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SILAGE MANAGEMENT - THE KEY TO QUALITY CORN SILAGE

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Corn harvested for silage in 1982 was about 22% of the total acres planted in South Dakota for all purposes. Over 4.3 million tons of corn forage were ensiled for a state average of 5.8 tons per acre. Statistics such as these emphasize the role of corn silage as a feedstuff for the livestock producer. The data also suggest the need for extensive management in silage making and an awareness of commercial silage additives available for use.

The preservation of crops by ensiling is a popular way of handling crops such as small grains, corn, sorghum or alfalfa grasses. The preservation process is chemical in nature and utilizes processes similar to those employed by the wine and cheese industry. Understanding the chemical changes that occur during fermentation will be helpful to the beef cattleman. In addition, certain management factors are also suggested to aid and promote optimum chemical reactions in silage making.

The purpose of this discussion is to review the process of making silage and re-emphasize those management decisions which if practiced will lead to making quality silage. The use of silage additives continues to be an item of consideration in today's silage management program. Some of the additives under investigation at the South Dakota Agricultural Experiment Station will be discussed here at least where results are currently available. Research from other experiment stations will also be presented.

What Happens in the Silo

The events that occur in silage fermentation begin immediately after silo filling.

Day 1 - Plant respiration phase. As the silo is being filled, oxygen becomes entrapped in the forage. Metabolism (enzyme activity) within plant cells and the activity of microorganisms present on the forage proceed until the oxygen is used up with the production of heat.

Day 2 - Transition phase. Plant respiration stops but enzymatic activity of plant cells continues. Anaerobic (without air) microbial activity begins and the fermentation starts to speed up with the formation of lactic acid in the silage mass.

Day 3 - Fermentation on the third day is characterized by increased enzyme activity and increased fermentative activity of the anaerobic bacteria. Lactic, acetic and propionic acids are formed and the pickling process is initiated. The pH (acidity or alkalinity) of the silage begins to decrease or become acid.

Day 4 through day 20. All fermentative activities continue until the acidification process is complete. At this time, the pH is about 4.0 to 4.5. The silage then enters a stable phase and can be stored indefinitely if left undisturbed. If the silage becomes disturbed, oxygen may be introduced and undesirable bacteria increase and molds will develop. This leads to the formation of butyric acid and a rise in pH. Proteins become denatured and the overall result will be a loss of nutrients from the silage.

Management - The Key to Quality Corn Silage

There are at least five important management practices that should be followed in making quality silage. They are:

1. Ensile at the proper stage of maturity and moisture content. These two factors often go hand in hand. Under ideal conditions, the harvest of corn forage should begin when the corn is in the dent stage. Moisture content should be in the range of 63 to 68%. Harvesting at this stage of plant maturity will result in maximum dry matter yields per acre. Often, the "black layer" test is used as an indicator of maturity. However, moisture content of the whole plant may be lower than desirable by the time this layer is first observed. Kernel moisture in the range of 32 to 38% is also an indicator of desired maturity.

2. Length of cut. The field chopper should be equipped with sharp knives and the knives need to be in proper adjustment with the shear bar. A theoretical chop of 1/4- to 1/2-inch length is most commonly recommended. However, the choice will vary with the crop, the power available and the rate of chopping. Corn forage chopped too coarse will allow too much air to become entrapped as it is stored. Cattle will also refuse more of coarsely chopped than finely chopped silage. Fine uniform chopping will increase the density of the silage with better packing and result in a more uniform feed at feed out. Chopping finer than 1/4 inch may cause seepage and can also create handling problems during feeding.

3. Packing and filling the silo. After the forage is cut, exposure to the air should be kept to a minimum. It is necessary to build a substantial height of ensilage in the silo in order to press the air from the mass. Compaction of the upper layer is difficult to achieve unless the silo is filled continually. If filling is intermittent or delayed over several days, the upper layer from each filling will produce heat, increase mold and yeast growth and cause spoiling to occur.

4. Distribute evenly in the silo. Even distribution of forage in the silo during filling is highly recommended. This is done to avoid separation of lighter from heavier weight particles during the blowing process. Improper distribution can also cause a build-up of ensilage on one side of upright silos. The lighter weight material tends to settle out next to the wall. This practice results in poor packing and easy air penetration, both of which can lead to spoilage.

