Avoiding Silage Problems

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▪ Take Home Messages

- Preservation of silage depends on the combination of low pH, fermentation acids and the absence of oxygen.
- Design silos for a minimum feed out rate of 30 cm/day from the whole face.
- For ensiling in bunkers, piles or bags, ensile between 30 and 40% dry matter (DM) for most crops except legume forages (35 to 40% DM).
- Pack bunkers and piles to achieve a minimum bulk density of 700 kg/m^3.
- Seal silos with a high quality plastic film in one or two layers, whether an oxygen barrier film or thick polyethylene film.
- Plastic film needs to be held tightly to the silage surface to prevent it from acting as a bellows drawing oxygen under the plastic.
- Plastic laid down the walls of bunker silos can reduce or eliminate shoulder spoilage.
- Seal edges and joints in plastic with continuous weighting material (gravel filled bags, piles of soil, etc.)
- Use a defacer for unloading bunkers or piles to improve DM recovery by 1 or more percentage points by making a smooth face.
- When ensiling forages that could become clostridial, ensile them separately using a homo-fermentative lactic acid bacterial inoculant and then feed after 2 to 4 weeks of storage.
- When heating issues are common, review silage management first to see if density, sealing and feed out rates are contributing to the problem and correct those issues first. If silo design and management are good, using a chemical additive or a *Lactobacillus buchneri* inoculant at ensiling can help keep silages stable.

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▪ Silage Basics

The goal in ensiling a crop is to keep its nutritional value similar to that of the crop at ensiling. If we are to realize that goal, we need to understand how ensiling preserves the crop; then, all of the recommended steps in making high quality silage will make sense. Knowledge of preservation principles helps you troubleshoot when silage quality turns out poorer than expected.

The ensiling process is straightforward. We put a crop in a structure, pile, bag or wrapped bale so we can exclude oxygen. In the absence of oxygen, lactic acid bacteria ferment crop sugars to primarily lactic acid as well as acetic acid, ethanol and other compounds. The acids lower crop pH. This fermentation may last a few days to a month or more depending on temperature and the dry matter (DM) content of the crop.

Preservation of the crop is dependent on 3 factors: low pH, the acids, and the anaerobic (oxygen-free) environment. The 3 contribute in different ways. When one is removed or not sufficient, silage quality may be compromised.

Low pH is the primary means of preventing the growth of clostridia bacteria. Clostridia produce butyric acid from sugars and lactic acid and ferment amino acids to ammonia and amines. Significant clostridial activity (typically butyric acid levels >0.5% DM) reduces intake and predisposes cows to ketosis. The necessary pH to prevent clostridia from growing depends on the DM content of the silage (Figure 1). A lower pH is needed in low DM silages to stop clostridia.

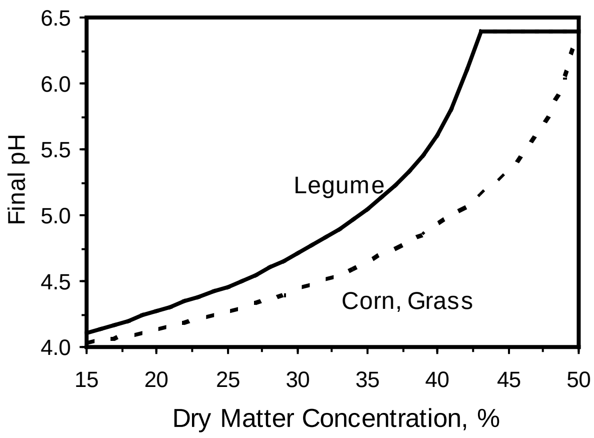

Figure 1. The pH below which growth of *Clostridium tyrobutyricum* ceases (Leibensperger and Pitt, 1987).

Lactic acid and acetic acid not only lower pH but can inhibit the growth of some microorganisms. High lactic acid concentrations (>5% DM) help prevent *Listeria monocytogenes* (cause of listeriosis in cattle and humans) in silage from growing, as well as inhibiting some spoilage bacteria. High acetic acid is effective at inhibiting yeasts and molds that spoil silages in the presence of oxygen. Acetic acid is the primary means by which inoculants containing *Lactobacillus buchneri* improve aerobic stability.

