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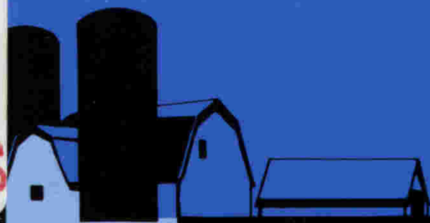

Selected Additives to Corn Silage and Their Effect on Ensiling Losses, Digestibility, and Cattle Feedlot Performance

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ABSTRACT

Eight upright brick silos, each with the capacity of about 10 tons of silage, were used to study the effect of addition of selected silage aids to corn silage on dry matter recovery, nutrient content, digestibility, and the performance of Angus feeder heifers fed these silages. There were four types of experimental silages, with a total of five silos per experimental treatment over three successive years, except for the Crop Cure treatment in which one silo was lost due to rat infestation. The four experimental treatments were: (1) an untreated corn silage, which served as the control; (2) Silabac-treated corn silage (Silabac is a commercial inoculant described by its manufacturer as a "live" lactic acid-producing bacterium.); (3) Culbac-treated corn silage (Culbac is a dead lactobacillus fermentation product.); and (4) Crop Cure-treated corn silage (Crop Cure is sodium diacetate, which acts similarly to acetic acid but is a powder.). Silabac and Culbac are considered to be fermentation stimulants, while Crop Cure is considered a fermentation inhibitor. Several other somewhat similar silage additives are commercially available.

Regarding losses of dry matter, the addition of Culbac resulted in only 4.1 percent loss during ensiling as compared to a 9.4 percent loss in the untreated silage ($P < .10$). Dry matter losses due to spoilage were also significantly ($P < .10$) decreased (3.4 percent vs. 5.2 percent) as compared to the control. Total recovery of dry matter after ensiling and spoilage losses was significantly ($P < .10$) higher in Culbac-treated silage (92.5 percent) than in untreated silage (85.4 percent). Silabac and Crop Cure treatment resulted in only slight, nonsignificant improvement of dry matter recovery.

Chemical composition was similar among the four silages and was well within normal ranges for corn silages. Digestibility by sheep was similar for all silages. For some unexplained reason ether extract (crude fat) digestibility for untreated silages was lower ($P < .10$). However, values for total digestible nutrients (TDN) on a dry basis were very similar among treatments and ranged from 68.2 percent to 69.8 percent.

All silages were fed to Angus feeder heifers for about 90 days (silage period), followed by full feeding of corn for about 70 days. During the silage period, there were no significant differences in gains ($P > .10$) and only slight differences in feed efficiency ($P < .10$) due to silage treatment. No differences in gain or efficiency due to treatment were observed in the full-feeding period and the two combined periods ($P > .10$).

After the full-feeding period, the heifers were slaughtered and various carcass characteristics were determined or calculated. The addition of either Culbac or Silabac produced somewhat leaner carcasses, since backfat thickness ($P < .10$) and yield grade ($P < .10$) were significantly reduced. Therefore, the only benefit of the silage aids observed in this 3-year study was a decrease of dry matter losses by about one half due to Culbac addition and slightly leaner carcasses due to the addition of either Silabac or

Culbac. However, the markedly increased dry matter recovery due to the Culbac treatment resulted only in a numerical improvement of 1.7 percent in overall feed efficiency.

INTRODUCTION

A successful silage program depends on high yields of good quality forage to be ensiled. Although the process of ensiling preserves the forage, it is also accompanied by feeding value losses that are often very extensive. Therefore, ensiling is essentially a destructive process because the chemical changes necessary to preserve the forage material are always accompanied by losses of feed nutrients. Improper storage, unloading and transport, and excessive time in feed bunks result in further losses in amount and quality of nutrients. Thus, the goal of a successful silage program, besides high yields of good quality forage, is to minimize the nutrient losses inherent to the ensiling process. Eventually, it may be possible to decrease nutrient losses during silage making until they are insignificant.

The processes that produce losses during the various phases of silage making and their causative agents are presented in Table 1. Immediately after the forage is cut, residual respiration occurs due to the action of plant enzymes in aerobic conditions. Respiration continues throughout the entire silo-filling process and for a time after sealing, until the oxygen and enzymes are exhausted. Sugars and starches are converted to carbon dioxide, water, and heat.

Anaerobic fermentation occurs after sealing. The losses that occur during this phase are effluent loss and gaseous loss, both of which involve nutrient losses of starches and sugars, organic acids, nitrogenous compounds, and minerals. Both are the result of the action of lactobacilli, clostridia, leuconostoc, and, to a lesser degree, other microorganisms on readily fermentable carbohydrates like sugars and starches. In addition, some of the effluent loss is caused by the high pressures produced in tall silos when high moisture materials are ensiled. If air has access to the fermenting forage, aerobic deterioration occurs during storage, with most of the loss occurring soon after sealing and extending until the trapped oxygen is depleted. However, inadequate sealing of a silo permits continuous infiltration of oxygen, and aerobic deterioration continues throughout the storage phase. Aerobic deterioration is primarily caused by the action of yeasts and molds and possibly by bacteria. After the silo is opened, aerobic deterioration of the silage occurs on the newly exposed surface pending its removal, during its unloading and transport (during which time it is being aerated further), and finally continues in the feed bunk until it is consumed by the ruminant animal.

