Avoiding the Two Greatest Silage problems

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Introduction

The two greatest silage problems are shrinkage (dry matter losses) and heating (aerobic spoilage). Therefore, one of the main aims of silage making is to reduce losses of dry matter during the preservation process. Dry matter losses occur during the three main stages of silage preservation namely the aerobic respiration stage after cutting, the anaerobic fermentation stage after sealing, and the aerobic feedout stage after the silo is opened. Dry matter (DM) losses from silage range from 10% under good management to 40% under poor management and the financial implications are often ignored or underestimated. Bolsen and Bolsen (2012) described the magnitude of the problem. If corn silage is priced at $50/ton and 10 % of the DM is lost during ensiling, the true value of the corn silage is $56/ton, but if 40% of the DM is lost, the true value of the corn silage is $83/ton. Also, if 40% of the 109 million tons of silage produced last year (USDA NASS, 2012) was lost to shrinkage, the value would be $2.2 billion at a cost of $50/ton, whereas it would be $600 million if shrinkage was 10%. These numbers emphasize the importance of minimizing DM losses during silage making.

Heating and spoilage during feedout is one of the greatest contributors to DM losses (Table 1). Spoilage occurs when yeasts and molds that were dormant during the fermentation begin to grow and oxidize nutrients into carbon-di-oxide and heat after they are exposure to oxygen in the air. In addition to increasing DM losses, Spoilage reduces silage quality. Feeding spoiled high-moisture shelled corn to dairy cows reduced milk production by 3.2 kg/d (Hoffman and Ocker, 1997). Feeding spoiled silage also reduced fiber digestibility and DM intake in cattle (Figure 1) and destroyed the rumen fiber mat (Bolsen and Bolsen, 2012). In addition, molds in spoiled silage may produce mycotoxins that can reduce the performance and health of cattle and cause serious health problems for producers.

Management recommendations to reduce silage spoilage and shrinkage

Silage spoilage increases as silage maturity and dryness increase. It is more difficult to pack the drier, harder stems of more mature forage in order to eliminate the air pockets that allow spoilage-causing molds to grow. Consequently, harvesting forages at the correct maturity stage can help to reduce DM losses, heating and spoilage. In the past, the recommendation was to harvest corn for silage at the 1/3 to ½ milk-line stage. This advice is no longer valid. Rather, corn and sorghum should be harvested when the DM is about 35%. To achieve this harvest stage, corn plants should be taken from representative parts of the field and chopped and dried to measure the DM content at least two weeks before the anticipated harvest dates. Monitoring the weather and DM content during this period will help to accurately predict when to harvest. In the southeast, most grasses should be harvest as four to six-week regrowths for silage making depending on whether the aim is to maximize milk per ton or milk per acre.

Table 1. Dry matter losses in silage under good or poor management (Rankin, 2010)

	Management	
Source	Good	Poor
Respiration	0-4%	10-15%
Fermentation	4-6%	10-15%
Seepage	0-2%	5-15%
Aerobic storage	5-7%	10-20%
Total	9-17%	20-40%

Drying should ideally be done using an oven. Microwave and Koster drying procedures may also be used but these are less accurate. More information on forage moisture determination methods is available at http://pubs.ext.vt.edu/442/442-106/442-106_pdf.pdf. Several real-time moisture estimation methods now exist which use capacitance, microwave or near infrared sensors. These allow estimation of the moisture of the forage from a digital display on choppers. Capacitance sensors are calibrated at specific forage densities therefore, they can be inaccurate if the density of the forage being packed differs from that used for the calibration (Digman and Shinners, 2008). Microwave and near infrared sensors are generally accurate if they are calibrated well and the lens is clean, undamaged and properly aligned with the intake of the forage into the chopper. Alternatively, hand-held near infrared sensors are also available. These are accurate but often expensive.

As shown in Figure 1, silage DM losses increase as silage density decreases. Therefore, whatever can be done to increase silage density is very important. Producers should use their heaviest tractor for packing and should pay serious attention to packing well at the side walls and the top layer. These areas are more likely to be less dense during packing. We recommended that producers should aim for a density of 15 lb/cu ft on a DM basis. A survey of the density at the center of over 40 corn silage bunkers revealed that the average density at the center was 13 lb/cu ft but it was only 10 lb/cu ft at the top (Visser, 2005). Based on the data in Figure 1, packing at 10 lb/cu ft instead of 15 lb/cu ft will increase DM losses by about 60%.

