The Silage Triangle and Important Practices Often Overlooked

Keith Bolsen, Ben Brent, Mary Kay Siefers, Estela Uriarte, Tobina Schmidt, and Ron Pope
Kansas State University, Manhattan, Kansas 66506-0201
www.oznet.ksu.edu/pr_silage

The points of the ***silage triangle*** are represented by persons responsible for (1) the animals, (2) the forage, and (3) the harvesting process. In some beef and dairy operations, one person is responsible for all three points. But in many instances, both growing the silage crop and harvesting and ensiling the crop are done completely on a contract basis, creating a situation where a different person is at each point of the triangle. When communication between the points of the triangle is ineffective, inefficiencies can result that directly affect the bottom line.

Although a livestock operation's nutritionist - often an outside consultant - is not a direct part of the triangle, he or she has an obvious vested interest in how well the triangle performs. The nutritionist might be the key person in assuring effective communication between the triangle's three points.

The nutritionist's major responsibility is generally to the *animal* point of the triangle, so among his/her major responsibilities could be (1) educating the client about proper silage management, and (2) fostering communication. Ideally, the nutritionist might moderate an annual meeting between the livestock manager, the forage grower and the custom harvester, making sure that all involved are on the "same page" regarding expectations and implementation of the entire silage program.

In other cases, a small livestock producer might be on the wrong end of a tight supply/demand situation and therefore lack the economic power to make demands on the grower and/or harvester. Then, the nutritionist must focus directly on the producer, and make sure that the things directly under the producer's control are done right. The producer probably has control over inoculating, packing, and sealing, and certainly has control over managing the feedout face and discarding spoiled silage.

Inoculating Silage Crops

Effective bacterial inoculants promote a faster and more efficient fermentation of the ensiled crop, which increases both the quantity and quality of the silage. Inoculants have inherent advantages over other additives, including low cost, safety in handling, a low application rate per ton of chopped forage, and no residues or environmental problems. The bacteria in commercial products include one or more of the following species: *Lactobacillus plantarum* or other *Lactobacillus* species, various *Pediococcus* species, and *Enterococcus faecium*. These strains of lactic acid bacteria (LAB) have been isolated from silage crops or silages and were selected because: 1) they are homofermentative (i.e., ferment sugars predominantly to lactic acid) and 2) they grow rapidly under a wide range of temperature and moisture conditions. Recently, several products have also contained *Lactobacillus buchneri* (a heterofermentative

LAB) or strains of *Propionibacterium* (which are capable of producing propionic acid during the ensiling process).

Inoculant research at Kansas State University. Evaluation of silage additives began in 1975 in the Department of Animal Sciences and Industry. A summary of results from over 200 laboratory-scale studies, which involved nearly 1,000 silages and 25,000 silos, indicate that bacterial inoculants are beneficial in over 90% of the comparisons. Inoculated silages have faster and more efficient fermentations -- pH is lower, particularly during the first 2 to 4 days of the ensiling process for hay crop forages, and lactic acid content and the lactic to acetic acid ratio are higher than in untreated silages. Inoculated silages also have lower ethanol and ammonia-nitrogen values compared to untreated silages.

Economics of bacterial inoculants. What is the "bottom line" calculation of the value of inoculating corn silage and alfalfa haylage for a dairy herd is with an average milk production 87 lbs per cow per day and a daily DM intake of 54.2 lbs? The increase in net income, calculated on a per ton of crop ensiled or per cow per day or per cow per year basis, is realized from increases in both preservation and feed utilization improvements. The additional "cow days" per ton of crop ensiled, because of the increased DM recovery, and the increased milk per cow per day from the inoculated silage or haylage (0.25 lbs) produced a $6 to $7 increase in net return per ton of corn ensiled and about a $14 to $15 increase in net return per ton of alfalfa ensiled.

Recommendations. Why leave the critical fermentation phase to chance by assuming that the epiphytic microorganisms (those occurring naturally on the forage) are going to be effective in preserving the silage crop? Even if a dairy or beef cattle producer's silage has been acceptable in the past--because silage-making conditions in most regions of North America are generally good -- there are always opportunities for improvement. Although whole-plant corn and sorghum ensile easily, research data clearly show that the quality of the fermentation and subsequent preservation and utilization efficiencies are improved with bacterial inoculants. Alfalfa (and other legumes) are usually difficult to ensile because of a low sugar content and high buffering capacity. However, adding an inoculant helps ensure that as much of the available substrate as possible is converted to lactic acid, which removes some of the risk of having a poorly preserved, low-quality silage. Finally, if producers already are doing a good job but using a bacterial inoculant for the first time, they probably will not see a dramatic difference in their silage. But the benefit will be there -- additional silage DM recovery and significantly more beef or milk production per ton of crop ensiled.

