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EFFECT OF INOCULANTS ON HIGH MOISTURE CORN FERMENTATION CHARACTERISTICS AND CATTLE PERFORMANCE

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Summary

High moisture corn was ensiled untreated (treatment 1) or treated with one of three different inoculants (treatment 2 = lactobacillus; treatment 3 = lactobacillus + streptococcus; treatment 4 = lactobacillus + serratia), each at two moisture levels (27.2% and 22.4%). Inoculant effects on fermentation were moisture dependent. The pH, acetate concentrations and dry matter losses were generally lower and lactate concentrations higher due to inoculation at 27.2% moisture. Overall, treatment 3 was somewhat more effective than treatments 2 or 4. Inoculation effects were generally less at 22.4% moisture. Inoculant effects on soluble N were small and probably of little nutritional importance. Aerobic stability was decreased by inoculation and lower moisture. Inoculation did not positively affect daily gain, feed:gain, feed intake or carcass characteristics.

(Key Words: Corn, Grain, Inoculant, Fermentation, Cattle.)

Introduction

Much of the feed consumed by cattle in this country is ensiled. The fermentation process that occurs during ensiling produces large quantities of acid, particularly lactic acid, which in turn preserves the ensiled feed as long as oxygen is excluded. Some loss of nutrients during fermentation is unavoidable. However, losses are reduced in conditions where fermentation rates are increased and greater levels of lactic acid are produced. One successful approach to improving fermentation characteristics has been to inoculate feeds at the time of ensiling with microorganisms which promote lactic acid production. Most of the research evaluating inoculants has involved whole plant corn, sorghum and alfalfa silages. Little information is available on their effects on ensiled, high moisture corn grain. Effectiveness of inoculants with high moisture corn grain may be different due to form and availability of the fermentation substrate.

The objective of this study was to determine the effects of three microbial inoculants, lactobacillus[3], lactobacillus + streptococcus[4] and lactobacillus + serratia[4], on fermentation characteristics of ensiled, high moisture corn grain and the subsequent performance of yearling cattle finished on the treated corn.

Materials and Methods

Approximately 200 ton of high moisture corn were purchased locally and delivered during a 2-day period during harvest to the Southeast South Dakota Research Farm. The corn was coarsely cracked and ensiled in plastic silage bags at an average of 25 tons per bag. Four treatments were applied at the time of ensiling: treatment 1) control (no inoculant); treatment 2) lactobacillus; treatment 3) lactobacillus + streptococcus; treatment 4) lactobacillus + serratia. One bag of each treatment was ensiled each day and treatments were applied in liquid solution by way of a spray nozzle mounted on the discharge of the grinder and supplied at least 10^5 organisms per gram of corn. Moisture content of the corn was 27.2% on the first day but only 22.4% on the second.

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[3]Ecosyl® contains lactobacillus plantarum, ICI Americas Inc.
[4]Experimental inoculant of ICI Americas Inc.

Fermentation characteristics were determined on the unensiled high moisture corn as well as ensiled core samples taken at 1, 2, 7, 21 and 56 days postensiling. Composite samples were also taken during feedout from each bag and analyzed (>286 days postensiling).

The corn samples were analyzed for pH, acetic and lactic acids by gas-liquid chromatography and Burroughs buffer-soluble N. Acetic and lactic acid concentrations are expressed as a percent of dry matter as determined by Karl Fisher procedure (methanol extraction) in an effort to take into account differences in volatile compound content.

Inoculant effects on dry matter loss were determined by weighing 2.2 lb of high moisture corn after treatment into nylon bags which were tied closed and inserted into the middle of the plastic silage bags during filling. The nylon bags were recovered during feedout and the contents removed and weighed. Dry matter content of the corn before and after ensiling was determined by Karl Fisher procedure.

During feedout, triplicate 11-lb samples were taken from each bag to determine aerobic stability. In order to ensure that no prior deterioration had occurred, samples were taken approximately 2 feet behind the surface of the ensiled corn. These samples were placed in 5-gallon insulated buckets and a thermocouple was imbedded in the center of each sample. The thermocouples were attached to a multipoint recorder and temperatures were recorded hourly for 260 hours.