A recent concept about packing silage is that the density should be estimated on a wet weight basis rather than a dry weight basis. Voids or air pockets in the silage make it porous and the greater the voids, the more porous the silage is. This is because the voids serve as pathways that allow oxygen penetration into silos. Oxygen is what stimulates the growth of spoilage molds hence it is critical to minimize oxygen penetration and reduce silage porosity by increasing density. However, silage porosity increases as the silage gets drier, therefore, it is more accurate to measure silage density on a wet weight basis than on a dry basis. For corn silage bunkers, producers should aim to achieve a wet or bulk density of 44 lb/cu ft. This allows producers to estimate silage density without calculating the moisture content.

In Figure 2, two suggested locations of coring locations on the silage face are shown. Either of these is acceptable. Ensure that corers are sharpened or serrated (teeth on the edges). Using high-torque, spiral assist or motor-driven corers can enhance the silage sampling process. When taking silage cores, it is essential to be safety conscious and always aware of the danger of silage avalanches. A much safer approach to estimating silage density is to use the spreadsheets available at the University of Wisconsin website at http://www.uwex.edu/ces/crops/uwforage/storage.htm. Click on 'Bunker silo density calculator' or 'Pile silo density calculator'. You will need to enter details like your silo height, silage delivery rate, packing layer thickness, dry matter content, and the weight and percentage packing time for each tractor. An advantage of this approach is that it can be used for planning purposes before the silage is packed into the bunker and no corers are required. However, the accuracy of the result depends on the accuracy of the estimates entered into the spreadsheet. Another method of calculating silage density based on the weight and volume of silage removed during feedout is available but much less accurate (Norell et al., 2013). New methods of measuring silage density on choppers in real time using radiometry have been developed in Germany.

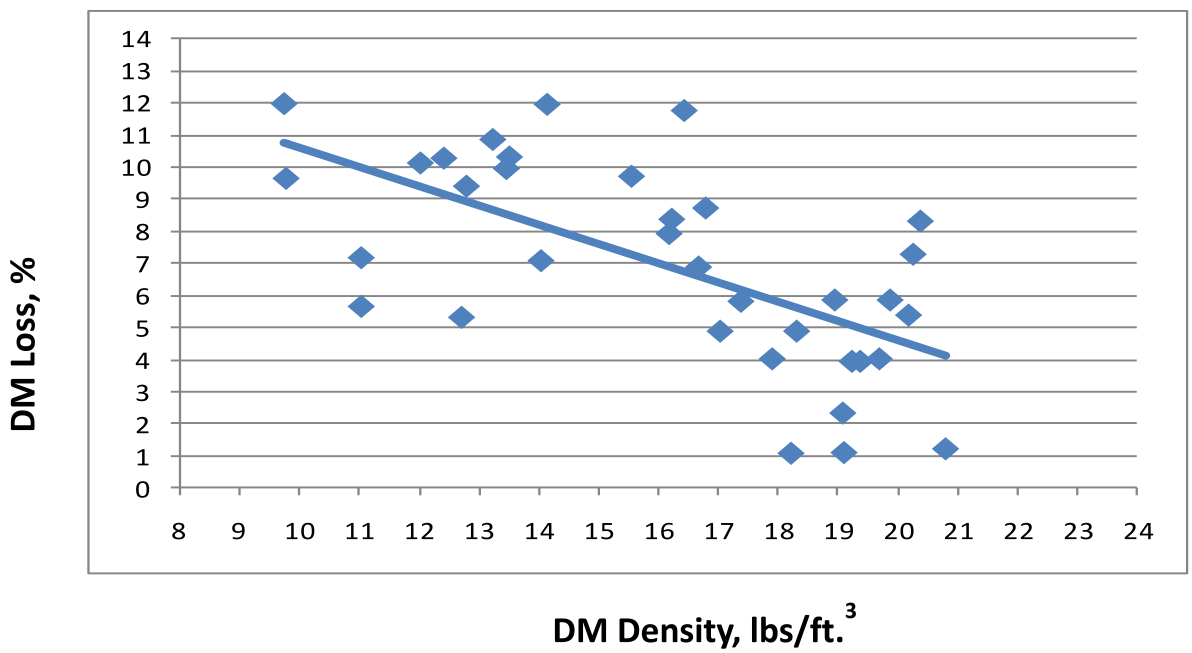

Figure 1. Relationship of dry matter loss to density in corn silage.

