Dairy Research, Teaching, and Extension
UNIVERSITY OF DELAWARE

SILAGE MANAGEMENT 101 – THE BASICS

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INTRODUCTION

Harvest and storage management can have marked effects on silage quality and nutrient recovery. The objective of this paper will be to briefly discuss some recommended management practices to make high quality silages and maximize nutrient recovery after ensiling.

PREHARVEST PREPARATION

The condition of equipment to be used during harvest and silo filling should be optimized. Knives should be sharpened on the chopper. Silos and forage wagons should be cleaned before filling and moldy and spoiled silages should be removed so that they do not contaminate fresh forage. Bag, bunk and drive over pile silos should be placed in an area with good drainage and a slight pitch away from the feeding end of the bag to prevent accumulation of runoff and rain water. We preferably like to put bags and drive over piles on a poured concrete or asphalt pad. Although this can be costly, it speeds up silage removal and results in less waste, especially during rainy/muddy weather. The ground around bag silos should be kept clean and free of weed growth to deter damage to the bags by animals. When filling multiple bag silos keep them at least 3 ft. apart. This will minimize damage to adjacent bags when feeding.

FORAGE MATURITY AND DM

Harvesting forages at optimum maturity is important because it sets the stage for the rest of the year. High forage quality drives intake and in turn, this drives milk production. Not even the best nutritionists in the world can make cows maximize their milk production if they are working with poor quality forages. Corn silage should be harvested when the whole plant is at about 35 ± 2% DM. Depending on the conditions, corn plants will dry down at a rate of about 0.5

percentage units per day (faster in dry and hot weather). Based on your acres and equipment you may have to start at a lower DM and you may end at a higher DM but the key is to avoid the extremes. Harvesting corn silage that is too wet (typically < 28-30% DM) results in excessive fermentation that often produces high concentrations of total silage acids and may result in excessive seepage losses. Specifically, these wet silages are often characterized by high concentrations of acetic acid produced from "wild" fermentations. A common problem when feeding large quantities of wet corn silages is a reduction in DM intake because of the high acid content. In contrast, extremely dry corn silage (> 40% DM) should be avoided because the low moisture restricts fermentation and this material is more difficult to pack which often leads to poor aerobic stability. In addition, dry corn silage is usually very mature and thus the digestibility of starch digestibility may be low.

For lactating cows, high quality grass should be harvested when forage is in the early boot to boot stage of maturity. Grasses that are headed out at harvest are high in NDF and lignin and less digestible. For dry cows and heifers this may not be an issue, but for high producing cows, mature grasses are undesirable. Alfalfa for high producing cows should be harvested no later than $1/10^{th}$ bloom or about 40% NDF. Alfalfa can be monitored using a scissor cut method and sending the samples to a lab for a quick NIR determination for nutritive content. The use of PEAQ sticks have also been calibrated in certain states. Grasses should be harvested in the boot stage of maturity. Growing degree days may also be a useful tool for harvesting grasses.

WIDE SWATHING

One of the biggest challenges for making good alfalfa or grass silage is managing the period of wilting to result in maximum conservation of fermentable sugars and obtaining an adequate dry matter level to prevent the growth of clostridia. During prolonged wilts, sugars are metabolized by the plant in the windrow; thus a quick dry down is beneficial. Wet grass and alfalfa silages are more prone to undergo clostridial fermentations when the DM is less than 30-35%. Wilting these crops above this level of DM makes it harder for clostridia to dominate the ensiling process.