Several commercial products referred to as fermentation aids or silage additives are being marketed with the claim that they will improve the silage-making process and thereby reduce the losses of nutrients. Efforts have been made by McCullough (1977) and McDonald (1981) to classify the various types of silage additives. Table 2 is an extension of McDonald's classification. Fermentation stimulants include lactic acid-producing bacteria, enzymes, and easily fermentable carbohydrate sources. The purpose of these fermentation stimulants is to facilitate the rapid growth of lactic

Table 1. Chemical processes that occur during silage making

Degradative Processes During Various Phases of Silage Making

Phase	Process	Causative Agents
Before ensiling	Residual respiration	Plant enzymes
After ensiling	Residual respiration	Plant enzymes
	Anaerobic fermentation	
	- Effluent loss	Lactobacilli, Clostridia, Leuconostoc, moisture
	- Gaseous loss	" "
	Aerobic deterioration	
	- During storage	Yeasts, molds, possibly bacteria
After opening	Aerobic deterioration	
	- Pending removal	Yeasts, molds, possibly bacteria
	- Unloading, transport	" "
	- In feed bunk	" "

Nutrient Components Lost During Various Processes of Silage Making

Process	Components Lost
Residual respiration	Sugars and starches
Aerobic deterioration	Sugars, starches, organic acids, nitrogenous compounds, cellwall components
Anaerobic fermentation	Sugars, starches, organic acids, nitrogenous compounds, minerals

Table 2. Classification of fermentation manipulators

Fermentation Stimulants	
Lactic Acid Bacteria	**Carbohydrate Sources**
Lactobacillus	Glucose
Acidophilus	Sucrose
Casei	Molasses
Plantarum	Grain
Xylosus	Whey
	Beet pulp
	Citrus pulp
Pediococcus	
Acidilactici	
Cerevisiae	
	Enzymes
Streptococcus	
Cremoris	Amylases
Faecalis	
Lactis	Cellulases
Fermentation Inhibitors	
Acids	**Others**
Mineral	Formaldehyde
Formic	Paraformaldehyde
Acetic	Sodium nitrate
Lactic	Sodium chloride
Acrylic	
Benzoic	Antibiotics
Sorbic	Bronopol
	Carbon dioxide
Aerobic Deterioration Inhibitors	
Acetic acid	Sorbic acid
Propionic acid	Caproic acid
Butyric acid	Pimaricin
Acrylic acid	Ammonia
Nitrogen-containing Nutrients and Minerals	
Ammonia	Limestone
Urea	Other mineral sources
Biuret	

Adapted from McDonald (1981)

acid-producing microorganisms. Since fermentation is essentially a destructive process it may be advantageous to quickly arrest any if not all fermentative activity through the use of fermentation inhibitors. Aerobic-deterioration inhibitors are added to silages to diminish the degradation of the silage by aerobic microorganisms. Finally, nitrogen-containing nutrients and minerals are added to silages to supplement a silage, making it a better balanced feed nutritionally.

The objectives of this study were to determine the effects of manipulating the fermentation process on: (1) the recovery of corn silage dry matter; (2) nutrient content and digestibility of the corn silages by wethers; and (3) the intakes, gains, feed efficiencies, and carcass characteristics of slaughter beef heifers fed the corn silages.

EXPERIMENTAL PROCEDURES

During each of three years, corn plants in the early dent stage were ensiled in eight 10-ton upright brick silos. Two silos were assigned to each of four experimental treatments. The four experimental treatments were: (1) an untreated corn silage, which served as the control; (2) Silabac-treated corn silage (Silabac is a commercial inoculant described by its manufacturer as a "live" lactic acid-producing bacterium.); (3) Culbac-treated corn silage (Culbac is a dead lactobacillus fermentation product.); and (4) Crop Cure-treated corn silage (Crop Cure is sodium diacetate, which acts similarly to acetic acid but is a powder.) Silabac and Culbac are considered to be fermentation stimulants, while Crop Cure is considered a fermentation inhibitor. Several other somewhat similar silage additives are commercially available.

In this study, the effects of three silage additives on fermentation and spoilage losses were measured. Also, a digestion trial with sheep was conducted using the experimental silages to determine possible differences in digestible nutrients. Finally, the experimental silages were fed to Angus feeder heifers in a feedlot study and the possible effects of the additives on various animal performance and carcass measurements were determined.

Dry Matter Losses

Experimental Silages

Pioneer Hybrid 31 was the corn variety used to make the silage for all three yearly trials. The plant population averaged 17,000 plants per acre. In the fall following the silage harvest, the fields were seeded to small grain. This crop was used as pasture for beef cows and heifers during the wintering period, as weather permitted. In the spring, the small grain residue was plowed under. Before planting the corn, 125 pounds of nitrogen, 60 pounds of potassium, and a "medium" level of phosphorus per acre were applied to the fields used to produce the experimental silages. Corn greenchop was harvested in the late dough to early dent stage. Before the greenchop was blown into the silo, each filled silage wagon, which had its tare weight taken previously, was reweighed to determine the amount of greenchop material it contained. When applicable, Silabac, Culbac, or Crop Cure was broadcast by hand over each load at the rate of one pound per ton on a wet basis, as suggested by the manufacturers.