While acetic acid is good for slowing yeast and mold growth, rarely is the combination of high acetic acid concentration and low pH sufficient to prevent all spoilage microorganisms from growing. Spoilage microorganisms (whether yeasts, molds or bacteria) require oxygen to grow; so, keeping oxygen out of the silo by an effective seal is the only means of completely keeping them in check. When the silo is opened, oxygen can readily diffuse through the open face and spoilage microorganisms begin to grow potentially increasing losses, reducing silage quality, and in the worst cases, heating the silage.

▪ Silo Design

The first step, and one of the most important for avoiding silage problems, is to have a properly designed silo. Current recommendations from the University of Wisconsin are to design bunkers or piles so that a minimum of 30 cm of silage are removed from the whole face each day. When using bags, you will want to take more than 30 cm/d. These high feed out rates are recommended because there is enough oxygen 1 m back from the face of a well-packed silo to allow spoilage microorganisms to grow at full speed based on studies in Germany, Israel and the U.S. At the former recommendations of 15 cm/d, spoilage microorganisms have a week to grow before the silage is in the feed bunk. As shown in Figure 2, losses during feed out go up dramatically at low feed out rates because you are increasing the time the silage is exposed to oxygen prior to the cattle eating the silage.

Tools are available under the Harvesting and Storage section (http://fyi.uwex.edu/forage/harvest/) of the University of Wisconsin Team Forage website to help in the proper design of a bunker, pile or bag silos. To use these, you need to know the number of livestock that are being fed and the expected inclusion rate of that silage in their rations. These numbers along with estimated silage density permit a range of solutions leading to feed out rates at or above the 30 cm/day recommendation.

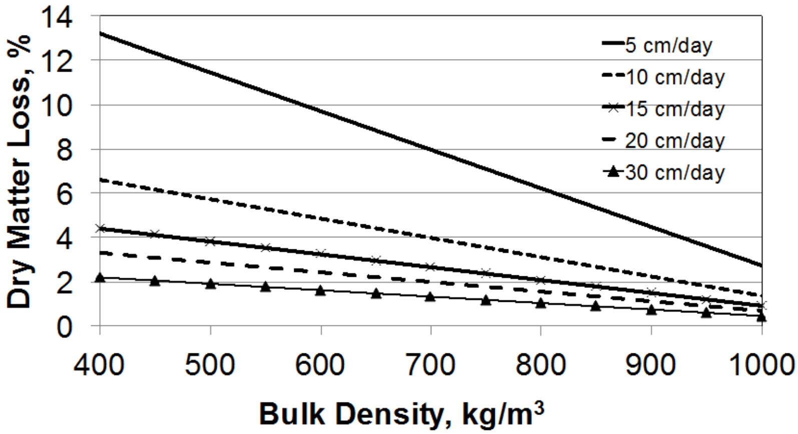

Figure 2. Simulated dry matter losses during bunker silo emptying as a function of bulk density and feed out rate based on Pitt and Muck (1993).

▪ Harvest at the Right DM Content

Ensiling at the right DM content helps to avoid a variety of silage problems. For horizontal silos, the recommended range for best ensiling results is 30 to 40% DM. Why that particular range? At less than 30% DM, there are 2 major risks. One risk is silage effluent or seepage, which is a loss of soluble nutrients from the silage, and is far more environmentally damaging than manure slurry. With tall bunkers or piles (>5 m high at the peak), you may need to ensile several points drier than 30% to avoid effluent and avalanches.

The second risk of ensiling too wet is clostridial fermentation. As indicated in Figure 1, the lower the DM content, the greater the amount of fermentation and the lower the pH needed to avoid clostridial fermentation. The level of risk depends on the crop. The risk is low with corn silage, which has a high sugar content and low buffering capacity resisting pH drop. The risk is intermediate with most grass and small grain silages. The risk is highest with legume silages like alfalfa. In Wisconsin, we typically recommend 35% DM as the minimum DM content for ensiling alfalfa because our environmental conditions make it difficult to get silage pH below 4.7; so, ensiling drier is necessary to avoid clostridial fermentation. While clostridial fermentation is rarely a problem when ensiling corn silage at less than 30% DM, there has certainly been anecdotal evidence of abnormal fermentations when corn is ensiled too wet. Also, you may be losing starch content in harvesting corn at less than optimum maturity (half to three-quarters milk line).