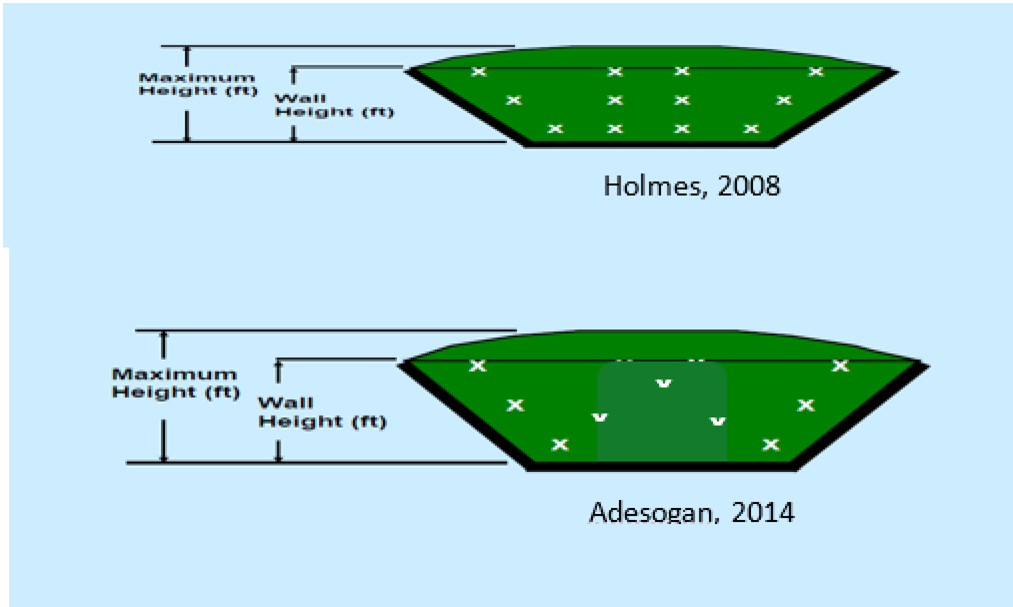

Figure 2. Suggested coring locations on the silo face.

To minimize spoilage and heating after opening bunker silos, it is critical to feed the silage out an appropriate rate. Feedout rates of at least 6 inches a day are recommended and rates of 12 inches a day are preferred. To achieve these rates, the width of the bunker face or pile should not be excessive. It is often wiser to build bunkers or piles that are narrow rather than wide.

Using additives to reduce silage spoilage and shrinkage

Additives can be used to reduce DM losses and heating in silages, but an understanding of the efficacy and role of the different types is necessary to achieve desired improvements in silage preservation. The following section describes the main silage additives used in the US.

Organic acids

Adding organic acids rapidly acidifies forages thus inhibiting the growth of the Clostridia and Enterobacteria that increase DM losses and protein degradation during ensiling. Examples of such acids include propionic, benzoic, sorbic, and formic acids etc. In the US, propionic acid is probably the most widely used silage preservation acid because its' strong antifungal activity increases bunk life by inhibiting spoilage yeasts and molds. The undissociated form has the antifungal effect therefore, lower pH values increase the efficacy of the acid. When added at 1 to 2% of the forage fresh weight, propionic acid limits DM losses and increases bunk life but it is also corrosive. Buffered propionic acid (salts of the acid like ammonium propionate) is less corrosive and when applied at concentrations of 0.1 to 0.2%, it may not affect the fermentation but can improve the aerobic stability (Kung, 2000) though higher rates are often more effective. Propionic acid should be applied at the chopper to ensure uniform distribution throughout the forage. Applying propionic acid to a silo face is not recommended because the acid does not penetrate far behind the silo face. Buffered propionic acid products cost about $ 10 -11/ton therefore they are more expensive than inoculants and should be used when quality silage is required from large acreages in a short period of time. Other acids like benzoic and sorbic acid are also effective mold and yeast inhibitors but due to their high cost, they are often sold in mixtures with propionic acid.

Acids are particularly useful if silage is made from wet silage. Drought stressed forage is usually wetter that it seems to be, therefore acid treatment may improve the preservation by rapid acidification which prevents clostridial proteolysis and butyric acid production.