Selecting a bacterial inoculant. The inoculant should provide at least 100,000 and preferably 200,000 colony-forming units of viable LAB per gram of forage. These LAB should dominate the fermentation; produce lactic acid as the sole end product; be able to grow over a wide range of pH, temperature, and moisture conditions; and ferment a wide range of plant sugars. Purchase an inoculant from a reputable company that can provide quality control assurances along with independent research supporting the product's effectiveness.

Achieving a Higher Silage Density

Achieving a high density of the ensiled forage in a silo is an important goal for dairy producers. First, density and crop DM content determine the porosity of the silage, which affects the rate at which air can enter the silage mass at the feedout face. Second, the higher the density, the greater the capacity of the silo. Thus, higher densities typically reduce the annual storage cost per ton of crop by both increasing the amount of crop entering the silo and reducing crop losses during storage. Recommendations have usually been to spread the chopped forage in thin layers and pack continuously with heavy, single-wheeled tractors. But the factors that affect silage density in a bunker, trench, or drive-over pile silo are not completely understood. Kurt Ruppel (Cornell University) measured the DM losses in alfalfa silage in bunker silos and developed an equation to relate these losses to the density of the ensiled forage (Table 1). He found that tractor weight and packing time per ton were important factors; however, the variability in density suggested there were other important factors not considered.

In a recent study, Brian Holmes, extension specialist at the University of Wisconsin-Madison, and Rich Muck, agricultural engineer at the U.S. Dairy Forage Research Center in Madison, measured silage densities over a wide range of bunker silos in Wisconsin. The densities were then correlated with crop/forage characteristics and harvesting and filling practices. Samples were collected from 168 bunker silos and a questionnaire completed about how each bunker was filled. Four core samples were taken from each bunker feedout face and core depth, height of the core hole above the floor, and height of silage above the core hole were recorded. Density and particle size were also measured.

The range of DM contents and densities observed in the hay crop (mainly alfalfa) and corn silages are shown in Table 2. As expected, the range in DM content was narrower for the corn silages compared to the hay crop silages. The average DM content of the corn silages was in the recommended range of 30-35%. But several of the haylages were too wet (less than 30% DM), which can lead to effluent loss and a clostridial fermentation, or too dry (more than 45% DM), which can lead to extensive heat damage, mold, and the risk of a fire. The average DM density for the hay crop and corn silages was similar and slightly higher than a commonly recommended minimum DM density of 14.0lbs/ft^3. Some producers were achieving very high DM densities, while others were severely underpacking. One very practical issue was packing time relative to the chopped forage delivery rate to the bunker. Packing time per ton was highest (1 to 4 min/ton on a fresh basis) under low delivery rates (less than 30 tons/h on a fresh basis). Packing times were consistently less than 1 min/ton (on a fresh basis) at delivery rates above 60 tons/hour.

There are several key factors that dairy producers can control to achieve higher densities, which will minimize DM and nutrient losses during ensiling, storage, and feedout.

- **Forage delivery rate.** Reducing the delivery rate is somewhat difficult to accomplish, as very few dairy producers or silage contractors are inclined to slow the harvest rate so that additional packing can be accomplished.
- **Packing tractor weight.** This can be increased by adding weight to the front of the tractor or 3-point hitch and filling the tires with water.

- **Number of tractors.** Adding a second or third packing tractor as delivery rate increases can help keep packing time in the optimum range of 1 to 3 minutes per ton of fresh forage.
- **Forage layer thickness.** Chopped forage should be spread in thin layers (6 to 12 inches). In a properly-packed bunker silo, the tires of the packing tractor should pass over the entire surface before the next forage layer is distributed.
- **Filling the silo to a greater depth.** Greater silage depth increases density. But there are practical limits to the final forage depth in a bunker, trench, or drive-over pile. Safety of employees who operate packing tractors and who unload silage at the feedout face becomes a concern. Packing in bunkers that are filled beyond their capacity and the chance of an "avalanche" of silage from the feedout face pose serious risks.

Table 1. Dry matter loss as influenced by silage density.

Density (lbs of DM/ft^3)	DM loss at 180 days (% of the DM ensiled)
10	20.2
14	16.8
16	15.1
18	13.4
22	10.0

Table 2. Summary of core sample analysis from the bunker silos.