Ensiling too dry increases the potential for aerobic spoilage. This is discussed in more detail under packing, but a drier crop is more difficult to pack and achieve a low porosity (i.e., the fraction of volume in the silo filled with gas surrounding silage particles) that limits oxygen movement into silage from the open face or an opening in the cover.

The other major silo types have higher optimum DM ranges. With wrapped bales, the best results are from ensiling forages between 40 and 60% DM. Long forage particles do not ensile as well as chopped forage so a higher range is needed to avoid clostridial fermentation. Tower silos need drier forage to avoid effluent and also for optimum material handling.

▪ Particle Size

A range of theoretical lengths of cut is readily achievable on most forage harvesters today. Also, various types of kernel processors are commonplace for harvesting whole-crop corn. Is there a best particle size setting to avoid silage problems? Unfortunately there is not an easy answer. From an engineering perspective, small particle size (e.g., 10 mm theoretical length of cut) is best for creating a high density in the silo, which in turn limits oxygen movement into the silo and thus DM losses. However, ruminant livestock need their ration to contain some long fiber for good rumen function. If the ration contains sufficient long hay, then silage particle size is not that important and can be set low. If silages are the only sources of forage in the ration, then harvesting at a longer theoretical particle size (e.g., 20 mm) may be necessary for good livestock health.

With whole-crop grain silages, cracking the kernels is an important factor for efficient utilization of the starch. This is usually accomplished by a kernel processor on the forage harvester. Because kernel processors reduce particle size, the theoretical length of cut for the harvester is usually set higher (e.g., 20 mm). Kernel processing score for corn silage (percentage of starch passing through a 4.75 mm sieve) is now available from forage testing labs in the U.S. to assess how well kernels have been broken. Optimum scores for kernel processing in corn are values above 70%. Kernel processing is important for utilization of the starch in the silage by livestock, and not to avoid a silage management problem.

▪ Packing

The packing of bunker or pile silos may have a substantial impact on losses by minimizing the porosity, the principal factor governing the movement of oxygen into the silo whether during feed out or if there is damage to the cover. To keep porosity at approximately 40% or less (a reasonable target), you need to achieve a bulk or as-fed density of at least 700 kg/m^3.

How do you achieve high densities in bunkers or piles? Research carried out in Wisconsin by Dr. Brian Holmes (University of Wisconsin-Madison) and me indicates the most important factors are packing tractor weight, packing time/tonne of crop, crop moisture and spreading layer thickness. Density increases with heavier tractors, more packing time per tonne, higher crop moisture and spreading each load over a larger area in the silo. Taller bunkers and piles will achieve higher densities than lower ones. However, height should be restricted to the height that your unloading equipment can reach for safety reasons. Drier crops take greater effort to achieve a high bulk density. When packing piles, all slopes (sides, back, front) should be no greater than 1:3 height:length. This helps achieve a high density while providing for safe packing side-to-side as well as front-to-back. In addition, these low slopes allow for a tight seal between the cover and silage, which will minimize losses, especially during feed out.

We developed 2 spreadsheets to improve silage density (Bunker Silo Density Calculator, Silage Pile Density Calculator), and these are available on the UW Team Forage website under the Harvest and Storage section (http://fyi.uwex.edu/forage/harvest/). These spreadsheets allow you to estimate how changes in your packing practices affect density. As harvest rate increases, achieving a high density may require more than one packing tractor, and using tractors of similar weight maximizes the effect of adding more packing tractors. If a second tractor is less than half the weight of the first tractor, then the additional tractor provides little benefit. If you have a high harvest rate but small bunkers, filling 2 bunkers simultaneously with one packing tractor in each may be an alternative.

