Managing Bunker, Trench, and Drive-over Pile Silages for Optimum Nutritive Value: Five Important Practices

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The points of the silage triangle are represented by persons responsible for (1) the dairy cattle, (2) the forage, and (3) the harvesting process. In some dairy operations, one person is responsible for all three points. But in many instances, both growing 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, which directly affect the bottom line.

Although a dairy cattle 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 dairy cattle 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 should moderate an annual meeting between the dairy manager, the forage crop grower, and the custom harvester. This can ensure that all involved understand and agree regarding expectations and implementation of the entire silage program. In other cases, a small dairy producer might be on the wrong end of a tight supply/demand situation and therefore lack the economic power to make demands on the crop grower and/or custom harvester. Then, the nutritionist must focus directly on the dairy producer, and make sure that the things directly under the producer's control are done correctly.

This paper focuses on five important silage management practices that are in the control of dairy producers and that are sometimes poorly implemented or overlooked entirely. These are (1) using an effective bacterial inoculant, (2) achieving a high silage density, (3) effective sealing, (4) properly managing the feedout face, and (5) discarding spoiled silage.

Use a Bacterial Inoculant

For detailed summaries on the effect of bacterial inoculants on silage fermentation, preservation efficiency, and nutritive value, see reviews by Muck (1993); Kung and Muck (1997); and Muck and Kung (1997).

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. Results from 28 farm-scale trials, which evaluated 71 silages, showed that bacterial inoculants consistently improved fermentation efficiency, DM recovery, feed to gain ratio, and live weight gain per ton of crop ensiled in both corn and sorghum silages (Bolsen et al., 1992).

Economics of bacterial inoculants. A "bottom line" calculation of the value of inoculating corn silage and alfalfa haylage for dairy cows is presented in Table 2. The dairy herd in this example has an average milk production 87 lbs per cow per day and a daily DM intake of 54.2 lbs (Table 1). 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 $6.67 increase in net return per ton of corn ensiled and a $14.95 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) is 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.

Table 1. Silage, haylage, and grain mix inputs in the example dairy herd ration.

Ration	Dry matter intake, lbs	Dry matter, %	Amount as-fed, lbs	$ per lb	Daily ration cost, $
Corn silage	11.4	35.0	32.6	0.015	0.49
Alfalfa haylage	11.2	40.0	28.0	0.03	0.84
Grain mix	31.6	87.5	35.1	0.075	2.63
Total	54.2		95.7		3.96

Table 2. Comparison of preservation efficiency and feed utilization efficiency with and without an inoculant.

	Corn silage		Alfalfa haylage	
	Untreated	Inoculant	Untreated	Inoculant
Preservation efficiency:				
Dry matter recovery, %	90.0	91.25	87.5	90.0
Dry matter recovered per ton ensiled, lbs	1800	1825	1750	1800
Amount fed daily, lbs	32.6	32.6	28.0	28.0
"Cow days" per ton ensiled	55.2	56.0 (+0.8)	62.5	64.3 (+1.8)
Milk gained per ton ensiled, lbs		69.6[1]		156.6[5]
Milk value gained per ton ensiled, $		$8.70[2]		$19.57[6]
Utilization efficiency:				
Increased milk yield/cow/day, lbs	Inoculated corn silage = 0.25 lbs increase in milk/cow/day.		Inoculated alfalfa haylage = 0.25 lbs increase in milk/cow/day.	
Milk gained per ton of crop ensiled, lbs	56.0 cow days × 0.25 lbs of milk = 14.0 lbs milk gained/ton ensiled.		64.3 cow days × 0.25 lbs of milk = 16.0 lbs milk gained/ton ensiled.	
Milk value gained per ton ensiled, $	14.0 lbs of milk × $0.125/lb = $1.75 gained value/ton ensiled.		16.0 lbs of milk × $0.125/lb = $2.00 gained value/ton ensiled.	
Combined efficiencies	($8.70 + $1.75) × ($2.78 + $1.00)[3,4] = $6.67 gained value/ton of crop ensiled.		($19.57 + $2.00 × ($5.62 + $1.00)[7,4] = $14.95 gained value/ton of crop ensiled.	
Bottom line:				
Additional cost	32.6 lbs × 305 days ÷ 2000 = 5.0 tons/cow/yr. 5.0 tons ÷ 0.9125 = 6.1 tons to ensile/cow/yr[8]. 6.1 tons × $1.00/ton = $6.10/cow/yr. $6.10 ÷ 305 days = $0.02/cow/day.		28.0 lbs × 305 days ÷ 2000 = 4.3 tons/cow/yr. 4.3 tons ÷ 0.90 = 5.3 tons to ensile/cow/yr[8]. 5.3 tons × $1.00/ton = $5.30/cow/yr. $5.30 ÷ 305 days = $0.017/cow/day.	
Additional income	5.0 tons × $6.67 = $33.35/cow/yr. $33.35 ÷ 305 days = $0.11/cow/day.		4.3 tons × $14.95 = $64.28/cow/yr. $64.28 ÷305 days = $0.21/cow/day.	
Increased net income	$0.11 - $0.02 = $0.09/cow/day. $0.09 × 305 days = $27.45 /cow/yr.		$0.21 - $0.017 = $0.19/cow/day. $0.193 ×305 days = $57.95 /cow/yr.	