In each trial, representative samples of the greenchop were taken from each wagon load. Two replicate upright brick silos, measuring 6 feet x 30 feet and having the capacity of approximately 10 tons of silage each were filled with silages that had received their respective experimental treatments. These silos and their adjacent cattle-feeding facilities had also been used in previous silage research at the Tobacco Experiment Station (Chamberlain et al. 1978). The greenchop was allowed to ferment for approximately 145 days before the first silo in each treatment was opened. In all three trials, the amount of spoiled silage in each silo was determined and a sample of the spoiled silage was taken for dry matter determination. Fresh silage samples were taken during each trial, when the silos were first opened and at 28-day intervals thereafter.

All forage samples (greenchop, fresh, and spoiled silage) were dried at 60°C for 72 hours and allowed to air equilibrate for 72 hours. Air-equilibrated dry matter was determined, and samples were ground through a 1-mm mesh screen of a Wiley Mill. The air-equilibrated silage samples were composited by treatment for each trial. Silage and greenchop were analyzed by AOAC (1975) methods for residual dry matter at 100°C, complete proximate analysis, acid-detergent fiber, acid-detergent-fiber nitrogen, and lignin.

Measurements Taken

Dry matter losses from the ensiled greenchop during the various phases of silage making were determined for each of the four treatments during each of the three years. First, dry matter recovery after the ensiling process as well as percentage loss was calculated. Then recovery of edible silage, as a proportion of dry matter recovered after the fermentation process, was calculated by subtracting from these values corresponding values for spoiled silage dry matter. Finally, the two losses were combined in the calculation of edible dry matter as a proportion of dry matter originally ensiled.

Dry matter recovery from the fermentation process was the quotient of the amount of dry matter recovered after fermentation and the amount of dry matter originally ensiled. Amount of dry matter ensiled was calculated as the product of the amount of wet greenchop ensiled and percent dry matter. Similarly, dry matter recovered after fermentation was the product of wet silage removed from the silo and its dry matter percentage.

Dry matter lost due to spoilage was obtained from (1) the amount of visibly spoiled material removed after each silo was first opened and throughout the emptying of the silo and from (2) the dry matter percentage of the spoiled silage. Amount of dry matter lost due to spoilage and, conversely, edible dry matter recovery were also expressed as a proportion of the ensiled dry matter.

Statistical Analyses

The experimental unit used was a silo. Data from the three trials were pooled by treatment. Significant treatment effects were determined by an analysis of variance. When necessary, Student Newman Keuls multiple range test was used for mean separation.

Digestion Trial

Silages produced the first year were fed concurrently to mature wether sheep in a total-collection digestion trial at the Knoxville Experiment Station and to heifers in feedlot trials at the Tobacco Experiment Station in Greeneville. The digestion trial was conducted to determine nutrient digestibility of corn silages treated with the various fermentation aids. Silages for the digestion and metabolism studies were obtained from the Tobacco Experiment Station on two separate days and transported from Greeneville to Knoxville. The silages were refrigerated until fed to the wethers.

Conduct of Trial

Sixteen mature Hampshire-cross wether sheep were used. These sheep averaged 164 pounds in body weight and were all approximately five years old. Four wethers were allotted, by weight and age, to each of the silage treatments. The sheep were placed in metabolism crates (Briggs and Gallup 1949) and maximum silage intakes were determined during an 8-day preliminary period.

The animals were fed twice daily with one-half of the rations being fed at both 8 a.m. and 4 p.m. Water was offered one-half hour before each feeding, then removed shortly before feeding. A trace mineralized salt block was offered free choice. The preliminary period was immediately followed by a 7-day collection period during which feed, refusal, and feces samples were collected. Daily representative samples of feeds and refusals were taken and composited. Ten percent aliquot samples of the daily fecal outputs were measured, by weight, and composited for each sheep. Mold growth was inhibited by adding a few thymol crystals daily.

Chemical and Statistical Analyses

Feed and fecal samples were dried at 60°C for 72 hours and allowed to air equilibrate for the same period of time. The samples were then ground through a 1-mm screen of a Wiley Mill. Complete proximate analysis and acid-detergent fiber determinations were conducted according to AOAC (1975) methods on the feed and fecal samples. Since refusal samples were negligible, they were not analyzed chemically. Apparent digestion coefficients of each respective nutrient and percent total digestible nutrients were calculated.

Significance of treatment effects on digestibility parameters were determined by an analysis of variance and a Student Newman Keuls multiple range test.

Feedlot Trial

One feedlot trial in each of three successive years was conducted at the Tobacco Experiment Station at Greeneville. Each of the trials began in the fall and ended the following summer. The feeding system consisted of two periods. The first phase of each trial was the silage-feeding period. During this period, heifers were fed free choice one of the four experimental corn silages (discussed previously in the "Dry Matter Losses" section) together with two pounds of grass-legume hay per animal per day and an amount of a protein supplement calculated to meet National Research Council (1984) protein requirements for normal growth.

The second period of the feeding program for each trial was the full-feeding period. This period began with a 2-week transition period in which the proportion of concentrate in the ration increased as the proportion of silage in the ration decreased, until the silage supply was exhausted. After that, the heifers were then on a full feeding of ground corn, 3.1-lb hay per animal per day, and enough soybean meal to meet National Research Council (1984) requirements. When an individual heifer's backfat thickness reached 12 mm or more, she was removed from the experiment and sold for slaughter.