5. Seal or cover silo. It is important that the silo filling job be properly finished. There are several things that can be done at the end of silo filling to help with the handling and keeping qualities of the silage. Try to place some wetter silage, if available, at the top of the silo to supply extra weight for compaction. Forage stored in tower silos should be leveled on the top and compacted to remove air.

There are some special management practices for making quality silage in pits, piles or bunkers. Packing is a most important practice with these types of storage. With bunker silos and piles, continuous packing with a wheel-type tractor during filling and for a few days after filling is recommended. Moisture content of forage for bunker silos should be somewhat higher than upright silos (65 to 72%). A bunker should be covered with a plastic cover and weighted down with tires or any suitable heavy material. Piles of silage should also be covered with plastic with the edges and ends of the cover sealed with a layer of soil.

Which Silage Additive?

Many attempts have been made to alter, assist or even replace some of the chemical reactions involved in the formation of silage by use of additives. A large number of commercial additives are available. These can be classified into three categories according to how they function in silage formation. Additives are classified as being nutritive, nonnutritive or fermentation inhibitors.

Nutrient additives include those added to the forage to contribute something to the fermentation and enhance the nutritive quality of the silage. They include molasses, grains, dried beet and citrus pulp, whey, limestone, urea and nonprotein nitrogen products such as anhydrous ammonia or ammonia suspensions.

Nonnutritive additives are perhaps better referred to as "aids to fermentation." These compounds are added to the forage at ensiling and function to alter the rate or enhance the fermentation such that a higher proportion of one or more nutrients is retained in the silage dry matter. These products include bacterial and yeast cultures, enzymes, flavors and antioxidants.

A third general type of additive includes compounds which inhibit the natural microbial fermentation of silage. Many products of this group lower the pH and create poor conditions for microbial growth. These include the strong mineral acids (hydrochloric, sulfuric and phosphoric), acetic and propionic acid, formic acid and formaldehyde and various antibiotics.

Selection of an additive belonging to one of these different groups should be based upon what is to be accomplished in a silage program and the results of scientific investigations. Farmers should insist on seeing reliable research data as to whether the product reduces losses from fermentation or improves the nutrient quality of the silage as compared to untreated silage harvested and stored under the same conditions. Additives should not be expected to replace good management practices in producing top quality silage.

Silage Additives - What to Look For

There are a number of silage additives commercially available on the market. Not all additives function in the same manner so it is very important that the product be adequately researched. The following questions should be considered: Does the additive (1) provide a nutrient such as energy or nitrogen or aid the fermentation process in such a way as to enhance the feeding value of the silage, (2) reduce spoilage and dry matter losses, (3) present problems in handling and in application and (4) require special equipment to apply it at the recommended rate? It is important that the benefits of a silage additive offset the cost of the product as well as any costs for special equipment that may be needed.

Results of Some Silage Additive Studies

Microbial Inoculants

Several experiments have been conducted at the South Dakota Agricultural Experiment Station using either experimental silos or upright stave silos. Comparisons of untreated corn forage and forage inoculated with Lactobacillus acidophilus or Lactobacillus plantarum involved measurements of fermentation characteristics, quality, preservation, digestibility and feedlot performance. Portions of these data are presented here. Full length articles are published elsewhere (see Literature Cited).

Low heat production and generous acid formation during fermentation are desirable characteristics of silage formation. Ensiling temperatures of corn silage are shown in figure 1. Temperatures of untreated silage were higher throughout a 30-day observation period than temperatures of forage inoculated with Lactobillus acidophilus. Lactic acid formation (figure 2) and production of organic acids (figure 3) were also higher for inoculated forage than untreated forage on most days of the 30-day observation period. The chemical