Packing bag silos properly is an art. The adjustment of density varies by the model of bagging machine. The goal is to produce as high a density as possible while maintaining a smooth bag. This is easier with corn silage than with alfalfa. A lumpy bag allows oxygen to move easily back from the face when feeding and makes the silage more susceptible to spoilage losses in warm weather.

▪ Sealing

Spoiled silage at the top of a bunker or pile is common. Unfortunately, it presents producers with a real dilemma. Do you feed the spoilage and risk the health of your herd from potentially feeding mycotoxins, listeria or other pathogens, or do you pay for the removal and risk the safety of the farmhand who removes the spoiled silage? The best alternative is to do such a good job of sealing the silo that there is no spoiled silage. There are 3 critical components to eliminating top spoilage: the quality of the plastic film, how well the joints and edges are sealed, and how well the film is held against the crop.

Let us begin with the type of plastic. Today, the only good solution for covering a silo or bale is plastic. In the past, plastic meant polyethylene, and there were different thicknesses and colors. Today, oxygen barrier films and polyethylene cling films are also available. The oxygen barrier films typically are a sandwich with an inner layer of film that is very resistant to oxygen movement covered on both sides with polyethylene.

So what film should you use to cover your bunker, pile, bag or bale? That is a difficult question to answer because no researchers have looked at all of the types and combinations of products on the market. Some researchers have done trials but looked for answers at the silo face rather than immediately under the plastic films; their results suggest there isn't much difference between films when in fact there can be substantial differences. When evaluating the research, it is very important to know how it was conducted, and in some cases it is not clear. So I am going to stick to studies we have done. These are studies done on real bunkers where we have compared the quality of the forage in the top 60 cm under the film before and after ensiling but really most of the difference is in the 15 cm immediately below the film.

Our initial studies compared 6 mil (6/1000") black polyethylene with 8.5 mil white/black polyethylene. With our various comparisons, color did not make any significant differences but thickness did. There was on average a 5-percentage point improvement in DM recovery in the top 15 cm using 8.5 mil vs. 6 mil polyethylene.

Several years later we compared the original 2 mil Silostop oxygen barrier film covered by a woven tarp to 8.5 mil polyethylene. We applied the polyethylene using our standard practice at the time, which meant that the plastic was just on top with tires and tire sidewalls completely covering the surface. The plastic was cut to lap up the wall to minimize rain entering the silage and held in place by tires. The Silostop film was used according to the manufacturer's system, which meant Silostop was placed on the bunker walls, and the tops of those sheets folded onto the top of the bunker. A top sheet of Silostop was laid over the whole top and then covered with a woven tarp secured with gravel bags. The Silostop system clearly outperformed our standard system near the walls (cores taken 60 cm away) with DM losses in the top 15 cm being reduced by 15 percentage points. The higher losses near the walls are attributable to the inadequate seal at the shoulder with the standard practice. In the middle of the sheets, DM losses were not significantly different between the 2 systems; however, pH and silage fermentation products from cores in the middle of the sheets (Table 1) did show lower pH and higher lactic acid to acetic acid ratios under Silostop, indicating less oxygen exposure under Silostop.

	Depth, cm	pH	Lactic Acid	Acetic Acid	L:A
Haylage					
White	0-15	4.89	2.5	4.0	0.6
Silostop	0-15	4.82	4.5	2.2	2.1
White	15-30	4.82	4.5	1.7	2.6
Silostop	15-30	4.75	3.8	1.4	2.7
Corn					
White	0-15	4.02	3.2	1.6	2.0
Silostop	0-15	3.98	3.0	1.2	2.6
White	15-30	4.00	4.1	1.4	2.9
Silostop	15-30	3.97	3.9	1.2	3.1

Table 1. Average silage pH and fermentation acid concentrations (% DM) in silage immediately beneath the center of 8.5 mil white polyethylene or Silostop oxygen barrier film in bunker silo trials at the U.S. Dairy Forage Research Center.

We have another comparison that adds to the picture. We compared Raven Industry's FeedFresh product, an oxygen barrier film, with their standard 5 mil polyethylene film in 2 bunker silos. On average, the FeedFresh product reduced DM losses by 8 percentage points in the top 15 cm.