Experimental Animals

During the month of September of each year, at least 50 Angus beef heifer calves were purchased at Tennessee fall feeder calf sales. During the first year's trial each heifer's pregnancy status was determined and the pregnant heifers were excluded from the experiment. During the second and third year's trials, heifers were also checked for pregnancy and those determined to be more than 100 days pregnant were removed from the experiment. All other heifers were given a 25-mg dose of lutalyse (prostaglandin $F_{2\alpha}$) to abort any developing fetuses and to equalize any possible effect that the abortafacient might have on subsequent animal performance. All the heifers used were of the "Good grade" and had an average weight of 550 pounds. Prior to the beginning of the silage-feeding period, all heifers were placed on permanent pastures.

In mid December, body weight, type score, and backfat thicknesses were determined and gain, average daily gain, and backfat gain were calculated. The heifers were allotted to eight groups of five animals each. Two groups of heifers were then randomly allotted to each treatment. The effort was made to have maximum equality of all parameters among groups within treatment. The measurements used for the allotment of the heifers as listed in their order of importance were: (1) weight, (2) backfat thickness, (3) average daily gain, (4) backfat gain, (5) frame score, and (6) muscling score.

Conduct of Trial

At the beginning of the silage-feeding period, each of the eight groups of heifers was placed in a 20 feet x 25 feet pen located within the Tobacco Experiment Station's beef cattle feeding barn. Four pens were on each side of the barn.

During the silage-feeding period, the heifers were fed the appropriate experimental corn silage ad libitum once daily. Increases or decreases in the amount of feed offered were determined by the previous day's refusal. Two pounds of hay per head per day were also fed. In addition, soybean meal was fed. The amount fed was based on the crude protein content of the silage and hay and on the crude protein requirements of feeding heifers (National Research Council 1984). The consumption of individual ration constituents (silage, concentrate, and hay) was recorded daily by lots.

The length of the silage-feeding period was 103 days during trial 1, 84 days for trial 2, and 86 days for trial 3. Heifers were weighed at approximately 28-day intervals and on two consecutive days at the conclusion of the silage-feeding period. The final two weights were averaged. Heifers were also measured for changes in backfat thickness at this time.

The full-feeding period started after one of the experimental silages was depleted. During the first 7 to 14 days, silage feeding was gradually reduced and grain feeding was increased. The amount of protein supplement fed was based on National Research Council (1984) protein requirements and protein content of the grain and hay. Also, an average of approximately three pounds of hay per heifer were fed. The length of the full-feeding period for the heifers averaged from 66 to 71 days during trial 1, from 61 to 65 days during trial 2, and 90-days for trial 3. When each individual heifer attained a backfat thickness of 12 mm or greater, she was weighed on two consecutive days and sent to slaughter.

Measurements Taken

Frame and muscling scores were determined just prior to the initiation of each trial and were used as one of the bases for allotting the heifers. Backfat thicknesses were also measured just prior to the beginning of each trial, at the end of the silage-feeding phase, and initially at four-week intervals in the full-feeding phase, and later at two-week intervals as heifers approached the 12-mm backfat thicknesses. Although the initial backfat thicknesses were used in the allotting of the animals, subsequent measurements were also considered as measures of the effect of the corn silage additives. Body weights of the heifers were taken in mid December for each trial; these weights were used in allotting the heifers. Body weights were also taken at the beginning and end of the silage-feeding phase and at 28-day intervals throughout the trials and more frequently as heifers approached slaughter condition.

Hot carcass weights were obtained at the slaughterhouse. Carcass grades, conformation, maturity, and marbling scores were determined by a USDA grader after the carcasses had chilled 48 hours. Ribeye area, fat thickness, and percent kidney fat were estimated according to procedures set forth by the American Meat Science Association (Schoonover et al. 1967).

Weight gains, average daily gain, and increases in backfat thickness were calculated for the silage period and for the full-feeding period. Feed efficiencies (feed/gain; gain/feed) were calculated for each lot and each treatment from daily feed intake of the animals, by lot, and the average daily gains of each lot.

Statistical Analyses

Data were collected for three consecutive years and significant differences due to treatment were determined by an analysis of variance. Contrasts were made between each individual additive and the control. Each lot was balanced by allotting heifers based on their initial weight. As a result, lot was considered to be the experimental unit. All variables were analyzed using the following model:

$$Y_{ijk} = \mu + trt_i + yr_j + (trt \times yr)_{ij} + e_{(ij)k}$$

where Y_{ijk} is the dependent variable associated with the k^{th} lot of heifers during the j^{th} year fed the i^{th} treatment; μ is the overall mean; trt_i is the effect of the i^{th} treatment (fixed variable), $i = 1\text{-}4$; yr_j is the effect of the j^{th} year (fixed variable), $j = 1\text{-}3$; $(trt \times yr)_{ij}$ is the effect of the interaction of the i^{th} treatment with the j^{th} year; e is the error term that is the lot within treatment—year effect. Treatment effects were tested using the error mean square, that is, lot within treatment—year mean square.

RESULTS AND DISCUSSION

Dry Matter Losses

The effect of corn silage additives on dry matter loss and recovery is presented in Table 3. These means are the average from five silos—two silos per treatment for two years and one silo the third year. The Culbac-treated silage figure is the mean of four silos, since one silo was lost due to rat infestation. Loss alone will be discussed, since recovery figures were calculated from the loss figures.