There is still considerable interest in drying alfalfa in wide swaths to minimize the time that plants lay in the field and might be subjected to rain and to reduce the loss sugars that can occur during excessive periods of respiration (Kilcer, 2008, Cornell University). In a study on three consecutive cuttings from the same field, we showed an average savings of about 20-24 hr of wilting time to reach 45% DM when comparing alfalfa wilted in 9 ft rows (67% of cutter bar width) versus 4 ft windrows (Kung et al., 2007). At all cuttings, silage could have been made starting at 35% DM on the same day of mowing in wide swathed alfalfa. Wide swathed alfalfa also had higher sugar content than narrow swathed alfalfa at chopping in our study. Similar findings have been reported by Undersander et al. (2008). However, in our study wide swathing did not have a large impact on the resulting silage fermentation and in fact wide swathing resulted in slightly higher NDF and lower CP, probably because of wheel traffic causing leaf damage to alfalfa in the wide swaths. This problem can probably be overcome depending on the equipment used for mowing. Wide swathing did not improve NDF-D of the resulting silage in our study although it did in the study reported by Cherney and Cherney (2006). A comment often heard from producers that have used the wide swath technique is the fact the DM content of the harvested crop is much more uniform than it is from narrow swathed alfalfa and that this has resulted in a more uniform product at feed out. Producers experimenting with this procedure should use caution during warm weather because wide swathed alfalfa can dry down extremely quickly. In our study, wide swathed alfalfa reached a DM of 45% in about 6 h on a day with temperatures of about 95°F. More recently, Kilcer (personal communication) has been advocating haylage in a day (~40-45% DM) with wide swaths at >90% of cutter bar width.

FORAGE PARTICLE SIZE

Chopping corn silage too fine or too coarse should be avoided. Finely chopped silage reduces the effective fiber and coarsely chopped silage does not pack well and often leads to sorting of the TMR. Recommendations for theoretical chop size usually run between 3/8 to 1/2 inch for unprocessed corn silage and about ¾ inch for processed silage. In diets where corn silage makes up the majority of the forage, 15 to 20% of the particles should be greater than 1.5 inches long. If using a Pennsylvania State Forage Separator with the fourth box (now with top, middle, low screens and bottom pan), about 8 % of the corn silage should be retained on the top screen to ensure optimum levels of effective fiber in the diet. If corn silage is not the major forage in the diet, about 3% of the top screen may be sufficient. For corn silage, the middle screen should have 45 to 65% of the particles after shaking and there should be no more than 5% of particles on the bottom pan. If corn silage is processed, a higher proportion of particles can be targeted for the top screen. In measurements that we have taken, some baggers decrease the proportion of corn silage particles on the top screen by about 10 to 15 units so this must be taken into consideration when setting chop length. Likewise, silage sampled using a corer does not accurately reflect the particle size of the fiber in the silo. Instructions for using the new particle size separator can be found at: http://www.das.psu.edu/research-extension/dairy/nutrition/pdf/evaluating-particle-size-of-forages.pdf In general, if faced with drier forages, cut shorter to achieve a tighter pack. If feeding long hay, silages may also be cut a bit shorter.

MECHANICAL PROCESSING

Mechanical processing of whole plant corn has been an accepted method to improve the quality of corn silage (Johnson et al., 1999). Whole plant processing crushes the entire plant through rollers and can be accomplished in the field during harvesting, at the silo but prior to storage, or after ensiling and just prior to feeding. Processing corn silage improves starch digestibility and allows for good packing in silos, even with a longer length of particle chop. Rollers should be set to obtain adequate kernel damage. In drier and more mature corn silage, clearances between rollers will usually need to be tighter. However, care should be taken to monitor the effectiveness of the processing. When large amounts of acreage require harvesting, there may be a tendency to open the rollers more than what is recommended in order to speed up the harvest, reduce energy use and to reduce wears on equipment. As a rule of thumb, adequate processing is occurring if more than 90-95% of the kernels are crushed or cracked and cobs are more than quartered. Commercial feed labs currently provide a Corn Silage Processing Score (CSPS), which is coupled to NIR analyses of corn silage. A dried corn silage sample is sifted through several screens and particles of corn that are greater than ¼ to ½ of a kernel are retained on a screen and considered difficult to digest. Small corn particles pass through a screen with 4.75 mm square holes and these are more easily digested by rumen microbes and the cow. The score provides feedback on processing as “optimum”, “average”, or “inadequately processed”. There is a negative relationship between the CSPS and fecal starch. Low CSPS scores are associated with high fecal starch contents. Fecal starches more than 2-3% suggest that starch is not well digested in the cow. An improvement in starch digestion is greater when more mature corn silage (e.g., black layer) is processed. However, always target harvest for about 35% DM (whole plant DM).