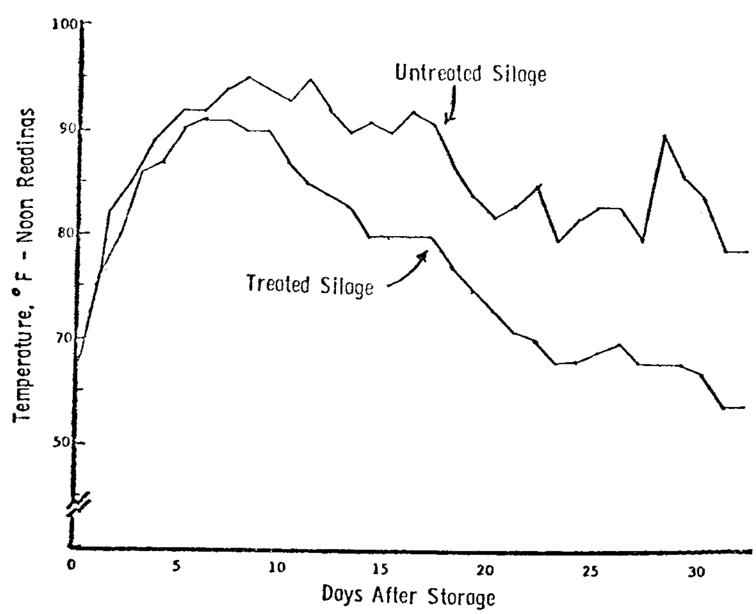

Figure 1. Fermentation Temperatures for Untreated and Treated Corn Silage

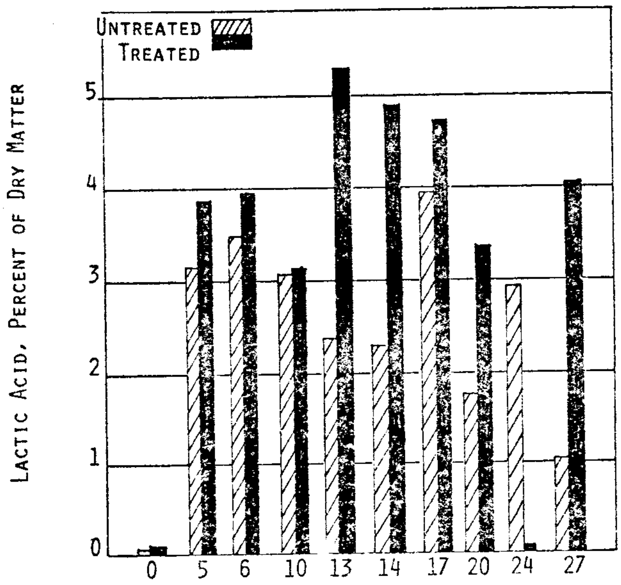

FIGURE 2. LACTIC ACID IN UNTREATED AND TREATED CORN SILAGE

TOTAL VFA CONTENT OF UNTREATED AND TREATED CORN SILAGE

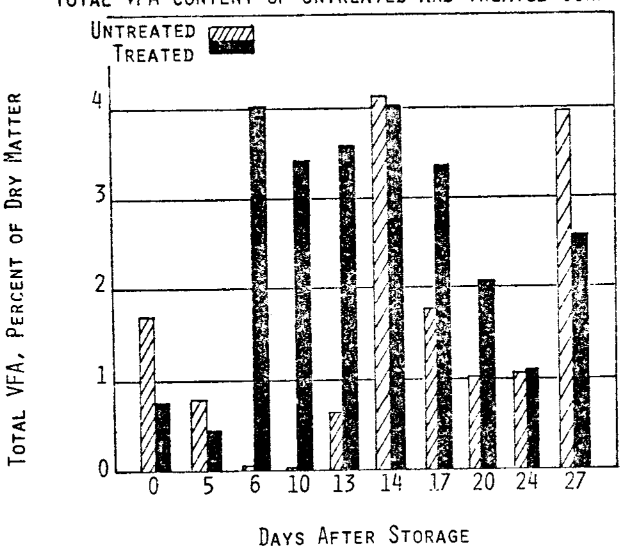

FIGURE 3. TOTAL VFA CONTENT OF UNTREATED AND TREATED CORN SILAGE

profiles for the two silages as they were removed from the silos for feeding are shown in table 1. Titratable acidity and lactic and volatile fatty acid concentrations were higher in treated than in untreated silage. Slightly more acetic acid was present in the treated silage. Differences between the two silages were not as prominent with regard to lactic and volatile acid content as those observed during the fermentation period. Nutrient digestibility and nitrogen retention values are shown in table 2. Utilization, in terms of digestibility, was about the same for the two silages. Steers fed the untreated silage retained slightly more nitrogen than steers fed the treated silage.