Dry matter lost during ensiling of the control silage was 9.4 percent. This amount of loss is comparable to that reported by other researchers (Bolsen et al. 1980; Nothnagel et al. 1983) for untreated silages. The addition of all three fermentation aids resulted in some numerical decrease in dry matter loss. Culbac-treated silage only lost 4.1 percent of its dry matter during ensiling. This was not significantly different ($P > .10$) but was numerically less than half (4.1 percent vs. 9.4 percent) of the ensiling loss obtained in the control silage.

Spoilage loss due to addition of Culbac was significantly different ($P < .10$) from that of the control silage. When the total dry matter loss

Table 3. Effect of silage fermentation additives on dry matter loss and recovery

	Corn silage[a]			
	Control	+Silabac	+Culbac	+Crop Cure
Number of silos/treatment	6	6	6	6
	---percent---			
Dry matter loss during ensiling	9.4	8.5 (.78)	4.1 (.17)	7.7 (.65)
Dry matter loss due to spoilage	5.2	4.2 (.29)	3.4 (.08)	5.9 (.44)
Total dry matter loss	14.6	12.7 (.56)	7.5 (.07)	13.6 (.79)
Total dry matter recovery	85.4	87.3	92.5	86.4

[a]Probability levels associated with calculated F-statistics were obtained by contrasting each additive individually with the control and are presented in parentheses following the appropriate mean. For example, treating corn silage with Culbac decreased dry matter loss due to spoilage from 5.2 percent to 3.4 percent. This decrease was significant at $P < .10$.

figure was obtained by adding fermentation and spoilage losses together, it was evident that treating with any additive resulted in at least a small numerical decrease in dry matter loss as compared to the loss in the control. The silage treated with Culbac, however, lost only about half of the dry matter during ensiling and due to spoilage (7.5 percent vs. 14.6 percent) as compared to the control and was the only treatment that had a loss figure significantly less ($P < .10$) than that of the control. Expressed another way, the treatment of corn greenchop with Silabac or Crop Cure did not result in a statistically significant reduction of fermentation and spoilage losses when contrasted with the control. However, the Culbac treatment improved the recovery of dry matter, after both ensiling and spoilage losses were considered, from 85.4 percent in the control silage to 92.5 percent in the treated silage.

Nutrient Composition and Digestibility

Nutrient Composition

The results of the chemical analyses of the experimental silages are presented in Table 4. The dry matter contents of the four corn silage treatments were similar. Percentages of all proximate constituents, acid-detergent fiber (ADF), and lignin were similar among the four silage treatments. On a dry matter basis, the crude protein content of the corn silage treatments was nearly identical at 8.9 percent for the control and Culbac, 8.7 percent for Silabac, and 9.0 percent for Crop Cure. These crude protein percentages were slightly higher than the average crude protein value for corn silage reported by the National Research Council (1975). The percentages of most other components are well within the normal range of corn silages.

A companion study (Johnson et al. 1986) to this work has been conducted where corn silages with the same experimental treatments were ensiled in experimental silos (55-gallon drums) and the production of organic acids was studied during various stages of the fermentation process. Lactic acid content in all treated silages was numerically higher than that in the control silage on all sampling days. On day 27 after ensiling, lactic acid content of treated silages was significantly higher ($P < .10$) than that of the control, i.e., control = 194.8 M/wet silage; Silabac = 219.3; Culbac = 245.5; and Crop Cure = 272.1. This higher lactic acid content of the treated silages indicated an improved quality of fermentation. The production of other organic acids (acetic, propionic, and isobutyric) remained unchanged.

The percentages of acid-detergent fiber-nitrogen (ADF-N) of all silages were higher than expected. This may be due to an increased possibility of inclusion of oxygen in the smaller than conventional experimental silos.

Table 4. Nutrient composition of experimental silage [a]

Component	Corn silage			
	Control	+Silabac	+Culbac	+Crop Cure
	percent			
Dry matter[b]	29.8	28.9	28.5	28.7
Crude protein[c]	8.9	8.7	8.9	9.0
Crude fiber[c]	22.0	21.9	21.6	21.9
Ether extract[c]	2.5	2.4	2.5	2.6
Ash[c]	4.9	4.8	5.0	5.2
Nitrogen-free extract[c]	61.7	62.3	62.1	61.5
Acid-detergent fiber[c]	31.7	31.6	31.9	31.0
Acid-detergent fiber-nitrogen[c]	10.9	10.1	11.7	10.9
Lignin[c]	3.4	3.6	3.4	3.2

[a]Average of trials 1 and 2.
[b]Fresh basis.
[c]Dry-matter basis.

This increased inclusion of oxygen can cause subsequent rises in temperature (Ruxton et al. 1975), which in turn can cause increases in the amount of ADF-N production and consequently decreases in crude protein utilization.

Nutrient Digestibility

The results of the digestion trial with sheep are presented in Table 5. Sheep fed the control silage consumed more ($P < .10$) silage dry matter than sheep fed the treated silages. No differences ($P > .10$) among experimental silage treatments were found in the digestibility of dry matter, organic matter, crude fiber, nitrogen-free extract, or acid-detergent fiber. McCullough (1977) and Burghardi et al. (1980) reported similar dry matter digestibility of corn silage treated with microbial and enzymatic fermentation aids as we obtained in this trial. In addition, digestibilities of individual nutrients obtained in this trial were similar to those reported by McCullough (1977), who found no differences ($P > .10$) among treatments from wethers fed microbial-treated, enzyme-treated, or untreated control corn silages.