Some people believe the original Silostop oxygen barrier film worked so well because of its clinginess, and today one sees thin polyethylene films that are clingy to be used as an underlayment. We have not studied these, but multiple layers of polyethylene will create a thicker barrier that should result in reduced losses whether or not the clinginess property is of any value.

Overall, research shows oxygen barrier films provide the lowest DM losses visually, indicating no spoilage has occurred. Polyethylene can perform similarly if you use an 8.5 mil product; however, 8.5 mil polyethylene is not common as a bunker cover. I would speculate most producers are using 4 to 6 mil products at a cost in DM losses of 10 to 5 percentage points, respectively, in the top 15 cm under great management.

Quality of film is not the full answer to preventing spoiled silage at the top. Sheets need to be overlapped sufficiently (at least 1 m), and the overlaps and edges secured with gravel bags or tires butted together. More than that, if any film is billowing in the wind, it can act like a bellows drawing in air around the edges of the sheet and permitting spoilage. To prevent this, the standard tires-touching-tires keep the plastic in place. Today a number of tarps (woven or expanded mesh) secured with gravel bags are available that can do a similar job of keeping the plastic tight to the silage. These tarps need to be reused for multiple years to be cost effective. In snowy places like Wisconsin, it is best to have narrow tarps laid parallel to the feed out face for easier removal during winter.

A particular problem with bunker silos is shoulder spoilage at the walls. This is caused by air infiltrating between the wall and the cover plastic as well as rain running off the plastic and through the silage at the wall. An effective way of eliminating shoulder spoilage is to place plastic down the walls prior to filling. These side wall sheets should lap onto the forage top at least 1 m at the end of filling, be covered by the cover sheet and then secured by gravel bags or tires butted together. Side wall film not only eliminates shoulder spoilage, it also limits oxygen penetration through concrete and cracks in the concrete and keeps silage acids from etching the concrete walls, extending their life.

At bunker ends or the edges of piles, it is important to have a tight seal with the ground or pad. Extend at least 1 m of plastic onto the ground or pad, and provide a continuous weighting on that film. Weighting can be soil, sand, gravel or gravel bags butted together. These typically will produce better results than tires.

Finally, inspect the plastic weekly and repair holes that develop during storage using tape designed for the film used. This is especially true for silo bags and wrapped bales as well.

▪ Feed Out

Once you open a silo for emptying, oxygen can move into the silage at the face. The exposure of the silage to oxygen and the subsequent DM losses are regulated by feed out rate as indicated in Figure 2, as well as by the porosity of the silage achieved in the packing process. By the time you get to emptying a silo, you have little ability to alter these factors, except for possibly increasing the number of animals or the amount of silage per animal being fed.

What you can do to minimize losses during feed out is to keep a smooth face and not leave piles of loose silage at the bottom of the face. The value of using a defacer versus bucket on a skid-steer or tractor provides a small but significant benefit in improved DM recovery (Figure 3). The benefit is greater if density and/or feed out rate are low. However, even under excellent conditions a defacer can pay for itself.