KEYS TO MAKING GOOD SILAGE

The keys to making quality silage are to 1) rapidly exclude air from the forage mass, which will result in 2) a rapid production of lactic acid and reduction in silage pH, and 3) to prevent the penetration of air into the silage mass during storage. Excessive air, due to slow silo filling or poor packing (overly dry forage or forage chopped too coarsely) allows the plant to respire for prolonged periods of time. This results in utilization of sugars and excessive degradation of plant protein. Air also encourages the growth of undesirable microbes such as yeasts and molds.

Air can be eliminated by fast filling (but not too fast), even distribution of forage in the storage structure, chopping to a correct length and ensiling at recommended dry matters (DM) for specific storage structures. Bunk and pile silos should be filled as a progressive wedge to minimize exposure to air and packed in 6 to 8 inch layers. The recommended optimal packing density for bunk and pile silos is 14 –16 lbs. of DM per cubic foot (Ruppel et al., 1995). Silage corers can be obtained from several commercial sources to help with obtaining estimates of silage density (extreme care should be taken when coring silos to avoid potential harm from falling silage). An Excel spreadsheet can be downloaded from the University of Wisconsin that helps with bunker silo filling (www.uwex.edu/ces/crops/uwforage/storage.htm). Users can input silo dimensions, tractor weight, forage delivery rate, forage dry matter, and packing time to estimate packing density. In several recent surveys of bag silos, packing densities are more commonly between 9 to 12 lb of DM/cu ft. Silage in bags should be packed tightly by monitoring the stretch marks on the bags. Tunnel extensions on older units can be added to increase pack density and teeth on Ag Bag and Kelly-Ryan machines should be sharp. Silo bags should be vented for about 2 days to rid the bags of excess gasses from fermentation. Care should be taken as to not expose yourself or animals to venting silo gasses.

Under anaerobic conditions (lack of air) the initial stages of silage fermentation is dominated by microbial activity. Fermentation is controlled primarily by a) type of microorganisms that are present, b) available substrate (water-soluble carbohydrates) for microbial growth, and c) moisture content of the crop. Lactic acid-producing bacteria utilize water-soluble carbohydrates to produce lactic acid, the primary acid responsible for decreasing the pH in silage. Unlike alfalfa and other grass silages, corn silage rarely undergoes clostridial fermentation because pH drops more quickly and lower than it does in alfalfa. However, preventing the proliferation of yeasts that produce alcohol, cause lower DM recovery, and are associated with poor aerobic stability, is a challenge in corn silage.

MICROBIAL INOCULATION

Forages can be inoculated with various microorganisms to alter the resulting pattern of fermentation in the silo. Muck (2008) suggested that inoculation could be helpful in three general areas. These include 1) the prevention of clostridial fermentation, 2) the enhancement of aerobic stability, and 3) the capability of making a good fermentation even better.

Bacteria that are classified as homolactic acid bacteria (those that only make lactic acid as an end product) such as *Lactobacillus plantarum* (although now technically classified as a heterolactic acid bacteria), *Pediococcus acidilactici, P. pentosaceus*, and *Enterococcus faecium* are the most commonly used in silage inoculants. In particular, use of these types of organisms addresses areas 1 and 3 described by Muck. When compared to untreated silages, silages treated with homolactic acid bacteria are often lower in pH, acetic acid, butyric acid and ammonia-N but higher in lactic acid content and result in better DM recovery (Muck and Kung, 1997). These effects are easier to detect in alfalfa (because of its high buffering capacity) than in corn silage. The rapid drop in pH and attainment of a low silage pH are crucial for preventing the growth of clostridia, which cause undesirable fermentations (excessive protein degradation, energy and DM losses, production of undesirable end products such as butyric acid and amines).