Table 1. Chemical Profiles of Corn Forage and Silage for Feeding as Affected by Bacterial Inoculation[a]

	Silage for feeding	
	Untreated	Treated
Dry matter, %[b]	36.86	35.17
pH	4.38	4.61
Titratable acidity[c]	6.42	8.27
Percent of dry matter		
Ash	4.84	5.53
Crude protein	8.79	8.39
Lactic acid	3.15	3.59
Volatile fatty acids		
Acetic	.95	1.35
Propionic	.57	.68
Butyric	.13	.01
Total	1.65	2.04

[a]Inoculated with Lactobacillus acidophilus fermentation product at rate of 1 lb. per ton of forage.
[b]Toluene distillation.
[c]Milliliters of .1N KOH to raise pH to 7.

Table 2. Digestibility and Nitrogen Retention With Beef Steers Fed Untreated and Microbial Inoculated Corn Silage.

	Untreated	Treated[a]
Number of steers	6	6
Avg. wt., kg	285	285
Avg. daily dry matter intake, kg	5.54	5.62
Avg. daily nitrogen intake, g	118.04	113.50
Digestibility, %		
Dry matter	69.45	68.83
Crude protein	68.06	67.72
Organic matter	71.17	70.65
Nitrogen balance, grams/day		
Fecal	37.2	36.8
Urinary	43.2	44.4
Retained	35.8	32.7
Percent retained of consumed	30.6	28.4

[a]Inoculated with Lactobacillus acidophilus fermentation product at rate of 1 lb. per ton of forage.

Feedlot performance of beef steers fed untreated or microbial-inoculated silage was compared in two experiments. A summary of these trials is presented in table 3. The dry matter content of the silages fed in experiment I was considerably higher (58%) than would be recommended. In experiment II, the silage dry matter was in the normal range of 38%. Average daily feed consumption, rate of gain and feed efficiency were about the same for steers fed untreated and inoculated silage in each of the trials.

TABLE 3. UNTREATED AND MICROBIAL INOCULATED CORN SILAGE FOR FEEDLOT STEERS. SDSU 1981, 1982

	UNTREATED	INOCULATED
EXPERIMENT I[A]		
AVG. INITIAL WT., LB.	775	775
AVG. DAILY GAIN, LB.	2.37	2.34
AVG. DAILY FEED, LB. (DRY BASIS)	24.6	24.0
FEED/100 LB. GAIN, LB.	1040	1020
EXPERIMENT II[B]		
AVG. INITIAL WT., LB.	521	521
AVG. DAILY GAIN, LB.	2.28	2.29
AVG. DAILY FEED, LB. (DRY BASIS)	14.3	14.4
FEED/100 LB. GAIN, LB.	634	630

[A] STEERS PER TREATMENT = 28; FEEDING PERIOD = 125 DAYS; SILAGE INOCULATED WITH LACBACILLUS ACIDOPHILUS FERMENTATION PRODUCT AT RATE OF 1 LB. PER TON OF FORAGE; RATION = 80% CORN SILAGE, 20% SUPPLEMENT.

[B] STEERS PER TREATMENT = 96; FEEDING PERIOD = 105 DAYS; SILAGE INOCULATED WITH LACTOBACILLUS PLANTARUM FERMENTATION PRODUCT AT RATE OF 1 LB. PER TON OF FORAGE; RATION = 80% CORN SILAGE, 20% SUPPLEMENT.

Recovery of dry matter for untreated and microbial-inoculated corn silage is shown in table 4. The trends in dry matter recovery in three experiments were small but consistently higher for the silage treated with a microbial additive. The average recovery values for three trials were 89.23 and 90.74% for untreated and treated, respectively.

