

Efficiency in Silage Preservation

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INTRODUCTION

Few farming operations invite as many different opportunities for injury or fatality as a silage program (Murphy 2007). Silage-related tragedy knows no age boundary as workers and bystanders of all ages have been injured or killed during silage harvest and feedout (Murphy and Harshman, 2006). Although silage injury statistics are not easily collated, countless stories of PTO and harvesting machine entanglements, highway mishaps between farm equipment and automobiles, entanglement in self-unloading wagons and blowers, and encounters with silo gas exist. Increasingly, stories involve bunker silos and drive-over piles (Murphy and Harshman, 2006; Murphy, 2007; Ag Weekly, 2008; and Bolsen and Bolsen, 2010).

From 2008 to 2012 an average of 99.3 million metric tons of whole-plant maize was harvested annually for silage in the USA (USDA, 2013). The amount of silage lost each year as a result of “shrink”, defined as tons of crop ensiled minus tons of silage fed, is too high in too many silage programs. It is estimated that between 16 and 20 percent of the corn silage put up in the U.S. this past year will be lost. That is about \$1.1 to 1.3 billion in feed inventory. If the U.S. could achieve a single digit shrink, the loss would about a \$600 million loss in corn silage. Almost all of the livestock operations could make improvements, which would not only allow them to feed a higher percent of their silage inventory, but also improve silage quality.

Presented here are three hazards involved with managing silage in bunker silos and drive-over piles, and the primary ways these hazards can be eliminated, reduced or controlled. Also presented are two management practices, which have the potential to decrease dry matter (DM) loss by 5 to 10 percentage points and have a positive effect on safety in bunkers and piles: achieving a high silage density and more effective sealing.

SILAGE SAFETY HAZARDS

Hazard one: tractor or truck roll-over

Tractor roll-overs account for about 50 percent of the approximately 200 tractor-related fatalities reported annually in the USA (**Figure 1**). Roll-over protective structures (ROPS) create a zone of protection around the tractor operator. When used with a seat belt, ROPS prevent the operator from being thrown from the protective zone and crushed by the tractor or equipment drawn by the tractor. A straight drop from a concrete retaining wall is a significant risk, so never fill higher than the top of a wall. Sight rails should be installed on above ground walls. Lights should be added to the rail if filling occurs at night. Always form a progressive wedge of forage when filling bunkers or piles. The wedge provides a slope for packing, and a 1 to 3 slope, or shallower, minimizes the risk of a tractor roll-over. Backing up the slope can prevent roll backs on steep

slopes. Use low-clearance, wide front end tractors equipped with well lugged tires to prevent slipping and add weights to the front and back of the tractors to improve stability. When two or more pack tractors are used, establish a driving procedure to prevent collisions.

Large-scale beef and dairy operations typically use trucks for transporting chopped forage to the bunker or pile (Swartz, 2010). Dump trucks can roll over on steep forage slopes, particularly if the forage is not loaded and packed uniformly. Trucks are less stable as the bed is raised, particularly if the surface is not perfectly flat. A tire rut or depression from a previous load, low tires on one side of a truck, uneven loading of a truck or a wind gust increase the risk of a truck tipping over during unloading, especially when two or more of these hazards combine at a single time point.

Figure 1. The front-end loader bucket blocking is the vision of the pack tractor operator (left). The silage truck and packing tractor operators are in dangerous positions above the wall in a bunker silo being filled with field-wilted alfalfa (center and right).



Hazard two: crushed by collapsing/avalanching silage

A major factor contributing to injury or fatality from avalanche/collapsing silage is over-filled bunker silos and drive-over piles (Holin, 2010a) (**Figures 2, 3, and 4**). On December 3, 1999, at 3:45 p.m., six tons of haylage in a bunker silo collapsed on Nick Schriner of Athens, Wisconsin. Schriner was rescued in a matter of minutes but he suffered a C6 spinal cord injury, which classifies him as a quadriplegic (cited by Bolsen and Bolsen, 2012b).

Figure 2. The payloader operators are at risk from collapsing corn silage in the over-filled bunker silos (left and center) and over-filled pile (right).