Crude protein digestibility by wethers fed the Culbac and Crop Cure silages were significantly lower ($P < .10$) than those of wethers fed the control and Silabac diets. ADF-N percentage of the Crop Cure diet (Table 4) was somewhat higher than that of the other diets, indicating that a smaller proportion of the crude protein in the Crop Cure silage was in a digestible form and thus resulted in lower crude protein digestibility. Crude protein digestibility of the Culbac silage was also depressed, however the reason for this is not understood.

Table 5. Digestibility of silage nutrients by sheep

	Corn silage			
	Control	+Silabac	+Culbac	+Crop Cure
Number of wethers	4	4	4	4
Body weight, lb	164	162	162	168
Dry matter intake, lb/day	3.01[a]	2.57[b]	2.33[b]	2.64[b]
Apparent digestion coefficients	percent			
Dry matter	68.1[a]	69.7[a]	67.7[a]	66.6[a]
Organic matter	67.1[a]	68.1[a]	68.5[a]	69.3[a]
Crude protein	56.8[a]	57.6[a]	54.3[b]	54.9[b]
Ether extract	75.7[a]	85.4[b]	82.4[c]	83.7[bc]
Crude fiber	57.6[a]	62.5[a]	55.9[a]	55.4[a]
N-free extract	75.2[a]	75.2[a]	75.0[a]	73.8[a]
Acid-detergent fiber	49.1[a]	47.3[a]	50.6[a]	47.6[a]
Total digestible nutrients, %[d]	68.2[a]	69.8[a]	68.7[a]	68.5[a]

[a,b,c,]Means on the same line with the same superscript are not significantly different ($P > .10$).
[b]Dry basis.

All treated silages had ether extract (EE) digestibilities significantly ($P < .10$) higher than that of the control silage. However, EE content of all silages was lower than the average EE content for corn silage reported by the National Research Council (1982). Therefore, the differences in EE digestibilities are considered to be inconclusive and not biologically important. Total digestible nutrients (TDN) were not significantly affected ($P > .10$) by dietary treatment, and the total digestible nutrients of all the silages were higher than the 55 percent total digestible nutrients required for maintenance of 75-kg ewes (National Research Council 1975).

Animal Performance

Silage-feeding Period

Consumption of the three feed constituents by the 30 heifers per treatment (3 years, 2 lots per year, and 5 heifers per lot) during the 91-day silage-feeding phase is presented in Table 6. The amounts of hay and soybean meal consumed were the same for all treatments because they were fed at the same predetermined levels. The four experimental corn silages were fed free choice and there were slight significant increases ($P < .10$) in the consumption of two of the treated silages on the dry-matter basis. This disagrees with the results of several other researchers. Bolsen et al. (1980) reported no differences ($P > .10$) in dry matter intakes of cattle fed corn silage treated with an enzyme additive compared to those fed a control silage. Burghardi et al. (1980) reported similar intakes among steers fed corn silages treated with lactobacillus acidophilus organisms and those fed an untreated control. Dry matter intake of calves and heifers offered an organic acid-treated corn silage or an untreated control were also shown to be similar (Leaver 1975).

No treatment differences ($P > .10$) were observed in total weight gains. Average daily gains were not significantly different ($P > .10$) when treatments were contrasted with the control. However, the heifers fed the control (1.88) and Silabac-treated (1.87) silages gained numerically somewhat faster than those fed the Culbac-treated (1.82) and Crop Cure-treated (1.81) corn silages.

Feed efficiency among the heifers fed the treated silages was generally not significantly different ($P > .10$) from that of the controls, except for a slightly reduced efficiency due to Crop Cure addition. Heifers fed the control silage had the lowest feed consumption per pound of gain (6.861), while the heifers fed the Crop Cure-treated silage were the least efficient with a feed-to-gain ratio of 7.293. When silage intake alone was used to calculate the gain-to-feed ratios, again the heifers fed the control silage were numerically most efficient while those fed the Crop Cure-treated silage were least efficient, with gain-to-feed ratios of 0.188 and 0.176, respectively.

Another type of feed efficiency figure was calculated in which dry matter recovery, weight gain, and feed intake is included in the same figure.

Table 6. Animal performance and feed consumption, silage-feeding phase

	Corn silage[a]			
	Control	+Silabac	+Culbac	+Crop Cure
Number of animals/treatment	30	30	30	30
Daily feed intake/heifer	pounds			
Corn silage—as fed basis	35.8	36.3 (.30)	36.3 (.23)	36.1 (.27)
Corn silage—DM basis	10.0	10.2 (.31)	10.3 (.05)	10.3 (.08)
Hay[b]	1.8	1.8	1.8	1.8
Soybean meal[b]	1.1	1.1	1.1	1.1
Total dry matter intake[c]	12.9	13.1	13.2	13.2
Weight and gain/heifer				
Initial[d]	552	548	556	552
Final	724	717 (.39)	722 (.63)	715 (.29)
Total gain	172	169 (.63)	166 (.30)	163 (.15)
Average daily gain	1.88	1.87 (.84)	1.82 (.37)	1.81 (.24)
Feed efficiency				
Feed/gain	6.861	7.005 (.83)	7.253 (.30)	7.293 (.20)
Gain/silage intake	0.188	0.184 (.53)	0.177 (.11)	0.176 (.09)
Gain/silage intake + loss	0.160	0.160 (.93)	0.163 (.60)	0.151 (.18)

[a]Probability levels associated with calculated F-statistics were obtained by contrasting each additive individually with the control and are presented in parentheses following the appropriate mean.