TABLE 4. PRESERVATION OF DRY MATTER IN UNTREATED AND INOCULATED CORN SILAGE. SDSU 1979, 1980, 1981

PERCENT OF DRY MATTER ENSILED:	UNTREATED %	INOCULATED %
EXPERIMENT I[1]		
RECOVERED AS FEED	82.94	84.17
RECOVERED AS SPOILAGE	10.21	10.02
NONRECOVERED	6.85	5.81
EXPERIMENT II[2]		
RECOVERED AS FEED	94.03	94.72
RECOVERED AS SPOILAGE	0.42	1.18
NONRECOVERED	5.55	4.10
EXPERIMENT III[3]		
RECOVERED AS FEED	90.72	93.32
RECOVERED AS SPOILAGE	NONE	NONE
NONRECOVERED	9.28	6.68

[A] FORAGE DRY MATTER, 38%; LACTOBACILLUS ACIDOPHILUS FERMENTATION PRODUCT APPLIED AT 1 LB. PER TON.

[B] FORAGE DRY MATTER, 58%; LACTOBACILLUS ACIDOPHILUS FERMENTATION PRODUCT APPLIED AT 1 LB. PER TON.

[C] FORAGE DRY MATTER, 38%; LACTOBACILLUS PLANTARUM FERMENTATION PRODUCT APPLIED AT 1 LB. PER TON.

Similar feedlot performance and preservation data were reported by workers at the Kansas Agricultural Experiment Station[1]. These workers recovered about the same proportions of inoculated silage (91.7%) and untreated silage (88.7%). Formation of lactic and volatile acids was also similar for the two silages.

Other Silage Additives

Three additives were studied in an experiment with lambs. Sila-Bac[2], Pro-Sil[3] and organic acids[4] were added to corn forage at ensiling. Silage quality profiles and nutrient digestibility of the silages are shown in table 5. Addition of a microbial inoculant had little effect on the chemical

TABLE 5. CORN SILAGE QUALITY AND UTILIZATION BY LAMBS SDSU, 1981

	UNTREATED	SILA-BAC[A]	PRO-SIL[B]	ORGANIC ACIDS[C]
PH	4.03	4.06	4.49	4.44
TITRATABLE ACIDITY[D]	11.9	10.1	9.6	9.1
AMMONIA NITROGEN[E]	3.6	3.8	28.8	6.6
LACTIC ACID[F]	3.7	3.4	4.5	0.4
TOTAL ORGANIC ACIDS[F]	2.3	1.9	2.0	2.7
DIGESTIBILITY OF:				
DRY MATTER, %	73.18	71.52	68.77	70.35
CRUDE PROTEIN, %	69.95	66.17	65.34	65.77
NITROGEN RETAINED[G]	36.9	35.4	30.2	37.6

[A] LACTOBACILLUS ACIDOPHILUS FERMENTATION PRODUCT, 1 LB./TON.

[B] APPLIED AT RATE OF 6.43% OF FORAGE DRY MATTER.

[C] 80% PROPIONIC-20% ACETIC ACID MIX APPLIED AT RATE OF 20 LB./TON.

[D] MILLILITERS .1N KOH TO RAISE PH TO 7.

[E] PERCENT OF TOTAL NITROGEN.

[F] PERCENT OF DRY MATTER.

[G] AS % OF NITROGEN CONSUMED.

characteristics of the silage or the utilization of dry matter and nitrogen in the silage. Ammonia nitrogen was higher in silage which had been treated with an ammonia-containing compound. This silage treatment resulted in higher lactic acid with reduced dry matter and crude protein digestibility and markedly lower nitrogen retention as compared to untreated silage. Silage treated with a fermentation inhibitor (organic acids) resulted in ammonia nitrogen concentrations that were higher and the near absence of lactic acid as compared to untreated silage. Nutrient digestibility was reduced with this additive. However, slightly more nitrogen was retained as compared to the untreated silage.

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[1] Bolsen, K. 1979. Kansas Agr. Exp. Sta. Progress Report.

[2] Lactobacillus acidophilus fermentation product, Microbial Products Division, Pioneer Hi-Bred International, Durant, Iowa.

[3] Ammonia-molasses-mineral suspension, Pro-Sil Division, Terra Chemicals International, Sioux City, Iowa.

[4] 80% propionic acid, 20% acetic acid.

