
g/100 g DM	.34	.46	.49
% of total N added	----	4.4	5.5
% of total N retained	----	12.6	13.4
NH_3–N			
g/100 g DM	.008	.42	.56
% of total N added	----	15.1	20.3
% of total N retained	----	43.4	49.3

[a]Overall means of all day × moisture treatment combinations.
[b]Treated straw sample (50 days × 54 percent moisture) which showed maximum or near maximum increase in total nitrogen content.

further improvements in digestibility after 10 days were small (Figures 1 and 3), and a large percentage of the improvement in digestibility had occurred by 5 days post-treatment (Figure 3). Total nitrogen content of the treated straw, however, continued to increase as days post-treatment increased (Figures 1 and 3). Both digestibility and total nitrogen content of treated straw continued to increase as moisture content increased (Figures 2 and 4). The overall improvements (e.g., mean of all day × moisture treatment combination) in IVDMD and nitrogen content due to NH_4OH treatment were: 30.6 and 34.9 percent (IVDMD) and 122 and 159 percent (total nitrogen content) for

Table 3. Solubilization and changes in digestibility of wheat straw fiber fractions[a] due to NH_4OH treatment

	Untreated[b] Straw	Treated straw[b]		Change due to NH_4OH		Change due to IVDMD		Total Change	
		Before IVDMD	After IVDMD	g/100 g DM	% of untreated straw	g/100 g DM	% of before IVDMD	g/100 g DM	% of untreated straw
NDF, g/100 g DM	73.3	67.0	60.2	− 6.3	− 8.6	− 6.8	−10.1	−13.1	− 17.8
NDS, g/100 g DM	26.7	33.0	39.7	+ 6.3	+23.6	+ 6.7	+20.3	+13.0	+ 48.7
ADF, g/100 g DM	49.1	53.2	52.6	+ 4.1	+ 8.3	− 0.5	− 1.0	+ 3.6	+ 7.3
ADL, g/100 g DM	7.7	8.5	16.6	+ 0.8	+10.4	+ 8.1	+95.3	+ 8.9	+115.6
Hemicellulose, g/100 g DM	24.1	13.8	7.6	−10.3	−42.7	− 6.2	−44.9	−16.5	− 68.4
Cellulose, g/100 g DM	39.5	42.3	31.3	+ 2.8	+ 7.0	−11.0	−26.0	− 8.2	− 20.7

[a]Neutral-detergent fiber (NDF), Neutral-detergent solubles (NDS), Acid-detergent fiber (ADF), Acid-detergent lignin (ADL).
[b]IVDMD of untreated and treated straw samples were 39.8 and 55.1 ± .37 percent, respectively.

Experiments I and II, respectively (Table 1). Maximum or near maximum improvements in IVDMD and total nitrogen content due to NH_4OH treatment were: 34.4 and 42.4 percent (IVDMD) and 144 and 209 percent (total nitrogen content) for Experiments I and II, respectively (Table 1).

Total nitrogen retention, ADF-N and NH_3-N

The overall mean quantity of nitrogen that was retained in the NH_4OH-treated straw samples was 0.95 g per 100 g dry matter (e.g., 1.73 minus 0.78 g) or 34.9 percent of the added nitrogen (Table 2). Fiber-bound nitrogen (ADF−N) and free ammonia nitrogen (NH_3-N) accounted for 12.6 and 43.4 percent of the retained nitrogen, respectively, when average across all day × moisture treatment combinations.

Concentrations and digestibility of fiber fractions

Total cell wall fiber (NDF) and the hemicellulose fraction were decreased 8.6 and 42.7 percent, respectively, by NH_4OH treatment alone (Table 3). During the IVDMD procedure 10.1, 44.9 and 26.0 percent of the NDF, hemicellulose and cellulose fiber fractions, respectively, which remained after chemical treatment disappeared or were digested. In total 17.8, 68.4 and 20.7 percent of the NDF, hemicellulose and cellulose fiber fractions, respectively, that were present in the untreated straw were lost due to the combination of (1) chemical effects on the fiber fractions and (2) digestibility during the IVDMD procedure. The total increase of 8.9 g for the ADL fraction would be the result of concentrating effects associated with the loss of the NDF, hemicellulose and cellulose fractions.