Ammonia and urea

Ammonia is a strong alkaline which is very effective at increasing bunk life because it inhibits the growth of spoilage-causing organisms in silage. Applying ammonia also increases the crude protein concentration of silage and may increase the digestibility. The anhydrous form is best for uniformly applying ammonia to silage and it should be applied at 0.3 to 1% of forage DM. Ammonia poisoning may occur if ammonia is not uniformly distributed in the forage or if high rates are applied. A main challenge with ammonia is that it is a very caustic and hazardous when inhaled or if it contacts skin. Therefore, protective clothing must be worn when handling anhydrous ammonia. Ammonia may also prolong the fermentation and increase DM losses because its' alkalinity buffers decreases in pH , therefore it is not ideal for forages with low sugar concentrations or high buffering capacities (Kaiser, 2004) or for drought stressed corn with high nitrate and or sugar concentrations. Use of ammonia for silage preservation has been limited by the inconsistent effects on animal performance (Kaiser, 2004), the potential fermentation restriction, the hazardous nature and high price of ammonia.

In the presence of adequate moisture, urea can be used as a forage preservative because it can be hydrolyzed into ammonia by urease enzymes on plants. Urea is safer to handle and apply than ammonia but to avoid toxicity problems, urea should be dissolved in water and uniformly mixed in the forage. Silages treated with ammonia or urea will have high soluble N concentrations and care should be taken to ensure degradable and undegradable protein requirements of the cow are met when such forages are fed (Kung, 2000).

Enzymes

Enzymes added to silage include amylase for degrading starch into sugars and cellulases or xylanases for degrading cell walls into sugars. Sugars released by the enzymes enhance the growth of silage bacteria and in some cases, fiber degrading enzymes also increase forage digestibility. Such enzymes are usually more effective on cereal silages and immature cool season grasses than on mature cool season grasses, legumes, or warm season grasses, which are more lignified. Nevertheless, Dean et al. (2005) showed that when applied at ensiling to bermudagrass silage, a fiber digesting enzyme reduced the pH and DM losses and increased fiber hydrolysis into sugars, reduced protein degradation to ammonia and increased aerobic stability. Three other enzymes tested in the study had only some of these beneficial effects. These different responses to enzyme treatment reflect the inconsistent responses to enzyme treatment of forages or total mixed rations in the literature. Kung and Muck (1997) reported that enzyme treatment increased liveweight gain, milk production and feed efficiency in 40, 33, and 27 % of

39 studies. This inconsistency is partly because enzymes differ considerably in their main activities, application rates, and microbial sources. Also, the optimal temperature (122 to 140^{o}F) and pH (4-5) for many commercial enzymes are greater than those in well-made silages. Lastly, low enzyme application rates are often used due to high enzyme costs. Recent technological advances in enzyme use by the biofuel industry may reduce enzyme costs in the future.

Enzymes are sometimes added to bacterial inoculants to degrade cell walls and increase the availability of sugars used as growth substrates by the inoculant bacteria. This approach has sometimes resulted in improved fermentation and or improved forage digestibility. Queiroz et al. (2012) showed that disease infestation reduced the NDF digestibility and fermentation of corn silage but a mixture of an inoculant and enzymes reversed these negative trends.

Inoculants

Inoculants are added to silage to dominate the epiphytic (natural) population of bacteria on plants that cause DM losses by inefficient fermentation of sugars. Three main types of inoculants are currently used.

Homofermentative bacterial inoculants**:** Homofermentative bacteria have been used to increase forage acidification and minimize DM losses for several decades. Rapid acidification is achieved by fermentation of plant sugars into lactic acid. This represents the most efficient type of fermentation because it avoids or minimizes DM and energy losses by preventing the growth of bacteria that cause such losses. The main bacteria used in such inoculants are Lactobacillus plantarum or acidilacti, Pediococcus pentosaceus or acidilacti and Enterococcus faecium. Pediococcus and Enterococcus spp. grow more vigorously at high pH than L. plantarum and may be more tolerant of residual oxygen in the silo. Consequently, some inoculants contain Pedioccocus and or Enterococcus spp. to ‘jump start’ the fermentation as well as L. plantarum for subsequent prolonged domination of the epiphytic bacteria. Homofermentative inoculants are particularly useful for improving the preservation of legumes like alfalfa and warm season forages with high buffering capacities and or low sugar concentrations. These inoculants typically reduce DM losses by about 2-3% and they increased DM intake, liveweight gain and milk production in 31, 53 and 47% of 39 studies reviewed by Kung and Muck (1997). They often cost $0.5 to $1.50, therefore, with a 2-3% reduction in DM losses and potential improvements in animal performance, they produce an economical response particularly with high silage costs of $50/ton or more.