Lactobacillus buchneri (a heterolactic acid bacterium) has been used to improve the stability of silages when they are exposed to air (area 2 described by Muck). This organism alone does not affect the initial process of fermentation as would a classical homolactic acid bacteria. However, under anaerobic conditions, this organism results in a "controlled" fermentation that produces moderately higher concentrations of acetic acid in inoculated silage when compared to untreated silage. Acetic acid helps to limit the growth of yeasts, which initiate the spoilage process when silages are exposed to air. Use of this organism has been very successful in high moisture corn, corn silage, in silages that are fed during warm weather, in silages that are fed from intermediate feeding piles, and in silages that are moved between silos. Production of moderate amounts of acetic acid by this organism has not been detrimental to intake nor has it led to excessive amounts of DM loss during ensiling (Kleinschmit and Kung, 2006).

The location of applying a microbial inoculant onto the forage is important. If silage is to be stored in a bunk, pile or pit silo the inoculants should be applied at the chopper for a more even distribution. Remember that these bugs don't have legs, nor do they swim! If all the inoculant gets put on in one spot, it will probably stay there (some distribution will occur during tractor movement and packing, but this is not efficient). For silage that will be stored in a bag silo, application at the chopper or bagger will probably not make a difference (in a few instances, forage is chopped and harvested far away from where it is ensiled; under these circumstances, it may be preferable to have the inoculant applied at the chopper so that the microorganisms can begin their work right away). Don't forget to properly calibrate your applicators to match forage delivery and don't increase the dilution or reduce the application rate! Also, remember that inoculants in water are stable for about 2 to 3 days but maybe less under very hot temperatures. If for some reason, unused liquid inoculants must be stored, do so in the shade and place a few ice packs into the tank. Do not allow the temperature of water in the applicator tanks to rise above about 100°F as this may decrease the viability of the bacteria (Mulrooney and Kung, 2008). Seal any unused portion of powders tightly to protect from moisture and store in a cool area.

SEALING SILOS

After filling silage should be covered with plastic as soon as possible and weighted down with tires (tires should be touching) or gravel bags to exclude air. Split tires are good alternative because they are easier to handle, do not accumulate water (thus less breeding grounds for mosquitoes that could carry the West Nile Virus), and are undesirable for animals to nest in. The return on investment (labor and plastic) is extremely high for covering bunk and pile silos (Bolsen et al., 1993). Oxygen barrier plastics are also now available for use (Borreani et al., 2007) and a two-step process (oxygen barrier plastic closest to the silage with another layer of normal plastic on top of it) has been commonly used. Producers have also had success in covering silage with two layers of normal plastic. Studies are needed to compare the two-step covering system with oxygen barrier plastic to two layers of normal plastic.

Use of plastic to line the side walls of bunker silos has also grown in popularity to prevent the seepage of water into the silo mass. Studies by Muck (2008) and McDonell et al. (2007) have shown silage with markedly higher quality close to the silo wall when using plastic on the side walls. McDonnell et al. (2008) reported that corn silage next to the wall without plastic had an NDF-D of only 42% whereas silage from the crop but next to a wall lined with plastic had an NDF-D of 57%. Plastic draped over the silo wall during silo filling should be protected from rips and holes that could occur as it rubs against the top of the silo wall.

CHALLENGES WITH BALE SILAGE

Individually or tube wrapped bale silage provides much flexibility in terms of storage locations and feed out. However, storing silage in this manner creates some unique challenges and may require more diligent management practices.

First, because bale silage is often ensiled at about 50% DM it requires a slightly longer wilting times than if the same crop were harvested at a lower DM and stored in larger silos (e.g., bunker or pile silos). The longer a crop lies in the field, the greater the risk that it could be rained on and prolonged wilts can reduce fermentable sugars required for a good fermentation. Related to the relatively low moisture content of bale silage is the fact that this results in a mild restriction to the overall fermentation process that can result in low levels of acid production required to stabilize the silage mass. Alfalfa ensiled at 35% DM can easily produce twice the amount of total fermentation acids than the same forage ensiled at 50% DM. Furthermore, the already relatively low moisture is exacerbated because of the usually longer chop length which, further restricts moisture and fermentable sugars that would have been more readily available if the forage was chopped to a smaller particle size as in conventional silages, adding an additional challenge to the fermentation.