It started out as a typical day for dairy nutritionist Doug DeGroff of Tulare, CA (Holin, 2010b). He pulled up to a client's corn silage pile for a forage sample, bucket and pitchfork in hand. After filling the bucket, he turned to walk back to his pickup to mix and core a sample. "The sun basically went out – I could not see any light and the feed hit me on my head and covered me completely," says DeGroff. "I knew what was happening before I hit the ground. The entire face fell on me ... about 18 tons broke away." DeGroff, who had celebrated his 36th birthday with his

wife and two toddlers two days before August 27 last summer, was caught in a silage avalanche. DeGroff offered these additional comments, “This particular pile did not look unsafe at all. It was only 3.4 to 3.6 meters tall at the time that I sampled it and was mechanically shaven. I personally have taken feed samples from piles where I should not have been. I knew they were not safe, but I took the risk. This pile looked safe from any angle you looked at it from. I feel very blessed to be here and that everything still works. Yes, it was a broken back, but it could have been so much more. I am not on pain medication, and I don’t think there are going to be long-term issues.”

Figure 3. The photos of the two bunker silos (left and center) and pile (right) were taken minutes after the avalanches occurred. The person operating the payloader was not seriously injured.



Figure 4. Over-filled bunker silos of corn silage (left and center) and alfalfa haylage (right).



An 11-year old boy died from injuries suffered after a feed pile collapsed on top of him at a Claremont farm (WMUR TV, 2010). Andy Wheeler had previously been listed in critical condition at Dartmouth-Hitchcock Medical Center. Police said it took as long as 20 minutes to find and free Wheeler from the feed pile after the accident Tuesday. Police said the boy was on vacation from Maple Avenue School, which is why he was hanging out at the MacGlaflin Farm, where his father works. He was riding his bike near a silage crib, where livestock feed is stored, police said. “The boy was in a silage crib where there was a large pile of silage, and that overhang collapsed,” said Police Chief Alexander Scott. Scott said it took some time for anyone to realize there was a problem. When he was found, an adult started CPR, and the boy was taken to a hospital. “It’s probably a pile close to 7.6 meters high, so when they are taking silage out, they are digging it out and that can result in an overhang,” he said.

Sugar Valley Volunteer Fire Company responded to a farm accident in Greene Township after Kenneth R Hettinger, 63, of Rebersburg, PA, became entrapped under three tons of silage (The Express, 2007). Fire personnel said farm employees removed Hettinger from the silage. Fire company volunteers attempted to resuscitate Hettinger but were unsuccessful, and he was pronounced dead at the scene.

Even if the pile looks like it should be safe – it is not. Here is an email written by a Ph.D. nutritionist a few years ago (Bolsen and Bolsen, 2013). “I had a near miss earlier this year. I was taking core samples at a large dairy customer’s pile of corn silage and had just moved away from the face when a large section just fell off. This was a very well packed pile and had immaculate face management.”

Here are guidelines that can decrease the chances of having serious accident caused by a silage avalanche (Holmes and Bolsen, 2009 and Bolsen and Bolsen, 2012a).

- Bunker silos and piles should not be filled higher than the unloading equipment can reach safely, and typically, an unloader can reach a height of 3.6 to 4.3 meters.
- Use proper unloading technique that includes shaving silage down the feedout face and never “dig” the bucket into the bottom of the silage. Undercutting, a situation that is quite common when the unloader bucket cannot reach the top of an over-filled bunker or pile, creates an overhang of silage that can loosen and tumble to the floor.
- Never park vehicles or equipment near the feedout face.
- Never allow people to stand near the feedout face, and a rule-of-thumb is never stand closer to the feeding face than three times its height (**Figure 5**).
- When sampling silage, take samples from a front-end loader bucket after it is moved to a safe distance from the feedout face.
- Spreadsheet software can help livestock producers properly size bunker silos and drive-over piles (<http://www.uwex.edu/ces/crops/uwforage/storage.htm>).

Figure 5. Never stand near the feedout face. Everyone in these photos is putting their life at risk.



Hazard three: complacency

Always pay attention to your surroundings and be alert! A nutritionist, Mac Rickels from Comanche, TX, almost lost his life taking samples from a bunker silo with a 9-m face. “Even though I was standing 6 m from the feedout face, 12 tons of silage collapsed on me. I did not see or hear anything. I had been in silage pits hundreds of times, and you just become kind of complacent because nothing ever happens. It just took that one time” (Schoonmaker, 2000).

At a recent Pennsylvania State University Forage Focus seminar, several farmers told of close calls while shaving bunker or pile feedout faces that seemed safe but collapsed quickly (Hay and Forage Grower, 2010). One told of the death of a worker while taking samples. “All three workers went up to the face and they pulled a sample, turned to walk away and the pile just fell away. It hit ... two people from the back and knocked them down. The other guy was walking toward the loader and it completely covered him up. We are still having a hard time dealing with

that.” After the accident, the farm developed a safety plan. “Our policy is that nobody is allowed closer to the bunker face than the height of the bunker long. No exceptions. If there is a tire there, we will get it later. If there is a forage sample, you better take it with a bucket. We thought that it wasn’t an issue, just like everybody else thought it wasn’t an issue. Then it happened to us. You don’t know what a bunker face is like.”

