Silage Management: Five Key Factors

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INTRODUCTION

Five important silage management factors in the control of the silage maker and often poorly implemented or overlooked entirely, are-- inoculating, packing, sealing, managing the feedout face, and discarding spoiled silage.

Perhaps no other area of silage management has received as much attention among both researchers and livestock producers in the last two decades as bacterial inoculants (Bolsen et al., 1995). Today, inoculants are the most widely used silage additive in North America. The economic benefits of bacterial inoculants are summarized in this paper, with emphasis on high-producing dairy cows being fed a corn silage/alfalfa haylage-based ration.

The factors that affect silage densities in a bunker, trench, or drive-over pile silo are not completely understood. Recommendations have typically been to spread the chopped forage in thin layers and pack continuously with heavy, single-wheeled tractors. A recent study is summarized in this paper, which measured silage densities over a wide range of bunker silos on farms in Wisconsin. The densities were correlated with crop/forage characteristics and harvesting and filling practices.

Plastic sheeting was first used to protect the surface of small *clamp* silos from air and rain or snow in Europe in the 1950s (Shukking, 1976). By the 1960s, sheets were usually made from polyethylene and ultra-violet stabilizers were added to prevent the material from disintegrating in sunlight. The great benefit of plastic sheeting was that air movement in and out of the silo could be reduced and as a result surface waste could be minimized. Yet, from the 1960s to early 1990s, most large bunker, trench, or drive-over pile silos in North America were left unsealed -- why? Because farmers 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. However, a much higher percent of the silos are being sealed with plastic sheets today. The economic benefits of sealing bunker silos are presented in this paper. These few simple equations can be hand-calculated or incorporated into a computer spreadsheet.

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 although recommended, the discarding of surface spoilage is not always a common practice on the farm! However, results of a recent study at Kansas State University showed feeding surface spoilage, which had developed in the top 3 feet of an unsealed bunker silo of corn silage, had a significant negative impact on the nutritive value of a whole-plant corn silage-based ration.

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 and Bolsen (1991); Muck (1993); Kung and Muck (1997); and Muck and Kung (1997).

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 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 liveweight 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 of 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) 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 lactic acid bacteria **(LAB)** per gram of *hay crop* 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.

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 per cow per day	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 = $6.11/cow/yr $6.11 ÷ 305 days = $0.02 /cow/day		28.0 lbs × 305 days ÷ 2000 = 4.27 tons/cow/yr 4.3 tons ÷ 0.90 = 5.2 tons to ensile/cow/yr[8] 5.2 tons × $1.00/ton = $5.20/cow/yr $5.20 ÷ 305 days = $0.017 /cow/day	
Additional income per cow per day	5.00 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 = $0.193/cow/day $0.193 ×305 days = **$58.86** /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, and an additional 10 percent was included in the tons ensiled as an inventory insurance protection.

Table 3: Dry matter loss as influenced by silage density[1]

Density (lbs of DM/ft^3)	DM loss at 180 days, % of the DM ensiled
10	20.2
14	16.8
15	15.9
16	15.1
18	13.4
22	10.0

[1] Adapted from Rupple (1992).

ACHIEVE AN OPTIMUM SILAGE DENSITY

Attaining a high density of the ensiled forage in a silo is essential for two reasons. First, and most important, density and DM content determine the porosity of the silage. Porosity, in turn, sets the rate at which air can enter the silage mass and, subsequently, the amount of spoilage that occurs during the storage and feedout periods. Rupple (1992) 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). Second, the higher the density, the greater the capacity of the silo. Thus, higher densities typically reduce the annual cost of storage per ton of crop by both increasing the amount of crop entering the silo and reducing crop losses during storage.

Methods used in the Wisconsin survey. Twenty collaborating county extension agents in Wisconsin measured densities in over 160 bunker silos, which were filled with either hay crop (primarily alfalfa) or whole-plant corn silages. Density was measured with a 2-inch diameter corer, taking cores at approximately 4 ft above the floor of the silo at four locations across the silage feedout face. Core depth, distance from the top surface, and distance from the floor were recorded. The cores and a random silage sample from each bunker were express mailed to the U.S. Dairy Forage Research Center for determination of weight, DM content, and particle size distribution. A survey was completed for each silo sampled and the information included: crop, stage of maturity, theoretical length of chop, number of packing tractors, tractor weight, number of tires per tractor, tire pressure, tire condition, number of drive wheels, silage delivery rate (tons/h), packing time per day (h), harvest time per day (h), filling time (h), filling technique, initial layer thickness (inches), silo dimensions, and maximum silage depth. These factors were then correlated with the measured DM densities.