[1]87.0 lbs of milk/cow/day × 0.8 "cow days" gained per ton ensiled. [2]69.6 lbs of milk × $0.125 per lb = $8.70 gained value per ton ensiled. [3]Haylage + grain mix costs/cow/day = $3.47 × 0.8 cow days = $2.78 added cost per ton ensiled. [4]Treatment (inoculate) cost = $1.00 per ton ensiled. [5]87.0 lbs of milk/cow/day × 1.8 "cow days" gained per ton ensiled. [6]156.6 lbs of milk × $0.125 per lb = $19.57 gained value per ton ensiled. [7]Corn Silage + grain mix costs/cow/day = $3.12 × 1.8 cow day = $5.62 added cost per ton ensiled. [8]Assumes a 91.25% "forage in" vs. "silage out" for the corn silage; 90.0% for alfalfa haylage. An additional 10 percent was included in the tons ensiled as an inventory insurance protection.

Achieve a Higher Silage Density

First, density and crop dry matter (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. Ruppel *et al*. (1995) 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 3). They 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, Muck and Holmes (1999) measured silage densities over a wide range of bunker silos in Wisconsin, and the densities were correlated with crop/forage characteristics as well as 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 distribution were also measured.
The range of DM contents, densities, and average particle size observed in the hay crop and corn silages are shown in Table 4. 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 50% 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 14.0 lbs/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 avalanch of silage from the feedout face pose serious risks.

Table 3. 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 4. 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
Avg particle size, inches	0.46	0.3-1.2	0.43	0.3-0.7

Protect Silage from Air and Water

Until recently, most large bunker, trench, or drive-over pile silos 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, DM losses in the top 1 to 3 feet can exceed 60 to 70% (Bolsen *et al*., 1993). This is particularly disturbing when considering, in a typical horizontal silo, 15 to 25% of the silage might be within the top three 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 (Holthaus *et al*., 1995).

The most common sealing method is to place a polyethylene sheet (6 mil) over the ensiled forage and anchor it down with discarded tires (approximately 20 to 25 tires per 100 ft^2 of surface area). Dairy 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.

Manage 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 surface area 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 6-12 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 high-moisture (HM) ensiled grains and whole-plant corn, sorghum, and winter cereal silages. Hoffman and Ocker (1997) fed aerobically stable and unstable HM shelled corn to mid-lactation cows for three, 14-day periods. Milk yield of the cows fed the aerobically deteriorated HM corn declined by approximately 7 lbs per cow per day during each period compared to cows fed fresh, aerobically stable HM corn.

Discard Spoiled Silage

Sealing a silage mass using a polyethylene sheet anchored with tires is not 100 percent effective. Aerobic spoilage occurs to some degree in virtually all 'sealed' silos; and the discarding of surface spoilage is not always a common practice on the farm. But results of a recent study at Kansas State University showed that feeding surface spoilage had a significant negative impact on the nutritive value of a whole-plant corn silage-based ration (Whitlock *et al*., 2000).

The original top three 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 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 organic matter (OM), neutral detergent fiber (NDF), and acid detergent fiber (ADF) digestibility (Table 5). 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.

Table 5. Effect of the level of spoiled silage on DM intake and nutrient digestibilities

	Ratio of normal:spoiled silage in the ration			
Item	100% normal	75:25	50:50	25:75
Spoilage layer, %[1]	0	5.4	10.7	16.0
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]

[1] The percent of the "slimy" layer silage in the ration (DM basis).
[a,b,c] Means within a row differ (P<.05).

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