[b]Hay and soybean were fed at constant levels across by treatments.

[c]Probability levels for total dry matter intake are the same as those of the corn silage intake on a dry matter basis since hay and soybean meal intakes were held constant.

[d]Initial weights of heifers were used in allotting them to treatment.

This efficiency figure compares the heifers' weight gains not only to the amount of silage consumed but also to the amount of greenchop originally ensiled or, in other words, the gain per silage intake plus ensiled material lost. Considering this efficiency, there were again no significant ($P > .10$) differences due to silage treatments when contrasted with the control. However, the heifers fed the Culbac-treated silage were the most efficient, at 0.163 lb of gain per lb of dry matter ensiled, while the heifers fed the Crop Cure-treated silage were the least efficient, at 0.151. The other two groups of heifers showed intermediate gains.

Full-feed Period

Separate data obtained during the full-feed period, which lasted from 72 to 73 days, are presented in Table 7. Since all heifers were fed the same ration during this period, the only difference in performance of the animals would be due to a possible carryover effect from the fermentation aids in the preceding silage period or due to compensatory gains. There were no significant differences ($P > .10$) due to treatment of corn silage when contrasted with the control in any of the measurements. However, heifers that had gained numerically somewhat less in the silage period (those fed the Culbac and Crop Cure silages) had compensatory gains in the full-feeding period and thus gained somewhat more. The reverse was the case for control and Silabac silage-fed heifers who gained somewhat more in the silage period and had numerically lower gains in the full-feeding period.

Combined Periods

The combined average daily gain figures (Table 8) of heifers fed one of the four experimental treatments were nearly identical, averaging 1.93 lb. Gain-to-feed ratios were similar among treatments as well. Of particular interest are the gain per total dry matter ensiled (intake plus silage dry matter lost during ensiling). As during the silage-feeding period alone, the heifers fed the Culbac-treated silage were numerically but nonsignificantly ($P > .10$) the most efficient, at 0.119 lb of body weight gain per one lb dry matter ensiled. This improved efficiency, as during the silage-feeding period, was directly related to the effect of Culbac in increasing corn silage dry matter recovery. However, this only constituted a numerical improvement of 1.7 percent in overall efficiency compared to heifer efficiency on control silage.

Table 7. Animal performance and feed consumption, full-feed phase

	Corn silage[a]			
	Control	+Silabac	+Culbac	+Crop Cure
Number of animals/treatment	30	30	30	30
Daily feed intake/heifer	pounds			
Corn silage—as fed basis	2.9	2.9 (.95)	3.0 (.48)	2.9 (.51)
Corn silage—DM basis	0.8	0.8 (.67)	0.8 (.64)	0.8 (.80)
Hay	3.1	3.1 (.86)	3.1 (.81)	3.1 (.95)
Corn	13.7	13.8 (.69)	13.8 (.68)	13.7 (.93)
Soybean meal	1.2	1.2 (.67)	1.2 (.64)	1.2 (.49)
Total dry matter intake	18.8	18.9 (.85)	18.9 (.79)	18.8 (.99)
Weight and gain/heifer				
Initial	724	717 (.39)	720 (.60)	715 (.30)
Final	868	863 (.63)	871 (.83)	865 (.82)
Total gain	144	146 (.80)	151 (.30)	150 (.35)
Average daily gain	2.00	1.99 (.88)	2.07 (.39)	2.08 (.34)
Feed efficiency				
Feed/gain	9.400	9.497 (.86)	9.130 (.72)	8.990 (.61)
Gain/feed	0.106	0.105 (.88)	0.109 (.50)	0.111 (.47)

[a]Probability levels associated with calculated F-statistics were obtained by contrasting each additive individually with the control and are presented in parentheses following the appropriate mean.

Table 8. Animal performance and feed consumption, silage and full-feed phases combined

	Corn silage[a]						
	Control	+Silabac		+Culbac		+Crop Cure	
Number of animals/treatment	30	30		30		30	
Total daily feed intake/heifer, lb	15.5	15.7	(.40)	15.8	(.12)	15.7	(.32)
Weight and gain/heifer	pounds						
Initial[b]	552	548		556		552	
Final	868	863	(.63)	871	(.83)	865	(.82)
Total gain	316	315	(.89)	315	(.86)	313	(.81)
Average daily gain	1.94	1.92	(.65)	1.93	(.76)	1.93	(.79)
Feed efficiency							
Feed/gain	8.000	8.163	(.58)	8.175	(.36)	8.140	(.50)
Gain/feed	0.126	0.123	(.49)	0.122	(.28)	0.123	(.41)
Gain/total DM intake and silage DM loss	0.117	0.117	(.55)	0.119	(.11)	0.116	(.56)

[a]Probability levels associated with the calculated F-statistics were obtained by contrasting each additive individually with the control and are presented in parentheses following the appropriate mean.

[b]Initial weights of heifers were used in allotting them to treatment.

Data Regarding Days on Feed and Carcasses

The number of days on feed and several carcass characteristics are presented as 3-year means in Table 9. The number of days the heifers were fed silage for each of the four treatments are the same since the silage-feeding period always ended when any one of the treatments was exhausted. The number of days on full feed were nearly identical among treatments. The heifers fed the Silabac-treated silage were on feed an average of one day longer than those fed the other treatments. There were no significant differences ($P > .10$) due to treatment of corn silage in any of these days-on-feed measurements when contrasted with the control.

