The Influence of Various Additives on the Solubilization of Nitrogen and Acid Production in Corn During High Moisture Storage

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Story in Brief

Samples of high moisture corn, both ground and whole shelled, were ensiled in sealed plastic bags for various lengths of time with several additives, namely, 80:20 Propionic:Acetic acids (Chem-Stor), ammonium isobutyric acid (AIB), $CaCO_3$ and Urea. The samples were analyzed for soluble nitrogen (SN), soluble non-protein nitrogen (SNPN), soluble protein (SP) and levels of lactic acid, acetic acid, and pH were determined.

In trial 1 ground corn was ensiled for times ranging from 0-56 days. The SN levels increased with time and represented 38.2 percent of the total nitrogen at 56 days. The SNPN represented on an average 70 percent of the soluble nitrogen and increased from 7.3 at zero time to 32.1 percent of the total-N at 56 days. The effects of the additives on SN levels were slight, however, Chem-Stor inhibited acid production considerably. The results with Chem-Stor indicate that bacterial fermentation does not play a major role in the solubilization of nitrogen.

The addition of urea to ground high moisture corn (trial 2) tended to increase the SP levels. The higher pH of the urea treated corn could have changed the solubility characteristics of the protein and thus increase the SP content. In trial 3 while shelled high moisture corn had considerable less SN at 56 days (14.8 percent) than the ground high moisture corn. No increase in lactic acid was observed at 56 days and acetic acid increased slightly, indicating that the fermentation process is much slower in the whole corn when compared to ground corn.

Introduction

Recently there has been an increased interest in the utilization of high moisture corn for feedlot cattle since grains stored in this manner have proven to be an economical source of energy. Feeding studies with high moisture corn have shown improved feed efficiency, however, de-

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creases in feed intakes have also been noted.

The changes in the feeding value of high moisture corn have been related to chemical changes occurring in the grain during storage. Evidence in the scientific literature indicates that with high moisture storage the protein fraction of corn changes dramatically from an insoluble to a highly soluble form. It has been inferred by some researchers that this conversion of protein to a more soluble form may be associated with decreased intakes of high moisture stored grains. In addition, studies in this laboratory have indicated that rations containing high moisture corn could be more prone to producing acidosis than dry corn rations. Therefore, the purpose of this study was to determine the effects of various additives, ensiling time, and methods of ensiling on the solubilization of nitrogen and acid production of high moisture corn.

Materials and Methods

Three trials were conducted on samples of high moisture corn obtained from Hitch Feedlot in Guymon, Oklahoma. Approximately 500 g of corn were sealed in air-tight plastic bags and were assigned to various treatments.

Trial 1.

Samples of ground high moisture corn were ensiled for time periods ranging from 0 to 56 days as listed in Table 1. To test the effects of additives on the solubilization of nitrogen and acid production 1.5 percent Chem-Stor[1] (80:20 propionic:acetic acids), 2.0 percent ammonium isobutyric acid (AIB)[2] and 0.5 percent limestone ($CaCO_3$) were added to samples of high moisture corn. Total nitrogen, soluble nitrogen (SN) and soluble non-protein nitrogen (SNPN) in addition to levels of lactic and acetic acid and pH were determined on the samples after the appropriate storage times. The soluble nitrogen was extracted in an aqueous buffer solution with an ionic strength of 0.14 in a shaking incubator for one hour. A portion of the solution was treated with tungstic acid to precipitate the protein and SNPN levels were determined. Soluble protein (SP) content was represented as the difference between the SN and SNPN fractions.

Since the AIB treatments contained 7.85 percent N the exact effects of the AIB on the soluble nitrogen content of the corn was derived by correcting for the added nitrogen. This was done by determining the NH_3-N at 0 days by ammonia distillation and subtracting this value from

[1]Celanese Chemical Co., Corpus, Christi, Texas.
[2]W. R. Grace and Company, Columbia, Maryland.

Table 1. The Influence of Storage Time and Additives on the Soluble Nitrogen Content of Ground High Moisture Corn.