In some cases, adding homolactic inoculants has reduced bunk life because the lactic acid they produce is used as a growth substrate by yeasts that initiate spoilage. Kung and Muck (1997) showed that inoculants (mostly homofermentative) improved bunk life in a third of studies, had no effect in another third, and reduced bunk life in a third of studies. Consequently, heterofermentative inoculants that increase bunk life by producing strong antifungal compounds during ensiling are preferred for improving bunk life.

Heterofermentative inoculants

These bacteria ferment sugars into lactic acid, acetic acid and or ethanol in a fermentation that is often less efficient than that of homofermentative bacteria. Consequently, DM losses are greater when they are applied, but their beneficial effects on bunk life often outweigh the increased DM losses. Lactobacillus buchneri is perhaps the most widely used of these inoculants. It is added to silage because the acetic acid it produces during the fermentation has a strong inhibitory effect on the growth of spoilage yeasts and molds. Kleinschmit and Kung (2006) conducted a meta analysis on data from 23 studies and showed that application of L. buchneri to corn silage increased acetic acid production, reduced yeast counts and increased bunk life when applied at 10^5 cfu/g and responses were greater when it was applied at 10^6 cfu/g. Also, DM losses were 2 percentage units greater in L. buchneri-treated silages than in the Control silage but the improvement in bunk life outweighed these losses.

Adding L. buchneri to corn silages has improved bunk life in several farm-scale studies (Arriola et al., 2011, Mari et al., 2011) but no feed intake or milk production responses occurred when the treated silage was fed (Driehuis et al., 1999; Taylor et al., 2002; Kristensen et al., 2010; Arriola et al., 2011). In contrast, L. buchneri treatment of alfafa silage has increased the bunk life of a total mixed ration and increased milk production in one study (Kung et al., 2003). Lactobacillus buchneri inoculants typically cost $1.50 to 2/ton. They are particularly cost effective in silages that are likely to heat such as corn and small grain silages and high DM forages. They are also likely to be effective in drought-stressed corn plants, which usually have high sugar concentrations that could enhance the growth of spoilage yeasts (Weiss, 2012).

Combo inoculants

Combo inoculants contain a mixture of homofermentative bacteria that reduce DM losses and heterofermentative bacteria that increase bunk life. In several studies, such inoculants have improved the bunk life of silages without increasing DM losses. Queiroz et al. (2012a) showed that a combo inoculant reduced the amount of spoiled silage and nutrient losses from corn silage by about 50% relative to the untreated control. Few studies have examined effects of such inoculants on animal performance. Arriola et al. (2011) reported that applying a combo inoculant containing P. pentosaceus and L. buchneri to corn silage did not improve the performance of dairy cows. Nevertheless, certain combo inoculants have been associated with other benefits including inhibition of mycotoxin production in diseased (Queiroz et al., 2012b) or damaged (Teller, 2012) corn plants and they inhibited the growth of *E. coli* O157 H7 when the pathogen was added to aerobically exposed corn silage (Pedroso et al., 2010).

Using and choosing inoculants

Inoculants should be stored in a cool, dry area after mixing with unchlorinated water and used within 24 hours to maintain the viability of the bacteria. To ensure uniform distribution in the forage, liquid inoculants are preferred and they should be applied at the chopper at the rate and for the forage stated on the label. The most effective products have at least 100,000 cfu/g or 90 billion live bacteria per ton.

Summary

Shrinkage and heating or spoilage are the two greatest silage problems. Proper management can prevent these problems. Additives will not overcome bad management, in fact excellent management may improve additive effects. The following questions should be used to choose additives:

1) Is my goal reducing shrinkage, heating or both? To reduce shrinkage, use a homolactic inoculant. To increase bunk life, use an L. buchneri inoculant or a propionic acid additive.

2) Have independent research trials demonstrated the efficacy of the product at reducing DM losses or increasing bunk life or animal performance?

3) Does the product give at least a two to one economic return?

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