Results of the Wisconsin survey. The range of densities and DM contents observed in hay crop and corn silages are shown in Table 4. Ranges of DM densities were similar for both hay crop and corn silages. The lowest densities suggested only minimal packing, while the highest densities were in the range typically observed in tower silos. Average DM densities were slightly higher than the recommended minimum density of 14.0 lbs/ft^3 on a DM basis.

Table 4: Summary of core sample analysis from 168 bunker silos.

Silage characteristic	Hay crop silage (87 silos)			Corn silage (81 silos)		
	Avg	Range	SD*	Avg	Range	SD*
Dry matter, %	42	24-67	9.50	34	25-46	4.80
Density on a fresh basis, lbs/ft^3	37	13-61	1.9	37	23-60	8.3
Density on a DM basis, lbs/ft^3	14.8	6.6-27.1	3.8	14.8	7.8-23.6	2.9
Avg particle size, inches	0.5	0.3-1.2	0.2	0.4	0.3-0.7	0.1

*SD = standard deviation.

The DM densities were positively correlated with the depth of silage above the location of the core sample, which clearly illustrated the benefit of *self-compaction* in bunker silos. To put densities on a common basis, all DM densities were adjusted to the median depth below the surface of the ensiled mass (7.0 ft) using equation 15 of Pitt (1983) and assuming a compressibility of 1.5×10^{-5} Pa^{-1}. The adjusted DM density was positively correlated with the average packing tractor weight (**W**, lbs), packing time (**T**; number of tractors x h/ton, fresh basis), and DM content (**D**; %). Density was inversely correlated with the initial depth of the crop when spread in the silo (**L**; inches). These factors combined together as follows:

$$\frac{W}{L}\sqrt{T \cdot D}$$

and explained only 18% of the variation. The use of rear dual tires or all dual tires on the packing tractor had little effect on density of the silage. Other factors, such as tire pressure, crop, and average particle size, were not significantly correlated with density of the silage. Thus, the low r^2 of the four-parameter packing factor probably reflects variability in accurately estimating parameters such as initial depth of the crop and packing time per ton, rather than any of the missing factors, which could also be important in determining the density of the ensiled forage.

One very practical issue raised in this study was packing time relative to the chopped forage delivery rate to the silo. 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) and generally declined with an increasing delivery rate. Packing times were consistently less than 1 min/ton on a fresh basis at delivery rates above 60 tons/h in the survey. These results suggest that farmers who use silage contractors for harvesting their crops should pay particular attention to spreading the crop in as thin a layer as possible in the bunker and use several packing tractors simultaneously.

The following options are suggested as ways to increase the packing factor and, thus, the DM density:

a. Reduce the delivery rate of chopped forage to the bunker, which increases the packing time per ton.
b. Decrease the packing layer thickness (i. e., from 12 to 6 inches).
c. Increase the depth of forage when the bunker silo is full.
d. Increase the DM content of haycrop forages by allowing a longer field-wilting time.
e. Increase the average tractor weight by adding more weight to each tractor, or by replacing one or more existing tractors with a heavier one.
f. Add more packing tractors. Use heavier rather than lighter tractors so the average weight is not reduced when a tractor is added.
g. Pack for additional time each day.

Options a. to d. are somewhat difficult to accomplish, especially if the harvest rate and bunker silo are both being *pushed to the limit*. Very few farmers or silage contractors will be inclined to slow the harvest rate so that additional packing can be accomplished. The most efficient fermentation process for an ensiled forage typically occurs in the range of 30-40% DM content. Increasing the DM content above 40% to improve density is likely to be counterproductive for an optimum fermentation. If the bunker silo is full, adding chopped forage above the *full mark* will be dangerous.

Options e. to h. are more often within the control of the farmer. Those who achieve high packing densities have adopted the use of very heavy tractors and use a shallow (less than 6-12 inches) packing layer thickness. When the delivery rate of chopped forage to the silo is quite high (as with self-propelled forage harvesters operating in a field of whole-plant corn), one or more additional packing tractors are added. In a properly-packed bunker silo, the tires of each packing tractor will pass over the entire surface of the layer of chopped forage being packed at least once.

PROTECT SILAGE FROM AIR AND WATER

Bunker, trench, and drive-over pile silos are economically attractive for storing large amounts of ensiled forage, but because so much of the surface of the ensiled material is exposed to air and rain, DM and nutrient losses can be extensive. If left unprotected, losses in the top 1.5 to 3.0 ft can exceed 50%. This is particularly disturbing when one considers that in the typical horizontal silo, over 20% of the silage might be within the top 3.0 ft. Furthermore, these losses cannot be seen until the silo is opened, even then, the spoilage is only apparent in the top 6 to 12 inches of silage, obscuring the fact that this area of spoiled silage represented substantially more silage when originally stored.