One hundred forty-four crossbred yearling steers were randomly allotted to treatment within weight block resulting in nine steers per pen and four pens per treatment. Initial and final weights were taken after an overnight removal of feed and water. Interim weights were taken approximately every 28 days after overnight removal of water only. The cattle were gradually adapted to a 90% concentrate diet over a period of 16 days. The diets are shown in Table 1. Treated corn containing 27.2% moisture was fed for the first 55 days on test. Treated corn containing 22.4% moisture was fed for the remainder of the study. Carcass data were collected 24 hours after slaughter.

TABLE 1. FEEDLOT DIET COMPOSITION (DRY MATTER BASIS)

Ingredient	1	2	3	4	5
			%		
High moisture corn		33.3	74.5	80.5	85.5
Rolled corn	53.6	33.2			
Alfalfa hay	38.0	28.0	21.0	15.0	10.0
Molasses	4.0	3.0	2.0	2.0	2.0
Supplement	4.4	2.5	2.5	2.5	2.5
<u>Analysis</u>					
Dry matter, %	85.6	80.7	75.3	74.6	74.1
Crude protein, %	13.8	13.0	12.4	11.9	11.5
Net energy, Mcal/cwt					
Maintenance	80.4	887.8	93.0	96.2	98.8
Gain	51.4	57.9	62.7	65.5	67.9
Calcium, %	.93	.74	.62	.53	.45
Phosphorus, %	.54	.30	.29	.30	.31
Potassium, %	1.45	.98	.81	.70	.60
Vitamin A, IU/lb DM	3295	2266	2266	2266	2266
Monensin, g/T DM	12.4	26.4	26.4	26.4	26.4

Fermentation data, aerobic stability and dry matter recovery were analyzed as a factorial with treatments, moisture content and time (for time series samples) as main effects. Dry matter intake, feed efficiency and carcass data were analyzed by the same procedures as a randomized block design. Average daily gain was analyzed as a complete random design using initial weight:height ratio as a covariate. When F tests were significant, means were separated by Duncan's multiple range test.

Results and Discussion

Fermentation characteristics were affected substantially by inoculation and moisture content as evidenced by the differences in pH, and acetate and lactate concentrations. Higher moisture resulted in lower pH ($P<.01$) and also affected the response to inoculation (Figure 1). Treatment 4 (27.2%) lagged behind and did not achieve a significant decrease in pH until 7 days postensiling and did not match the levels of treatments 2 and 3 until 21 days. There were no differences between inoculated treatments at 56 days when ensiled at 27.2% moisture but all were lower than treatment 1 ($P<.01$). In contrast, pH did not change through 56 days for control corn ensiled at 22.4% moisture ($P>.10$). Inoculation of the drier corn decreased pH for treatments 3 and 4 by 21 days and

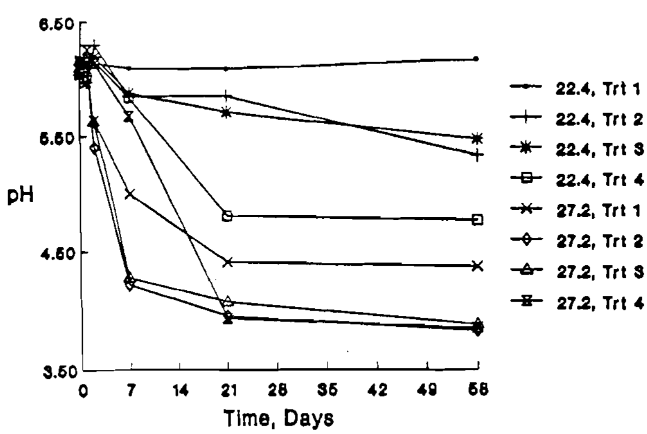

Figure 1. Effect of inoculant treatment on pH changes over time.

for treatment 2 by 56 days post-ensiling ($P<.01$). Treatment 4 resulted in the lowest pH at 56 days. The pH of the composite samples (>286 days) were higher ($P<.01$) than those at 56 days and varied little by treatment for the higher moisture corn. The pH was lower in most cases with higher moisture corn. Composite values reflect changes that occurred both during ensiling after 56 days and from exposure to air during feedout.