Additive	Level[1]	Ensiling Time	DM	Total N	Percent of Total Nitrogen: Soluble N	Soluble NPN	Soluble Protein
	%	Days	%	mg			
Control	–	0	74.3	14.9	15.8	7.3	8.5
Chem-Stor	1.5	0	73.9	15.2	16.1	7.9	8.2
AIB[2]	2.0	0	73.1	15.2	16.2	6.9	9.3
$CaCO_3$	0.5	0	73.8	15.3	15.5	7.8	7.7
Control	–	2	73.3	15.2	18.3	9.6	8.7
Control	–	6	73.0	15.1	21.9	15.2	6.7
Chem-Stor	1.5	6	72.7	15.1	19.9	15.9	4.0
AIB[2]	2.0	6	73.2	14.9	16.4	11.2	5.2
$CaCO_3$	0.5	6	72.8	15.7	18.6	15.3	3.3
Control	–	12	72.0	15.7	24.3	18.9	5.4
Chem-Stor	1.5	12	73.1	15.8	20.5	15.1	5.4
AIB[2]	2.0	12	72.2	15.5	17.9	13.0	4.9
$CaCO_3$	0.5	12	71.9	15.4	24.7	18.5	6.2
Control	–	21	72.4	15.1	31.7	20.0	11.4
Control	–	28	72.2	15.7	33.1	27.2	5.9
Chem-Stor	1.5	28	71.6	15.5	27.3	20.0	7.3
AIB[2]	2.0	28	71.4	15.2	29.5	20.4	9.1
$CaCO_3$	0.5	28	71.7	15.9	28.2	22.5	5.7
Control	–	56	71.9	15.3	38.2	32.1	6.1

[1] On an as is basis.
[2] Corrected for nitrogen content of treatment.

the total nitrogen, SN and SNPN fractions of the AIB treated samples. The acetic acid contained in the Chem-Stor treatment was corrected in the same manner by subtracting the 0 day levels from the acetic acid values determined at the later time periods.

Trial 2.

Since urea is commonly added to high moisture corn, this trial was conducted to test the effects of urea on the SN and acid levels of ground high moisture corn. Urea was added at the 0.5 percent level to samples of corn which were treated with the same additives as in trial 1. The treatments in this study are listed in Table 3 and all samples were ensiled for 28 days. Again, SN, SNPN, SP, lactic acid, acetic acid and pH were determined. The AIB and Chem-Stor treatments were corrected for nitrogen and acetic acid respectively as in trial 1. The urea treated samples were corrected for urea nitrogen by subtracting the difference in nitrogen between the treatment without urea and the corresponding treatment with urea from the urea treated samples of high moisture corn.

Trial 3.

Whole high moisture shelled corn was treated with various levels of Chem-Stor, AIB and $CaCO_3$ as can be observed in Table 5. Samples of the shelled corn were stored in air-tight plastic bags for 0, 28 and 56 days. Solubilization of nitrogen and acid levels were determined as in the previous trials and again the AIB and Chem-Stor values reported were corrected.

Results and Discussion

Trial 1.

The dry matter content of the ground high moisture corn samples are reported in Table 1. The average dry matter content at 0 days ensiling was 73.8 percent and there appeared to be a general tendency for the moisture content to increase with time. $CaCO_3$, AIB and Chem-Stor did not seem to have an effect on dry matter content. Total nitrogen content varied considerably and it seems that the variability could not be attributed to ensiling time or additives.

SN levels did show a definite trend of increasing with storage time; the controls ranged from 15.8 percent of the total nitrogen at 0 days to 38.2 percent at 56 days of ensiling. It is possible that the high SN values associated with length of storage could mean a decrease in the intake of high moisture corn as has been suggested. In addition, numerous investigators have shown that proteins of high solubility may be less efficiently utilized by ruminants. The chemical preservatives (Chem-Stor and AIB) may have decreased the percentage of SN to a certain extent, however, more testing is needed to determine if these differences are real or if they are of large enough magnitude to alter animal performance.

The SNPN (Table 1) values generally reflect the same trend as the SN values; an increase occurred with time (7.3 and 32.1 for 0 and 56 days respectively for the controls) and again the chemical preservatives may have slightly decreased SNPN levels. It is of interest to note that on the average the SNPN represented approximately 70 percent of the soluble nitrogen regardless of time or additive. The $CaCO_3$ treatment appeared to show no difference from the control in any of the soluble nitrogen fractions. As can be observed in Table 1 the soluble protein content of the ground high moisture corn remained remarkably similar and no difference could be attributed to storage time. The results of trial 1, therefore, indicate that the solubilization of nitrogen observed in this study occurs in conjunction with a breakdown of protein to a non-protein form.

The levels of lactic and acetic acids produced and pH can be observed in Table 2. In general, the acid levels increased with time as could be expected. However, lactic acid production was almost completely absent in the Chem-Stor treatments. The Chem-Stor also inhibited acetic acid production but not to as great an extent. The AIB appeared to inhibit lactic and acetic acid levels slightly, while the $CaCO_3$ tended to increase acid production.

The Chem-Stor treated corn had an initial pH of 4.5 which inhibited bacterial growth considerably and consequently only low levels of lactic and acetic acid were produced. However, the high initial pH (6.8) and buffering action of the $CaCO_3$ treatment seemed to encourage acid production by providing a more stable environment for bacterial growth and thus greater levels of acids were produced. Although the Chem-Stor almost completely inhibited fermentation as indicated by low levels of acid production, the SN values (Table 1) changed very little. Thus, it appears that the solubilization of nitrogen is due to chemical and physical processes occurring in the high moisture corn during ensiling and not to bacterial fermentation.