Top spoilage losses can only be minimized by sealing (covering) the ensiled mass with polyethylene sheets, which usually are weighted with tires or soil. Although this method reduces loss of nutrients, it is so awkward, cumbersome, and labor intensive that many producers feel the silage saved is not worth the time and effort required.

Top spoilage research has been conducted at Kansas State University since 1989, and the results document the magnitude of the DM and nutrient losses in the original top 3.0 ft of the ensiled crop.

Provided here are a few simple equations, that can be hand-calculated or incorporated into a computer spreadsheet (Huck et al., 1997). They allow producers to estimate the value of silage saved by sealing, based on the crop value, silo dimensions, cost of the sealing material, and labor to put the cover on and remove it during the feedout period.

Economics of sealing bunker silos. Calculating the value of silage saved by sealing is based on four economic inputs and two silo/silage inputs. The four economic inputs are:

1) Value of the silage ($/ton)
2) Cost of the polyethylene sheet (cents/ft^2 × number of ft^2)
3) Cost of the weighting material (zero was used in the examples)
4) Labor cost ($/hr × number of hrs).

Ten hours per 4,000 ft^2 of polyethylene sheet were used to calculate the labor cost. In order to account for overlapping from sheet to sheet and along the sidewalls or base, a covering efficiency of 80% was used.

The first of the two silo/silage inputs determines the amount of silage within the original top 3.0 ft of the silo after filling is complete. It is determined by multiplying the silo width (ft) by length (ft) by depth of interest (3.0 ft) by the silage density (lbs/ft^3) and dividing the product by 2,000 (lbs/ton).

The second silo/silage input estimates the amount of silage within the original top 3.0 ft of the silo that is lost as spoilage. These values (20% if sealed or 50% if unsealed) are based on research conducted at Kansas State University (Dickerson et al., 1991; Dickerson et al., 1992; Bolsen et al., 1993; and Holthaus et al., 1995).

The following example estimates the net return from sealing a horizontal silo 40 ft wide by 100 ft long (4,000 ft^2).

Economic assumptions:

1) Corn silage price: $25/ton
2) Polyethylene film: $0.055 per ft^2 of surface covered.
   $0.055 × 4,000 ft^2 = $220
3) Weighting material: zero cost assumed
4) Labor cost:
   10 hr per 4,000 ft^2 sheet × $20/hr = $200
   Sealing cost = $220 + $200 = $420

Silo/silage assumptions:

1) Assuming a silage density of 45 lbs/ft^3 (4,000 ft^2 surface 3.0 ft deep × 45 lbs/ft^3) ÷ 2,000 = 270 tons of silage within the original top 3.0 ft (total capacity of the silo is about 1,080 tons)
2) Assume 20% loss in the top 3.0 ft if sealed, 50% loss if unsealed.

Loss, unsealed:

270 tons × \$25/ton × 50% = \$3,375

Loss, sealed:

270 tons × \$25/ton × 20% = \$1,350
Cost of sealing = \$ 420
Net, sealed = \$1,770

Net return to sealing:

\$3,375 – \$1,770 = \$1,605

Although future technology might introduce a more environmentally and user-friendly product, polyethylene (6 mil) is the most effective sealing material available today. The most common sealing method is to place the polyethylene sheet over the ensiled forage and weight it down with discarded rubber tires (approximately 20 to 25 tires per 100 ft^2 of surface area).

Research-based calculations confirm that the financial loss incurred by not sealing silage is substantial and reinforces our recommendation that sealing the exposed surface of a bunker, trench, or drive-over pile silo is one of the most important management decisions in any silage program.

MANAGING THE FEEDOUT FACE

The silage feedout *face* should be maintained as a smooth surface that is perpendicular to the floor and side walls (in bunker, trench, and drive-over pile silos). This will minimize the square meters of surface that are exposed to air. The rate of progression through the silage mass must be sufficient to prevent the exposed silage from heating and spoiling. An average removal rate of 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 milk to dough stage whole-plant cereal silages.