“The accident happened on June 14, 1974 while making silage at Kansas State University’s Beef Cattle Research Farm. The blower pipe plugged for about the eighth time that afternoon, and I started to dig the forage out from the throat of the blower. The PTO shaft made one more revolution. Zap! The blower blade cut the ends off of three fingers on my right hand”. The injured person, Keith Bolsen, said later, “I was complacent and in a hurry to fix the problem, and I did something pretty stupid” (cited by Bolsen and Bolsen, 2006).

ACHIEVING A HIGHER SILAGE DENSITY

Silage density and preservation efficiency, measured as DM recovery, are positively related. Higher densities also increase the storage capacity of existing bunker silos (without over-filling) and decrease the height of drive-over piles (without reducing storage capacity). However, in recent surveys on farms, results show that many producers are not achieving the recommended minimum silage density of 245 to 260 kg per m³ (690 to 730 kg fresh weight bulk density per m³) (Visser, 2005 and Craig et al., 2009).

Case study beef cattle feedlot’s bunker silo

The actual first-year corn silage had a DM density of approximately 200 to 210 kg per m³. The Holmes-Muck spreadsheet was used to estimate the second-year corn silage density at two forage delivery rates (122.5 and 245 fresh tons per hour) and one, two, or three pack tractors (Holmes and Muck, 2007). Results are shown in **Table 1**.

The target density for second-year was 245 kg of DM per m³ (740 kg of fresh weight per m³). At a forage delivery rate of 122.5 tons per hour, two pack tractors were needed to reach the target (262 kg of DM and 780 kg fresh weight per m³). However, the expected forage delivery rate was about 245 tons per hour, and the estimated density would only be 168 kg of DM per m³ (505 kg fresh weight per m³) with one pack tractor and 204 kg of DM per m³ (612 kg fresh weight per m³) with two pack tractors. By adding a third pack tractor, the estimated density was 246 kg of DM per m³ (739 kg fresh weight per m³), which would reach the target. But more importantly, the higher silage density with the third tractor would lower the height of the feedout face from about 4.5 m to about 3.9 to 4.1 meters.

Several key considerations to improve density, which were presented by Holmes (2006) and Holmes and Bolsen (2009) and Bolsen (2013), include:

- Good communication is essential. For example, if forage delivery rate increases at any time during the day, you must be prepared to add an extra pack tractor.
- Producers should estimate silage density before the harvest begins using spreadsheet software (Holmes and Muck, 2007 and Holmes and Muck, 2008) and should be prepared to adjust their harvesting, filling and packing procedures.

- Employ well trained experienced people, especially those who operate the push-up/blade tractors. Provide training as needed.
- When pushing up, forage should be skimmed from the edge of the load of forage.
- Forage should be spread in uniform layers of 15 cm or less and packing must be done continuously during the entire filling process.
- Form a progressive wedge of forage and maintain a maximum slope of 1 to 3 (one meter of rise for each three meters of horizontal).
- The slope can be decreased to 1 to 4, depending on the forage delivery rate and number of pack tractors.
- Increase the weight of all push-up and pack tractors
- Abut the pack tractor tire with the track of the previous tractor pass.
- There should be at least two pack tractor passes over the surface of each layer of forage.
- Drive-over piles should be packed from side-to-side, as the progressive wedge advances, and the sides of the pile should never exceed a slope of 1 to 3.
- When two or more pack tractors are used, establish a driving procedure.
- When possible, drive up and back down packing slopes. Do not drive tractors in a circle and avoid making 180 degrees turns on the floor of a bunker or front apron of a pile.
- Increase pack tractor passes near the wall of bunker silos to increase the density of the forage that is within one meter of the wall.

MORE EFFECTIVE SEALING OF BUNKER SILOS AND DRIVE-OVER PILES

Bunkers and piles, by design, allow a large percentage of the ensiled material to be exposed to the environment. Although polyethylene sheeting, which is typically weighted with discarded car or truck tires or tire sidewalls, has been the common method used to protect silage near the surface, the protection provided is highly variable and often changes during storage (Holmes and Bolsen, 2009). Many livestock producers are quick to point out that putting tires on plastic is not an activity enjoyed by most employees. At the XII International Silage Conference, an oxygen barrier (OB) film (Silostop) was introduced as an alternative to standard black or white on black polyethylene to seal bunkers and piles. The OB film, which is 45µm in thickness, has dramatically improved the preservation efficiency and nutritional quality of silage in the outer 0 to 90 cm in bunkers and piles.