Silage characteristic	Hay crop silage (87 silos)		Corn silage (81 silos)	
	Avg	Range	Avg	Range
Dry matter, %	42	24-67	34	25-46
Density on a fresh basis, lbs/ft^3	37	13-61	43	23-60
Density on a DM basis, lbs/ft^3	14.8	6.6-27.1	14.5	7.8-23.6

Protecting Silage from Air and Water.

Until recently, most large bunker, trench, or drive-over pile silos in Kansas were left unsealed. Why? Because producers viewed covering silos with plastic and tires to be awkward, cumbersome, and labor intensive. Many believed the silage saved was not worth the time and effort required. But if left unprotected, dry matter (DM) losses in the top 1 to 3 feet can exceed 60 to 70%. This is particularly disturbing when one considers that in the typical "horizontal" silo, 15 to 25% of the silage might be within the top 3 feet. When the silo is opened, the spoilage is only apparent in the top 6 to 12 inches of silage, obscuring the fact that this area of spoiled silage represents substantially more silage as originally stored.

The most common sealing method is to place polyethylene sheet (6 mil) over the ensiled forage and weight it down with discarded tires (approximately 20 to 25 tires per 100 ft^2 of surface area). Producers who do not seal need to take a second look at the economics of this highly troublesome "technology" before they reject it as unnecessary and uneconomical. The loss from a 40- x 100-foot silo filled with corn silage can exceed $2,000. Loss from a 100- x 250-foot silo can exceed $10,000.

Managing the Feedout Face.
The silage feedout "face" should be maintained as a smooth surface that is perpendicular to the floor and sides in bunker, trench, and drive-over pile silos. This will minimize the square feet of surface that are exposed to air. The rate of feedout through the silage mass must be sufficient to prevent the exposed silage from heating and spoiling. An average removal rate 6 to 12 inches from the "face" per day is a common recommendation. However, during periods of warm, humid weather, a removal rate of 18 inches or more might be required to prevent aerobic spoilage, particularly for corn, sorghum, and whole-plant wheat silages.

Feeding Spoiled Silage: The Consequences.
Sealing with a polyethylene sheet weighted with tires is not 100 percent effective. Aerobic spoilage occurs to some degree in virtually all sealed silos. And the discarding of surface spoiled is not always a common practice on the farm. But results of a recent study at Kansas State University (Table 3) showed that feeding surface spoilage had a significant negative impact on the nutritive value of a whole-plant corn silage-based ration.

The original top 3 feet of corn silage in a bunker silo was allowed to spoil, and it was fed to steers fitted with ruminal cannulas. The four experimental rations contained 90% silage and 10% supplement (on a DM basis), and the proportions of silage in the rations were: A) 100% normal, B) 75% normal:25% spoiled; C) 50% normal:50% spoiled, and D) 25% normal:75% spoiled. The proportion of the original top 18-inch and bottom 18-inch spoilage layers in the composited surface-spoiled silage was 24 and 76%, respectively. The original top 18-inch layer was visually quite typical of an unsealed layer of silage that had undergone several months of exposure to air and rainfall. It had a foul odor, was black in color, and had a slimy, "mud-like" texture. Its extensive deterioration during storage also was reflected in very high pH, ash, and fiber values. The original bottom 18-inch layer had an aroma and appearance usually associated with wet, high-acid corn silages, i.e., a bright yellow to orange color, a low pH, and a very strong acetic acid smell.

The addition of surface-spoiled silage had large negative associative effects on DM intake and OM, NDF, and ADF digestibilities. The first 25% increment of spoilage had the greatest negative impact. When the rumen contents were evacuated, the spoiled silage had also partially or totally destroyed the integrity of the "forage mat" in the rumen. The results clearly showed that surface spoilage reduced the nutritive value of corn silage-based rations more than was expected.

For more information about these and other silage management practices visit the Kansas State University Silage Team's website at *http://www.oznet.ksu.edu/pr_silage*

Table 3. Effect of the level of spoiled silage on DM intake and nutrient digestibilities.

Item	Ration A	Ration B	Ration C	Ration D
DM intake, lbs/day	17.5[a]	16.2[b]	15.3[b,c]	14.7[c]
	Digestibility, %			
OM	75.6[a]	70.6[b]	69.0[b]	67.8[b]
CP	74.6[a]	70.5[b]	68.0[b]	62.8[c]
NDF	63.2[a]	56.0[b]	52.5[b]	52.3[b]
ADF	56.1[a]	46.2[b]	41.3[b]	40.5[b]

[a,b,c]Means within a row with no common superscript differ (P<.05).