IMPLICATIONS OF FEEDING SPOILED SILAGE

Whole-plant corn silage is a major source of energy in most growing cattle and lactating dairy cattle rations in North America, and an increasing percentage of it is being stored in bunker, trench, stack, and drive-over pile silos. Sealing with a polyethylene sheet weighted with tires is not 100 percent effective, and 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! What producers and researchers did not know previously were the nutritional consequences of mixing spoiled silage with well-preserved silage. However, results of a recent study at Kansas State University showed that feeding surface spoilage, which had developed in the top 3.0 ft of an unsealed bunker silo of corn silage, had a significant negative impact on the nutritive value of whole-plant corn silage rations (Whitlock, 1999).

Twelve crossbred steers, fitted with ruminal cannulas, were used in the study. A single source of irrigated corn was harvested at the 80% milkline stage of maturity and chopped to a 3/8 inch particle length. Three pilot-scale bunker silos, 3.0 ft deep, and a 40.0 ft section of a 9.0 ft diameter AgBag® were filled with alternating loads of chopped forage. After 90 days, the bunkers were sealed with single sheets of 0.6 mil polyethylene, and these silages were designated *spoiled*. The silage in the AgBag® was designated as *normal*. 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 diets were fed once daily at 0700, and the amount fed was adjusted so that approximately 10% of the as-fed ration was in the feed bunk at the end of each 24-hr period.

The pH and chemical composition of the whole-plant corn silages fed in the metabolism trial are shown in Table 5. The composition of the spoiled silages is reported for each of the two distinct visual layers, designated as the original top 18 inches and bottom 18 inches, and for a composite of the two layers after they were mixed, which represents the spoiled silage as it was actually fed in rations B, C, and D. With ash content as the internal marker, the estimated proportion of the original top 18 inches and bottom 18 inches spoilage layers in the spoiled composite silage was 23.8 and 76.2%, respectively. The normal corn silage had higher DM and OM contents and slightly lower starch and CP contents than the spoiled composite silage. The normal corn silage also had low NDF and ADF percentages, which reflect the high proportion of grain in the ensiled crop.

The high ash and fiber contents of the composite silage are associated with poor preservation efficiency and large OM losses during the aerobic, fermentation, and storage phases.

The original top 18 inch layer was visually quite typical of an unsealed layer of silage that has 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 the 90-day storage was also 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, e.g., a bright yellow to orange color, a low pH, and a very strong acetic acid smell.

Table 5: Chemical composition and pH of the whole-plant corn silages fed in the metabolism trial**.**

Silage	pH	DM	OM	Starch	CP	NDF	ADF
		%		---------------- % of the DM ----------------			
Normal	3.90	38.0	94.7	22.3	6.9	42.6	23.4
Spoiled top layer, composite of the original top 36 inches	4.89	26.4	90.9	21.3	9.4	48.9	31.0
<u>Spoiled layers</u>							
Original top 0 - 18 inches (slime layer)	8.22	19.1	80.0	2.7	17.7	57.6	48.3
Original top 18 - 36 inches (acidic layer)	3.67	27.6	94.3	26.1	6.7	45.5	25.5

Table 6: Effect of the level of spoiled silage on nutrient digestibilities for steers fed the four whole-plant corn silage rations**.**

	Ration			
Item	A	B	C	D
DM intake, lbs/day	17.5[a]	16.2[b]	15.3[b,c]	14.7[c]
DM intake, % of BW	2.36[a]	2.22[b]	2.10[b,c]	2.04[c]
	------------------------- Digestibility, % -------------------------			
DM	74.4[a]	68.9[b]	67.2[b]	66.0[b]
OM	75.6[a]	70.6[b]	69.0[b]	67.8[b]
Starch	94.6	95.0	93.3	95.3
CP	74.6[a]	70.5[b]	68.0[b]	62.8[c]
NDF	63.2[x]	56.0[y]	52.5[y]	52.3[y]
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 ($P<.05$).
[x,y] Means within a row with no common superscript differ ($P<.10$).

The original depth of the packed, whole-plant corn in the bunker silos was about 36 inches; however, the final depth of the spoiled silage was only about 22 inches, with approximately 7 and 15 inches in the top and bottom depths, respectively. This settling of the ensiled crop that occurred during the 90 days the bunker silos were unsealed, e.g., approximately 14 inches, is typical of settling depths observed in unsealed bunker, trench, or drive-over pile silos.

The addition of surface-spoiled silage had large negative associative effects on feed intake and DM, OM, NDF, and ADF digestibilities (Table 6). The first increment of spoilage had the greatest negative impact. When the rumen contents were evacuated, the spoiled silage also had partially or totally destroyed the integrity of the *forage mat* in the rumen. The results clearly demonstrated that surface spoilage reduced the nutritive value of corn silage-based rations more than was expected.

Future research should focus on the effect of feeding this surface spoilage on livestock performance and on the potential hazards to livestock

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