Another challenge to bale silage that is often overlooked is that because of its small mass, it is subject to more variable fluctuations in temperature due to changing environmental conditions. For example, during the early morning hours of a winter day it is not uncommon to find an accumulation of ice under the plastic after cutting open a bale. However, if that same bale were cut open in the afternoon after it has been exposed to the sun for several hours, ice would not be present on the surface of the bale. This occurrence indicates that there is migration of moisture which can result in pooling of moisture in certain parts of the bale. In extremely hot summer conditions, the forage interfacing with the face exposed to the sun probably reaches quite high temperatures. Think to yourself: “how many times can I freeze and thaw or heat and cool down a food before the integrity of that foodstuff becomes compromised?” While these processes also occur at the surface of a large pile or even in a bag silo, the amount of silage subjected to these wide temperature changes is quite small in large silos.

The last challenge that bale silage must overcome is related to the high ratio of plastic area to a small forage mass. This situation increases the probability of aerobic challenges because of oxygen permeating the plastic during storage especially as storage time increases and the integrity of the layers increasingly has the ability to be compromised by UV radiation and damage from animals.

Good management practices can help to reduce the chance that the challenges that have been discussed do not result in poor quality bale silage. These include wrapping bales as soon as possible with at least 6 layers of plastic, storing bales in clean and sheltered locations when practical, and avoiding prolonged storage of bales before use.

Try to feed out bale silage as soon as possible. The longer bale silage is stored, the higher the probability of spoilage.

ALLOW FORAGES TO "CURE" PRIOR TO FEEDING

A "fall slump" in milk production is a common occurrence on many dairy farms. It is characterized by some or all of the following: a moderate decrease in milk production, a decrease in intake, loose manure, and cycling intakes. Fall slumps are often a result of feeding corn silage that has not had adequate time to complete the fermentation process. Depending on the specific crop and conditions, most silages require 3-6 weeks before the fermentation process is complete. Jaeger et al. (2004) reported that digestibility of starch in high moisture corn improved with length of storage and that the effect was more pronounced in corn with a higher (30%) vs. lower (24%) moisture content. Recent data confirms that starch availability of corn silages and high moisture corn increases with prolonged storage. In fact, data summarized from the University of Wisconsin suggest that high moisture corn does not reach peak rumen starch digestibility until about 7-8 months of storage! The fall slump may occur because fresh corn forage contains high levels of fermentable sugars that can put the rumen into sub acute acidosis and because the starch content of the freshly chopped crop is low in rumen availability. The condition occurs most with corn silage because it is usually the highest proportion of forage fed in the diet. Fall slumps are most apparent when cows are switched abruptly from old corn silage to freshly cut corn forage. This occurs frequently on small farms that have only one silo for corn silage.

SILAGE FEEDOUT

Proper management for removal of silage from silos and management at the feed bunk can help producers to maximize profits and production. There is no "magic number" of silage removal per day that will universally prevent silage from spoiling. Enough silage should be removed from the silo face to minimize aerobic spoilage. Lesser amounts may be removed in areas of the country where ambient temperatures are very low during the winter months. Removal of silage should be such to minimize loose silage on the ground between feedings. Hot, moldy feeds should not be fed because they are low in nutritive value and digestibility and depress intakes. Feed bunks should be kept full, but clean of decaying feed. Muck and Huhnke

(1995) reported that air is able to penetrate into the face of silo as much as 3 ft. even if the packing density was 14 -15 lb DM/cu ft. Face shavers will probably be most beneficial when temperatures are warm and if less than optimal amounts of silage are removed on a daily basis. Extreme care should be taken to prevent air from penetrating the plastic and reaching the silage mass.

CONCLUSIONS

Great care should be taken to preserve and maintain the nutritive value of forage crops. Management starts in the field with harvesting crops at the optimum maturity and then following this with a quick wilt (for grasses and alfalfa), by chopping to an adequate particle size, treating with a good microbial inoculant, processing the plant (for corn silage), filling silos quickly and packing them tightly and finally managing the silage in the silo with plastic and weights to minimize exposure to air.

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