The changes in pH suggest a general improvement in fermentation due to inoculation. This is supported by changes in acetate and lactate concentrations as well; however, these were also moisture dependent. Acetate concentrations for treatments 3 and 4 at 27.2% moisture were lower than control from 7 days through 56 days postensiling ($P<.01$). Acetates at 56 days were .08, .07, .05 and .05% for treatments 1 through 4, respectively. At lower corn moisture content (22.4%), fermentation was apparently restricted to the extent that acetate levels did not change over time or by treatment through 56 days ($P>.10$) with the exception of treatment 4. Acetate concentrations of composite samples were generally higher than at 56 days ($P<.01$).

Lactate concentrations were inversely related to acetate concentrations and pH. Lactate increased over time ($P<.01$) and tended to increase more rapidly for inoculated corn (27.2% moisture) than control. This was most pronounced for treatments 2 and 3. Treatment 4 (27.2% moisture) lagged behind other treatments and did not achieve significant increases in lactate until 21 days postensiling ($P<.01$). Lactate concentration at 56 days was higher for treatment 3 than control (27.2% moisture), .92 and .62%. Lactate concentrations did not change with time or treatment at 22.4% moisture through 56 days ($P>.10$). Lactate increased significantly ($P<.01$) for the composite samples (>286 days) compared to 56 days, from .80 to 1.94% and .06 to .80% for 27.2% and 22.4% moisture, respectively. This increase indicates substantial fermentation even after 56 days ensiling.

Changes in Burroughs buffer soluble N as a percent of total N occurred due to treatment but were also moisture dependent. Soluble N increased over time at 27.2% moisture ($P<.01$) and was significantly higher for treatment 3 compared to control at 56 days, 32.74% and 24.68%. No differences were found by treatment or time at 22.4% moisture (P>.10) but overall were lower than soluble N levels at 27.2% (P<.01).

Dry matter (DM) losses are presented in Table 2. In all cases, DM losses were low, especially with 22.4% moisture corn, leaving little room for improvement. Nonetheless, they were reduced by over 2 percentage points by treatments 3 and 4 (P<.05) with 27.2% moisture corn. Lower moisture also resulted in smaller DM losses (P<.05). However, there were no differences among treatments with 22.4% moisture corn (P>.10).

TABLE 2. DRY MATTER LOSS OF UNINOCULATED AND INOCULATED HIGH MOISTURE CORN (% OF INITIAL DRY MATTER ENSILED IN NYLON BAGS)

Corn moisture	Treatment	Dry matter loss, %
27.2%	1	4.41[a]
	2	3.18[ab]
	3	2.06[bcd]
	4	2.40[bc]
22.4%	1	.41[d]
	2	.28[d]
	3	1.15[cd]
	4	.84[cd]

[a,b,c,d]P<.05.
Treatment x moisture interaction (P<.10).
SEM = .508.

Aerobic stability was characterized as degree x hours above air temperature as well as time until a sustained rise in temperature was achieved (Table 3). Onset of heating was substantially delayed only for treatment 1 with 27.2% moisture corn (P<.05). Extent of heating was inversely related to onset and was lowest for treatment 1 with 27.2% moisture corn (P<.05). Treatments 2 and 4 were intermediate while treatment 3 was highest (27.2% moisture). All treatments heated extensively with lower moisture.

Crossbred yearling steers were fed test diets differing only in high moisture corn treatment to determine effects on feedlot performance. The data are presented in Table 4. Final weights were lower for the steers fed treatment 4 (P<.10) compared to the others. This was due primarily to the lower average daily gain (ADG) of treatment 4 during the first 28 days (P<.10). No significant differences were found between treatments (P<.10) from day 1 through 55, the time in which 27.2% moisture corn was fed. Treatment 2 steers gained more rapidly during the final 29 days (P<.05) when 22.4% moisture corn was fed. For the entire study, steers fed treatment 4 had lower ADG than those fed the other treatments (P<.10).