Economics of sealing bunker silos and drive-over piles

Excel spreadsheets to calculate the profitability of sealing ensiled forage or HM grain in bunker silos and drive-over piles were developed from research at Kansas State University from 1990 to 1995 and equations published by Huck et al. (1997).

Two examples are shown in **Table 2** (Bolsen et al., 2012). In a 18 m wide x 88 m long bunker silo of corn silage, which has an average depth of 3.35 m, OB film would save an extra \$5,086 of silage in the original top 0.75 m compared to standard plastic. In a 27 m wide x 75 m long drive-over pile of alfalfa haylage, which has an average depth of 1.83 m, OB film would save about \$5,477 of haylage in the original top 0.75 m compared to standard plastic.

CONCLUSIONS

Think safety first! Silage-related injury knows no age boundary as workers and bystanders of all ages have been killed in a silage accident (Agricultural Injury Database, 1980-2004). Even the best employee can become frustrated with malfunctioning equipment and poor weather conditions and take a hazardous shortcut, or misjudge a situation and take a risky action (Murphy, 2007). It is best to take steps to eliminate hazards in advance than to rely upon yourself or others to make the correct decision or take the perfect response when a hazard is encountered. Packing forage to higher densities in bunker silos and drive-over piles can decrease the height of the feedout face without decreasing the storage capacity. Sealing bunkers and piles with the OB film, Silostop, can prevent surface spoilage and eliminate the need to ask employees to perform a potentially dangerous task.

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¹All photos courtesy of Keith Bolsen PhD & Associates LLC. Contact co-author Ruth E. Bolsen for copies.

Table 1. Spreadsheet calculations of silage densities in a bunker silo of corn silage for a case study cattle feedlot operation¹ (Holmes and Muck, 2007).

Component	2 tractors	1 tractor	2 tractors	3 tractors
Forage delivery rate, tons per hour	122.5	245	245	245
Bunker silo wall height, m	3.66	3.66	3.66	3.66
Maximum silage height above the wall, m	0.91	0.91	0.91	0.91
Forage DM content, %	33.3	33.3	33.3	33.3
Estimated forage layer thickness, cm	15	30	20	15
Tractor 1, weight in kg	25,000 (65)²	25,000 (65)²	25,000 (65)²	25,000 (65)²
Tractor 2, weight in kg	20,400 (85)²	---	20,400 (85)²	20,400 (85)²
Tractor 3, weight in kg	---	---	---	20,400 (90)²
Estimated DM density, kg per m ³	263	168	204	246
Estimated fresh wt. bulk density, kg per m ³	790	505	612	739

¹Values in **bold** are user inputs.

²Estimated actual packing time as a percent of filling time is shown in the parenthesis.

Table 2. Profitability of sealing corn silage in bunker silos and alfalfa haylage in drive-over piles with either standard plastic or OB film (Silostop).¹

Inputs and calculations	Corn std. plastic	Corn OB film	Haylage std. plastic	Haylage OB film
Silage value, \$ per ton	60	60	90	90
Silage density in top 0.75 m, kg per m ³	675	675	600	600
Density below top 0.75 m, kg per m ³	750	750	675	675
Bunker or pile depth, m	3.35	3.35	1.83	1.83
Bunker or pile width, m	18	18	27	27
Bunker or pile length, m	88	88	75	75
Silage lost in the original top 0.75 m, % of the crop ensiled ²	30	15	22.5	10
Cost of covering sheet, ¢ per square m	54	140	54	140
Total silage in the bunker or pile, tons	3,890	3,890	2,390	2,390
Total value of silage in the bunker or pile, \$	233,442	233,442	214,873	214,873
Silage in the original top 0.75 m, tons	802	802	910	910
Value of silage in original top 0.75 m, \$	48,114	48,114	82,013	82,013
Silage below original top 0.75 m, tons	3,090	3,090	1,480	1,480
Silage lost in the original top 0.75 m by not sealing, \$	28,870	28,870	41,010	41,010
Silage saved in the original top 0.75 m by sealing, \$	14,434	21,651	22,553	30,755
Sealing cost, \$	2,782	4,913	3,556	6,280
Net value of silage saved in the original top 0.75 m by sealing, \$	11,653	16,739	18,997	24,474
Net benefit by sealing with the OB film, \$	---	5,086	---	5,477
Total silage lost in the bunker or pile, % of the crop ensiled ³	14.1	11.0	14.8	10.9

¹Values in **bold** are user inputs.

²Values derived from Bolsen et al. (1993), McDonnell et al. (2007) and Kuber et al. (2008).

³Assumes that silage lost below the original 0.75 m was **10.0 percent** of the crop ensiled