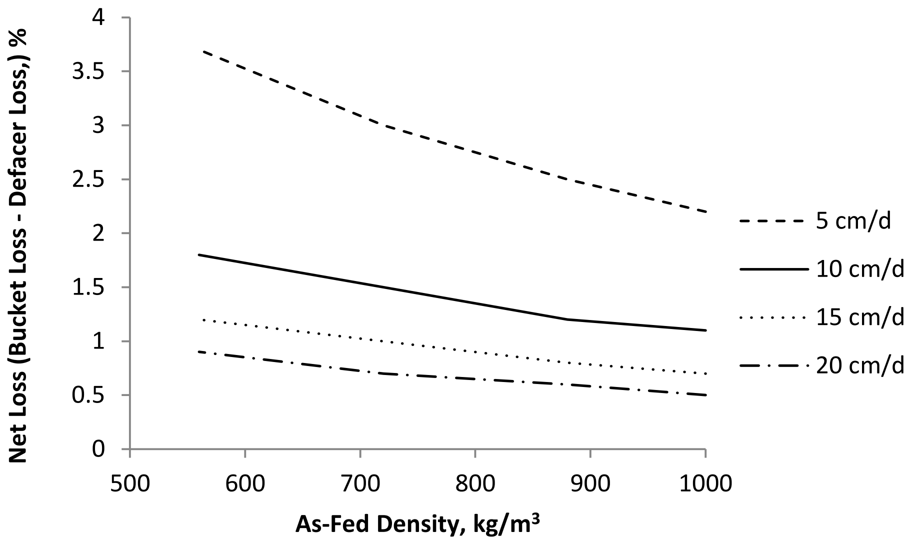

Figure 3. Net improvement in dry matter recovery by using a defacer as affected by bulk density and feed out rate (Muck and Rotz, 1996).

▪ Additives

It is not possible to provide a full discussion of silage additives here. However, additives may be tools to avoid some silage problems. There are 2 issues where silage additives may be of benefit: avoiding clostridial fermentation and reducing the potential for spoiling/heating silage.

Homo-fermentative lactic acid bacteria are the most common silage additives in North America. These bacteria supplement the natural population of lactic acid bacteria on the crop and help guarantee a fast, efficient fermentation in the silo. These inoculant bacteria produce primarily lactic acid and few other products. Because lactic acid is a strong acid, the inoculant helps guarantee the lowest possible pH from silage fermentation. They may be beneficial if ensiling a grass or legume silage that is a bit wetter than is recommended and there is the potential for the silage to turn clostridial.

Heating of corn silage in the feed bunk or at the silo face is a common problem during the summer. If this is a common problem for you, the first step is to review your silage management. High dry matter content, covering issues, low densities and low feed out rates are the most common sources of these problems and should be addressed before looking to silage additives. However, it is possible to be doing well in all these areas and still have some summer issues. Two classes of additives may be helpful: chemical additives and *Lactobacillus buchneri*. *Lactobacillus buchneri* slowly converts lactic acid to acetic acid, which inhibits yeasts and molds. Typically it takes 1.5–2 months of storage for a substantial effect. For silages that will be fed after a short ensiling time, a chemical additive may be more effective. Chemical additives include propionic acid, propionic-acetic acid mixtures, potassium sorbate and sodium benzoate. With all of these additives, one must be sure the application rate is at or above the label directions and the product is well mixed with the forage for these products to be effective in preventing heating.

▪ Potential Problems

Potential Clostridial Problems

Invariably there will be times when forage is ensiled too wet in order to avoid rain on wilted forage. In such circumstances, there are several things one can do to minimize the risk of having clostridial silage. One, do not layer that wet forage in with dryer forage in a bunker or pile. It will only potentially create a clostridial layer between good layers that will be difficult to separate. It is better to create a bag or a mini-pile of the wet forage that is ensiled separately. Two, use a good homo-fermentative inoculant to get pH as low as possible. Do not use an inoculant with *Lactobacillus buchneri* in the formulation. Three, feed this silage out as early as possible. The best situation is to allow it to ferment and stabilize for 2 to 4 weeks and then start feeding. Why? It usually takes months for a silage to go clostridial. So, by feeding out early, you may be able to completely feed the silage before it goes clostridial.

Potential Heating Problems

If you are beginning to see heating when feeding a particular silage, there are several things you can do to possibly minimize it: 1) Make sure you are very fastidious in leaving a smooth face on the silo and there is no loose silage left on the floor after feeding is done; 2) Minimize the amount of exposed silage on the top of the bunker or pile and keep tires or gravel bags butted against each other across the edge of the cover; 3) Consider increasing the number of feedings per day or increasing the number of animals fed from the silo; 4) If heating cannot be prevented, then application of propionic acid or a propionic/acetic acid mixture to the TMR may be needed to keep the ration cool in the feed bunk.

Visible Mold

Visibly moldy silage is greatly reduced in nutritional quality from what it was when placed in the silo. It may contain mycotoxins, bacterial toxins, and pathogens such as *Listeria monocytogenes*. Some silage nearby the moldy layer may be clostridial with butyric acid and amines. This material should be discarded because of its potential to adversely affect herd health. More importantly it should cause you to review your management because improved practices can avoid moldy silage.

▪ Acknowledgements and Disclaimer

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