Although ADG is in large part a reflection of feed consumption, daily feed dry matter intake (DMI) differed only during the first 28 days but not in a way that was directly related to gain. Treatment 3 had lower DMI (P<.05) than treatments 1, 2 or 4. As a result of differences in gain and intake, feed:gain ratio (F:G) was significantly poorer for treatment 4 (P<.10) for the first 55 days on test. During period 3, F:G was better for treatment 2 than treatments 1 and 4 (P<.10). For the entire study, treatment 4 had the poorest F:G (P<.10).

Carcass data were collected approximately 24 h after slaughter and are presented in Table 5. There were no differences between treatment groups with respect to carcass weight, fat thickness, rib eye area, kidney fat, quality or yield grade (P>.10). Dressing percent was significantly lower (P<.05) for treatment 3 than treatments 1 and 4.

Differences in pH, acetate and lactate concentrations between treatments indicate that inoculation generally improved fermentation characteristics (i.e., lower pH and acetate, higher lactate) in spite of the acceptable ensiling achieved with the uninoculated corn. The magnitude of the response was moisture dependent, however. The moisture content of the corn ensiled on the first day was 27.2% providing ideal conditions for ensiling. Moisture content was only 22.4% on the second day. This was outside the generally recommended range of 25 to 30% and fermentation was apparently restricted. Rate and extent of fermentation were increased markedly through days 56 due to inoculation at the high moisture level, but the response was greatly reduced with lower moisture. The pH and acetate and lactate concentrations were related to dry matter loss (r = .66, .89 and -.64 at 56 days, respectively). Overall, treatment 3 (lactobacillus +

streptococcus) appears to have had a somewhat greater effect than the other inoculants since it resulted in more rapid fermentation than 4 and a significant decrease in DM loss not achieved by 2.

Changes in fermentation are likely to affect animal performance through DMI. Aerobic stability (degree x hours) was most closely related to DMI (r = -.66) but only during the first 28 days. This was likely due to the low feedout rates while the grain intake of the steers was being increased. Aerobic stability had a negative correlation to DM loss (r = -.55 across moisture levels, r = -.80 within 27.2% moisture) which points to a potential problem in trying to reduce DM losses while also improving storage characteristics and bunk life.

Although soluble N percent was affected by treatment and moisture, these differences were relatively small and probably not of nutritional importance for the steers fed in this study. The requirements for rumen undegradable protein for feedlot cattle are not well defined but are probably less than 50 to 60% of the total dietary protein. Even with the greatest degradability assumed from the soluble N data, these diets would still have likely provided adequate levels of undegradable protein.

Unintended variability in moisture content of the ensiled corn presented difficulties for the cattle feeding study that could not be dealt with through statistical analysis. Factorializing the analyses as with the fermentation data would have required additional pens not available and lower feedout rates with fewer cattle per treatment. It was decided instead to feed the 27.2% moisture corn during the first 55 days and feed the 22.4% moisture corn for the remainder of the trial. This allowed treatments to be compared within moisture level by period and also for the entire study by ignoring moisture differences. While the latter approach is not ideal, it is nonetheless a frequent occurrence in commercial cattle feeding.

In general, inoculation had little effect on performance of the steers during the first 55 days or over the entire trial. The only noteworthy exceptions were associated with treatment 4 and its lower ADG and poorer F:G. No explanation for this is obvious from the data and does not seem to be consistent across periods. It may perhaps be related to the slower fermentation rate for treatment 4 compared to treatments 1, 2 or 3 (27.2% moisture), but this is only speculation. Carcass characteristics were also not affected by treatment with the exception of dressing percent for treatment 3. This difference occurred in spite of the fact that degree of finish (fat thickness, KPH %, yield and quality grades) was similar among treatments. Other factors such as differences in gut fill and mud are unlikely but can not be ruled out.