Several carcass measurements were either determined or calculated to ascertain if the additives affected the carcass composition or quality when contrasted with the control. The addition of Silabac or Culbac resulted in generally leaner carcasses than the control. Specifically, heifers that had consumed silages treated with either one of the two lactobacillus preparations (Silabac or Culbac) had significantly lower ($P < .10$) backfat thickness, numerically lower marbling scores, and nonsignificantly lower ($P > .10$) yield grades as compared to the control heifers. The opposite was also true in lean tissue measurements of the carcasses, since the addition of either of the two lactobacillus preparations also caused a trend toward higher loineye areas in the cattle fed these silages. It should be noted that

Table 9. Data regarding days on feed and carcasses

	Corn silage[a]						
	Control	+Silabac		+Culbac		+Crop Cure	
Number of animals/treatment	30	30		30		30	
Days on feed	days						
Silage-feeding period	91	91	(1.00)	91	(1.00)	91	(1.00)
Full-feed period	72	73	(.51)	72	(.94)	72	(.98)
Combined periods	163	164	(.51)	163	(.94)	163	(.98)
Carcass data							
Hot carcass weight, lb	482	484	(.66)	485	(.69)	481	(.85)
Fat thickness, in.	0.45	0.40	(.04)	0.40	(.04)	0.44	(.75)
Loineye, sq. in.	10.6	10.9	(.04)	10.8	(.15)	10.5	(.67)
Marbling score[b]	5.2	4.9	(.30)	4.7	(.11)	5.3	(.78)
Carcass grade[c]	11.8	11.5	(.49)	11.2	(.13)	11.7	(.73)
Kidney fat, %	2.3	2.3	(.71)	2.4	(.65)	2.4	(.41)
Yield grade	2.5	2.3	(.08)	2.3	(.11)	2.5	(.61)

[a]Probability levels associated with calculated F-statistics were obtained by contrasting each additive individually with the control and are presented in parentheses following the appropriate mean.
[b]Slight = 4; small = 5; modest = 6.
[c]High good = 11; low choice = 12.

these differences in carcass measurements due to type of silage feeding carried over even after the cattle had been fed the same full-fed high corn ration for 72 days after the silage feeding.

A conceivable explanation for the leaner carcasses of the heifers fed the Silabac and Culbac treatments is possible changes in nutrient partitioning or in biochemical pathways resulting in decreased rumen acetate levels. Work conducted by Burghardi et al. (1980) indicated that inoculation of corn silage with high levels of lactobacillus acidophilus organisms decreased ($P < .10$) acetate levels in the silage as compared to corn silage inoculated with a lower level of lactobacillus acidophilus organisms. If this decrease in acetate levels also occurs in the rumen, then there could be a resulting decrease in carcass fat content, since acetate is the primary fat precursor.

SUMMARY

Eight upright brick silos, each with the capacity of about 10 tons of silage, were used to study the effect of addition of selected silage aids to corn silage on dry matter recovery, nutrient content, digestibility, and the performance of Angus feeder heifers fed these silages. There were four types of experimental silages, with a total of five silos per experimental treatment over three successive years, except for the Crop Cure treatment in which one silo was lost due to rat infestation. The silages were (1) untreated

corn silage that served as a control; (2) Silabac-treated silage; (3) Culbac-treated silage; and (4) Crop Cure-treated silage.

Regarding losses of dry matter, the addition of Culbac resulted in only 4.1 percent loss during ensiling as compared to a 9.4 percent loss in the untreated silage ($P < .10$). Dry matter losses due to spoilage were also significantly ($P < .10$) decreased (3.4 percent vs. 5.2 percent) as compared to the control. Total recovery of dry matter after ensiling and spoilage losses was significantly ($P < .10$) higher in Culbac-treated silage (92.5 percent) than in untreated silage (85.4 percent). Silabac and Crop Cure treatment resulted in only slight, nonsignificant improvement of dry matter recovery.

Chemical composition was similar among the four silages and was well within normal ranges for corn silages. Digestibility by sheep was similar for all silages. For some unexplained reason ether extract (crude fat) digestibility for untreated silages was lower ($P < .10$). However, TDN values on a dry basis were very similar among treatments and ranged from 68.2 percent to 69.8 percent.

All silages were fed to Angus feeder heifers for about 90 days (silage period), followed by full feeding of corn for about 70 days. During the silage period, there were no significant differences in gains ($P > .10$) and only slight differences in feed efficiency ($P < .10$) due to silage treatment. No differences in gain or efficiency due to treatment were observed in the full-feeding period and the two combined periods ($P > .10$).

After the full-feeding period, the heifers were slaughtered and various carcass characteristics were determined or calculated. The addition of either Culbac or Silabac produced somewhat leaner carcasses, since backfat thickness ($P < .10$) and yield grade ($P < .10$) were significantly reduced. Therefore, the only benefit of the silage aids observed in this 3-year study was a decrease of dry matter losses by about one half due to Culbac addition and slightly leaner carcasses due to the addition of either Silabac or Culbac. However, the markedly increased dry matter recovery due to the Culbac treatment resulted only in a numerical improvement of 1.7 percent in overall feed efficiency.

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