Research results from the Kansas Station with an enzyme and ammonia-nitrogen additions to corn forage are presented in table 6. Feedlot performance, silage quality and feed bunk stability were about the same for enzyme-treated silage as for untreated silage. Addition of anhydrous ammonia to corn silage tended to lower steer gains and increase feed requirements. Protein content of the silage increased from 8.6 to 11.2%. The concentration of ammonia nitrogen in the silage at feeding was also higher as was the concentration of lactic acid. Addition of anhydrous ammonia significantly improved bunk life of the silage after 9 and 28 days.

The effect of silage additives on dry matter recovery is now becoming known. Table 7 shows a summary of five trials where several kinds of additives were compared. Many of the additives resulted in increased dry matter recovery. However, the savings amounted to only 2 to 3 percentage units.

TABLE 6. ENZYME AND NITROGEN TREATMENT OF CORN SILAGE[A] (20 STEERS/TREATMENT, 78-DAY TRIAL)

	UNTREATED	ENZYME[B]	NITROGEN[C]
AVG. DAILY FEED, LB.	18.9	19.7	19.3
AVG. DAILY GAIN, LB.	2.46	2.50	2.38
FEED/LB. GAIN, LB.	7.72	7.95	8.10
PH	3.60	3.73	4.00
AMMONIA NITROGEN[D]	4.97	4.14	37.26
CRUDE PROTEIN[E]	8.6	8.1	11.2
LACTIC ACID[E]	3.1	2.9	4.4
TOTAL VOLATILE ACIDS[E]	1.64	1.30	1.98
BUNK LIFE - LOSS OF DRY MATTER, %			
9 DAYS	4.9	7.2	<1.0
28 DAYS	29.5	31.6	2.3

[A] BOLSEN AND ILG. 1981. CATTLEMEN'S DAY '81. KANSAS AGR. EXP. STA., PP. 59-64.

[B] ENSILA PLUS[R] .19 LB./TON; PRODUCED BY AGRIMERICA, INC.

[C] COLD-FLOW[R] 9.1 LB./TON; PRODUCED BY USS AGRI-CHEMICALS DIVISION OF UNITED STATES STEEL.

[D] PERCENT OF TOTAL NITROGEN.

[E] PERCENT OF DRY MATTER.

TABLE 7. DRY MATTER RECOVERY OF CONTROL AND ADDITIVE CORN SILAGES IN 5 TRIALS[A]

TREATMENTS	RECOVERY OF FEEDABLE DRY MATTER, %
CONTROL	80.9
SILO-BEST[R]	87.5
CONTROL	87.4
SILO GUARD[R]	93.7
CONTROL	88.7
COLD-FLO[R]	91.5
SILA-BAC[R]	91.7
SILO BEST[R]	91.3
CONTROL	93.3
COLD FLO	88.5
ENSILA PLUS[R]	94.1
CONTROL	87.3
SILO BEST	88.7
SILA-FERM[R]	87.4
AVERAGE OF 5 TRIALS: CONTROL	87.5
ADDITIVE	90.5

[A] BOLSEN. 1982. CATTLEMEN'S DAY '82. KANSAS AGR. EXP. STA., P. 16.

Corn Stover Silage

Cornstalks may be harvested following removal of corn grain and fed as chopped forage or ensiled. These residues make suitable feeds for growing animals, brood cows and ewes when properly supplemented. Research is limited with regard to the effect of silage additives on low quality forages such as corn stover. Three additives were compared in a study of stover silage quality and utilization by lambs. These results are shown in table 8. Acceptable silage formation was observed in this trial as indicated by pH values and formation of lactic acid and volatile fatty acids. Stover silage treated with organic acids resulted in slightly higher ammonia nitrogen levels.

TABLE 8. CORN STOVER SILAGE QUALITY AND UTILIZATION BY LAMBS. SDSU, 1981

	UNTREATED	SILO-BAC[A]	PRO-SIL[B]	ORGANIC ACIDS[C]
PH	4.21	4.52	4.88	4.45
TITRATABLE ACIDITY[D]	7.2	4.8	5.6	8.4
AMMONIA NITROGEN[E]	0.15	0.15	1.01	0.82
LACTIC ACID[F]	2.13	2.06	2.19	0.46
TOTAL VOLATILE ACIDS[F]	3.19	3.32	3.53	4.90
DIGESTIBILITY OF:				
DRY MATTER	70.81	71.34	0[H]	68.45
CRUDE PROTEIN	79.32	78.02	0[H]	76.40
NITROGEN RETAINED[G]	35.3	30.1	0[H]	35.3

[A-G] SEE TABLE 5.