Table 2. The Influence of Storage Time and Additives on the Lactic Acid, Acetic Acid and pH Levels of Ground High Moisture Corn.

Additive	Level[1]	Ensiling time	Lactic[2] acid	Acetic[2] acid	pH
	%	days	%	%	
Control	–	0	0.02	0.05	6.3
Chem-Stor[3]	1.5	0	0.01	0.05	4.5
AIB	2.0	0	0.01	0.14	5.9
$CaCO_3$	0.5	0	0.01	0.07	6.8
Control	–	2	0.44	–	5.1
Control	–	6	0.91	0.25	4.5
Chem-Stor[3]	1.5	6	0.00	0.00	4.4
AIB	2.0	6	0.32	0.18	5.3
$CaCO_3$	0.5	6	0.97	0.55	5.3
Control	–	12	0.75	0.24	4.4
Cheem-Stor[3]	1.5	12	0.04	0.50	4.4
AIB	2.0	12	0.92	0.24	4.7
$CaCO_3$	0.5	12	1.15	0.44	5.0
Control	–	21	1.14	–	4.3
Control	–	28	1.46	0.19	4.3
Cheem-Stor[3]	1.5	28	0.07	0.14	4.5
AIB	2.0	28	1.20	0.23	4.7
$CaCO_3$	0.5	28	1.78	0.53	4.7
Control	–	56	1.25	0.36	4.3

[1] On an as is basis.
[2] Percent per gm of dry matter.
[3] Corrected for acetic acid content of treatment.

Trial 2.

The effects of urea on the soluble nitrogen fractions of ground high moisture corn are reported in Table 3. There seems to be no definite trend in the SN content of the corn ensiled with urea. The addition of urea did tend to increase the SN content of the Chem-Stor and AIB treatments, however, this difference could be due to experimental error. The percentage of nitrogen in the SP fraction did seem to be affected to a greater extent with urea. In all cases the SP levels for the urea treated corn were greater than the corresponding treatment without urea. The reasons for this are not fully understood; however, since the solubility of protein is dependent to a certain extent on pH, the increase in pH caused by the urea addition could be a possible explanation for higher SP levels.

The levels of lactic and acetic acid production tended to be greater for the urea treated corn and again the explanation for this could be due to pH changes. The addition of urea most likely kept the pH in a range where bacteria fermentation could continue for a greater length of time.

Trial 3.

The influence of ensiling time and chemical preservations on the nitrogen fractions of whole shelled high moisture corn are reported in Table 5. The total nitrogen content of the whole corn appeared to be greater than the levels observed for the ground high moisture corn (Table 1), however, these differences could be due to the corn samples and not treatment effects. Although both samples were taken from the

Table 3. The Influence of Additives and Urea on the Soluble Nitrogen Content of Ground High Moisture Corn.

				Percent of Total Nitrogen		
Additive	Level[1]	Urea[1] Level	Total N	Soluble N	Soluble NPN	Soluble Protein
	%	%	mg			
Control	–	–	15.7	26.2	22.9	3.3
Control[2]	–	0.5	15.7	29.9	15.3	14.6
Chem-Stor	1.5	–	15.5	26.5	21.0	5.5
Chem-Stor[2]	1.5	0.5	15.5	31.3	24.2	7.1
AIB[3]	2.0	–	15.0	22.1	19.6	2.5
AIB[2,3]	2.0	0.5	15.0	24.7	20.1	4.6
$CaCO_3$	0.5	–	15.5	29.3	24.4	4.9
$CaCO_3$	0.5	0.5	15.5	21.7	14.7	7.0

[1] On an as is basis.
[2] Corrected for urea nitrogen.
[3] Corrected for nitrogen content of treatment.

Table 4. The Influence of Additives and Urea on the Lactic Acid, Acetic Acid and pH Levels of Ground High Moisture Corn.

Additive	Level[1]	Urea[1] time	Lactic[2] acid	Acetic[2] acid	pH
	%	%	%	%	
Control	–	–	1.26	0.19	4.2
Control	–	0.5	1.41	1.58	4.9
Chem-Stor[3]	1.5	–	0.03	0.20	4.4
Chem-Stor[3]	1.5	0.5	0.02	0.30	4.4
AIB	2.0	–	1.09	0.34	4.8
AIB	2.0	0.5	1.43	0.37	5.0
$CaCO_3$	0.5	–	1.71	0.44	4.5
$CaCO_3$	0.5	0.5	1.64	1.01	5.3

[1] On an as is basis.
[2] Percent per gm of dry matter.
[3] Corrected for acetic acid content of treatment.

Table 5. The Influence of Storage Time and Additives on the Soluble Nitrogen Content of Whole Shelled High Moisture Corn.