In conclusion, the inoculants used in this study did positively affect fermentation and reduced dry matter loss during ensiling when moisture levels were adequate. Treatment 3 (lactobacillus + streptococcus) showed somewhat greater effect than the other treatments. Improvements in fermentation were negatively correlated with aerobic stability and this may present an obstacle to improving both simultaneously. The changes in fermentation were not generally related to differences in feedlot performance.

TABLE 3. AEROBIC STABILITY OF UNINOCULATED AND INOCULATED HIGH MOISTURE CORN

Corn moisture	Treatment	Degree x hours above air temperature[a]	Time to first significant temperature rise, hours[b]
27.2%	1	1065[c]	205.0[d]
	2	2960[e]	37.7[e]
	3	4948[d]	14.3[e]
	4	3324[e]	19.0[e]
22.4%	1	3685[de]	3.0[e]
	2	3429[e]	60.3[e]
	3	3476[e]	66.7[e]
	4	3696[de]	35.7[e]

[a] Cumulative degree x hours above air temperature determined over 260 hours. Treatment x moisture interaction significant ($P<.01$). SEM = 410.36.

[b] Determined as the point in time at which corn temperature increased and remained ≥9° F above air temperature. Standard deviation of air temperature = 4.4° F. Treatment x moisture interaction significant ($P<.01$). SEM = 22.36.

[c,d,e] $P<.05$.

TABLE 4. PERFORMANCE OF STEERS FED UNINOCULATED OR INOCULATED HIGH MOISTURE CORN[a]

	Treatment				
Item	1	2	3	4	SEM
Initial weight, lb	848	845	852	846	3.6
Final weight, lb	1116^{de}	1120^{d}	1117^{de}	1097^{e}	7.3
Average daily gain, lb					
1 to 28 days	2.77^{d}	2.68^{de}	2.64^{de}	2.34^{e}	.129
29 to 55 days	4.77	4.50	4.69	4.57	.140
56 to 84 days	2.12^{c}	2.70^{b}	2.32^{c}	2.15^{c}	.116
1 to 55 days	3.75	3.57	3.63	3.43	.099
1 to 84 days	3.19^{de}	3.27^{d}	3.18^{de}	2.99^{e}	.079
Dry matter intake, lb					
1 to 28 days	17.1^{c}	16.9^{c}	16.6^{b}	17.0^{c}	.12
29 to 55 days	21.7	21.8	20.9	22.4	.50
56 to 84 days	21.3	21.3	21.3	21.4	.22
1 to 55 days	19.4	19.3	18.7	19.6	.29
1 to 84 days	20.0	20.0	19.6	20.3	.27
Feed/gain					
1 to 28 days	6.27	6.35	6.41	7.30	.485
29 to 55 days	4.59	4.85	4.49	4.93	.142
56 to 84 days	10.14b	7.88^{c}	9.24^{bc}	10.04^{b}	.510
1 to 55 days	5.18^{e}	5.41^{de}	5.15^{e}	5.73^{d}	.156
1 to 84 days	7.06^{de}	6.40^{e}	6.77^{de}	7.49^{d}	.278

[a] Diets during the first 55 days on test contained 27.2% moisture corn. 22.4% moisture corn was used from 56 to 84 days.

[b,c] $P<.05$.

[d,e] $P<.01$.

TABLE 5. CARCASS DATA FOR STEERS FED UNINOCULATED AND INOCULATED HIGH MOISTURE CORN

	Treatment				
Item	1	2	3	4	SEM
Carcass weight, lb	703	701	698	695	5.1
Dressing percent	63.1[a]	62.7[ab]	62.4[b]	63.4[a]	.23
Fat thickness, in.	.56	.52	.59	.54	.022
Rib eye area, in^2	12.62	12.61	12.36	12.12	.120
KPH fat, %	2.2	2.3	2.2	2.3	.06
Quality grade[c]	10.22	10.20	10.56	10.56	.211
Yield grade	2.96	2.89	3.10	3.08	.102

[a,b] $P<.05$.
[c] 10 = high select; 11 = low choice.