[H] DATA OMITTED BECAUSE OF LOW PROTEIN INTAKE OF LAMBS WITH THIS TREATMENT.

However, level of lactic acid was markedly lowered with this treatment. Dry matter and crude protein digestibility were about the same for the silage treated with microbes. This additive lowered the percentage of nitrogen retained as compared to the control. Nutrient digestibility was lowered with the silage treated with organic acids as compared to untreated silage. However, nitrogen retention values were the same.

A second corn residue experiment was conducted utilizing beef steers. Cornstalks were harvested and processed as stacks or chopped forage which was ensiled in a bunker silo. The data are presented in table 9. Silage quality was similar to that observed in the previous trial. In the feeding trial, steers fed the stover stacks consumed more dry matter, but the gains were about the same as for steers fed the stover silage. Digestibility of dry matter and crude protein was also about the same for the two forages. Steers

TABLE 9. CORN STOVER SILAGE VS. CORN STOVER STACKS FOR GROWING BEEF STEERS[A]. SDSU, 1981

	CORN STOVER SILAGE	CORN STOVER STACKS
DRY MATTER, %	47.0	73.6
CRUDE PROTEIN, %	4.8	4.4
PH	4.51	---
TITRATABLE ACIDITY[B]	6.20	---
LACTIC ACID[C]	2.13	---
TOTAL VOLATILE ACIDS[C]	2.73	---
AVG. DAILY RATION, LB. (DRY)[D]	13.2	15.3
AVG. DAILY GAIN, LB.	.76	.81
FEED/LB. GAIN, LB.	17.5	19.4
DIGESTIBILITY OF:		
DRY MATTER, %	57.48	56.60
CRUDE PROTEIN, %	59.89	60.66
NITROGEN RETAINED[E]	19.3	21.7

[A] THIRTY-SIX STEERS/TREATMENT. 101-DAY TRIAL.

[B] MILLILITERS .1N KOH TO RAISE PH TO 7.

[C] PERCENT OF DRY MATTER.

[D] APPROXIMATELY 50% SILAGE OR STOVER-50% ALFALFA DRY BASIS.

[E] PERCENT OF NITROGEN CONSUMED.

fed the stover stacks retained slightly more nitrogen than steers fed the stover silage. Feedable dry matter was not determined for either forage. There was considerable spoilage in the upper layers of the bunker silage. Stover stacks accumulated moisture during storage with some evidence of molding.

Summary

The discussion of silage making and factors affecting silage quality includes the following points:

1. The events that occur in the silo after filling take the form of complex chemical reactions involving the microorganisms on the plant and in the chopped plant material.

2. Key management practices are recommended to aid in making quality silage.

3. Selection of additives from the different classes should be based on reliable controlled research data.

4. Silage treated with a microbial additive lowered heat production and increased lactic and volatile acid production during fermentation. These benefits did not carry over to feeding and did not improve the digestibility of nutrients or nitrogen retention by cattle or sheep. Feedlot performance by cattle in two trials was about the same when feeding treated or untreated silage.

5. Addition of ammonia-containing compounds to corn forage increased lactic acid formation and ammonia levels in the silage. Dry matter and protein digestibility were reduced with ammonia treatment. Stability in the feed bunk was greatly improved with anhydrous ammonia.

6. Preservation of dry matter was reported with different silage additives. An average of five experiments indicates dry matter recovery of 87.5% for untreated silage compared to 90.5% for silage treated with an additive.

7. Corn stover forage can be harvested and fed as dry stacks or ensiled. Acceptable silage quality was obtained with ensiled stover. Feedlot performance was about the same with steers fed stover silage as with steers fed corn stover stacks. Management in harvesting and storage of corn crop residues and handling these materials during feeding needs to be well planned.

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