Additive	Level[1]	Ensiling Time	DM	Total N	Percent of Total Nitrogen		
					Soluble N	Soluble NPN	Soluble Protein
	%	Days	%	mg			
Control	–	0	76.0	16.8	11.3	7.9	3.4
Control	–	28	75.5	16.9	11.7	7.6	4.1
Chem-Stor	1.0	28	76.1	16.4	17.9	14.0	3.9
Chem-Stor	1.5	28	75.7	16.6	18.2	13.9	4.3
AIB[2]	1.0	28	75.7	16.4	11.2	7.4	3.8
AIB[2]	2.0	28	74.9	16.4	10.0	5.1	4.9
Control	–	56	74.2	16.8	14.8	11.1	3.7
Chem-Stor	1.0	56	75.7	16.9	17.3	14.2	3.1
Chem-Stor	1.5	56	76.2	16.6	21.7	16.0	5.7
AIB[2]	1.0	56	73.8	16.8	12.2	8.4	3.8
AIB[2]	2.0	56	74.8	16.4	14.0	11.2	2.8

[1] On an as is basis.

[2] Corrected for nitrogen content of treatment.

same pit at approximately the same time, corn was continually being brought in from different areas and this might be a more plausable explanation for the difference in nitrogen content.

The results of this trial (Table 5) indicate that considerably less nitrogen is in the soluble form at 28 and 56 days (11.7 and 14.8 respectively) in whole high moisture corn when compared to ground corn at the same time periods. The reason for this is not completely understood although it is possible that the grinding process could expose more substrate to enzymatic or chemical attack and thus cause an increase in the solubilization of corn protein. SNPN levels remained approximately the same percentage of the total soluble nitrogen (73 percent) as observed previously with ground corn (70 percent). SP levels seemed to remain fairly constant and were similar to the levels observed in the ground corn. Since the SNPN and SP values were of similar magnitude when expressed as a percentage of the SN fraction, it appears that the main difference between the whole and ground ensiled corn used in this study was the extent of total nitrogen solubilization.

The levels of acid produced, reported in Table 6, indicate that the fermentation process of corn ensiled whole is considerably slower than that of the ground high moisture corn (Table 2). The levels of lactic acid were low and remained essentially unchanged regardless of treatment. The acetic acid levels did increase at 56 days, especially for the AIB treatments, indicating that some bacterial fermentation is taking place. The pH of the control samples remained unchanged (6.1) at 0 and 28 days, however, at 56 days it dropped to 4.9.

Conclusion

High moisture storage of ground corn has increased the soluble nitrogen levels considerably and a large percntage of this nitrogen is in a non-protein form. The effects of this increase in nitrogen solubility on

Table 6. The Influence of Storage Time and Additive on the Lactic Acid, Acetic Acid and pH of High Moisture Corn Ensiled Whole

Additive	Level[1]	Ensiling time	Lactic[2] acid	Acetic[3] acid	pH
	%	days	%	%	
Control	–	0	0.02	0.16	6.1
Control	–	28	0.05	0.18	6.1
Chem-Stor[3]	1.0	28	0.00	0.00	4.7
Chem-Stor[3]	1.5	28	0.02	0.00	4.5
AIB	1.0	28	0.02	0.09	5.5
AIB	2.0	28	0.02	0.04	5.4
Control	–	56	0.05	0.68	4.9
Chem-Stor[3]	1.0	56	0.02	0.00	4.8
Chem-Stor[3]	1.5	56	0.02	0.00	4.6
AIB	1.0	56	0.02	1.92	5.6
AIB	2.0	56	0.02	1.60	5.8

[1] On an as is basis.
[2] Percent per gm of dry matter.
[3] Corrected for acetic acid content of treatment.

animal performance is open to question and further investigations should be conducted in this area.

The acid level of high moisture corn stored in the whole form indicate that the fermentation process is considerably slower. Technical difficulties involved in storing whole corn in a pit silo tend to indicate that a chemical preservation might be necessary to prevent spoilage.

Feedlot Performance and Carcass Merit of Calves From Hereford, Hereford x Holstein and Holstein Cows

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Story in Brief

Calves out of Hereford cows required the shortest feeding period, gained most rapidly and most efficiently, followed by calves out of Crossbreds.

Calves out of Hereford cows produced carcasses with more muscling, as indicated by more ribeye area per cut. carcass, and a higher conformation grade, while calves out of Holsteins produced heavier carcasses with less external and internal fat and produced more carcass weight per day of age. Calves out of Crossbreds and Holsteins were similar in marbling and carcass grade, and slightly superior to Herefords in these traits.

Calves out of Hereford cows were most profitable in the feedlot; calves out of Crossbred and Holstein cows were similar in profitability. Based on carcass value less feeding costs, calves out of Hereford cows had the highest value at weaning, followed by calves out of Crossbreds and Holsteins.

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