OPPORTUNITIES TO IMPROVE CORN SILAGE QUALITY IN CALIFORNIA

Noelia Silva-del-Río

Corn silage is a commodity commonly fed in California dairy operations. It provides a source of digestible fiber and readily fermentable energy for dairy cattle. There are regional differences in the quality and quantity of harvested corn silage. This proceedings paper addresses those differences and compares the top two dairy states in the US: California (South West Region) and Wisconsin (Mid West Region). Moreover, this paper discusses opportunities in California to mitigate silage dry matter losses, focusing on management practices at harvest, storage and feedout.

Key words: crop dry matter, packing density, kernel processing, silage face management

INTRODUCTION

Dairy farmers all over the world, plant corn silage as a source of digestible fiber and readily fermentable energy for their cattle. Twenty years ago, there were only 200,000 acres dedicated to corn silage in California. Parallel to the dairy industry's growth, corn silage acreage has increased over time. In 2007, a total of 445,000 acres of corn silage were harvested in California (CDFA). Most corn silage is planted in the Central Valley, where growing conditions are exceptionally good for corn: quality and quantity of sunlight, fertile soils and available water for irrigation. Under these conditions, California dairy producers are presented with the opportunity to grow a very valuable forage crop.

The quality and quantity of corn stored in the silage structure depends on the management practices at: 1) pre-harvest (hybrid selection, cultural practices, pest and weed control); 2) harvest (kernel process, theoretical length cut, dry matter, climate conditions); and 3) post-harvest (storage and feed out). These proceedings will address regional differences in corn silage production, as well as opportunities to minimize silage dry matter losses focusing on management practices at harvest, storage and feedout.

REGIONAL DIFFERENCES OF CORN SILAGE: CALIFORNIA VS WISCONSIN

California corn silage differs from corn silage grown in cooler regions of the US. To illustrate the uniqueness of California corn silage, a comparison with corn silage produced in Wisconsin (the second largest dairy state in the US) follows. Corn silage statistics for the past three decades are presented in **Fig 1** for California (CDFA) and **Fig 2** for Wisconsin (USDA NASS-WI). Yields are approximately 10 tons more per acre in California than in Wisconsin. High yield hybrids with 115 days or more relative maturity can perform very well under California growing

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conditions, but not in cooler climates. In the West, corn plants are 10 to 15% taller (personal communication with senior researcher from a corn breeding company). Wisconsin corn silage production relies on rain, while in California we have the advantage of using timely crop irrigation.

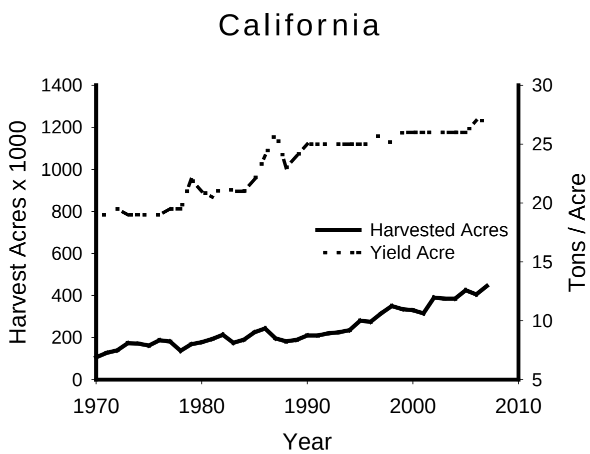

Fig 1. Acres harvested and tons per acres in California from 1970 to 2007 (source CDFA-2008).

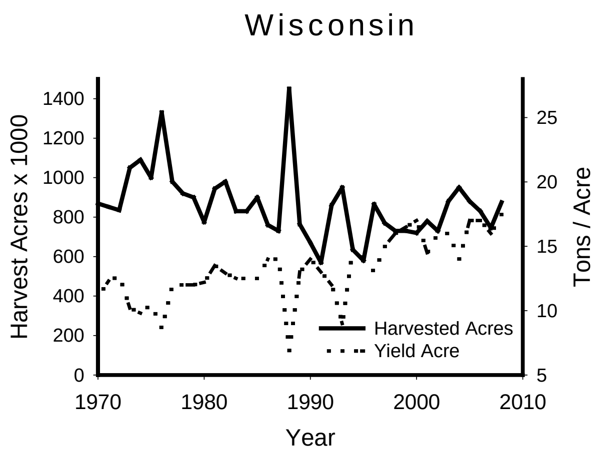

Fig 2. Acres harvested and tons per acres in Wisconsin from 1970 to 2008 (source USDA-NASS-WI).

Nutrient composition and lactic to acetic acid ratios of corn silage crops harvested in California and Wisconsin in 2009 are presented in **Table 1**. Fibers [Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF)] were determined by an in house laboratory method. Thus, absolute fiber values are not comparable with results from analytical labs following the Van Soest methodology. Nevertheless, the relative values for ADF and NDF between California and Wisconsin can still be compared. Overall, lignin and fiber (NDF and ADF) are higher in California corn silage. Similarly, previous research showed higher lignin and NDF content when corn silage was grown in the Southern US when compared with the Northern US regions (Sniffen et al., 1992). One possible explanation for higher ADF, NDF and lignin in California could be differences in ear to stover ratios. High yield hybrids grown in favorable climate conditions are tall and the stover may represent a larger portion of the whole corn plant.

In 2009, corn silage ash averaged 6.1 % for California and 3.7 % for Wisconsin. High ash values indicate greater contamination from soil and soil microorganisms. In the Central Valley, the summer seasons is very dry and that favors a dusty environment (there is no rain to wash the dirt off the plants). At harvesting, choppers and trucks raise dust that settles in the crop being harvested. One of the implications of high ash or dirt in corn silage is the faster wear out of harvesting equipment. During corn harvesting, knives need to be sharpened every hour and half for 5 minutes and replaced after 250 hours of use (personal communication with a local custom harvester).

Table 1. Nutrient composition and lactic acetic ratio of corn silage crop harvested in California and Wisconsin in 2009.

	California (n=131)		Wisconsin (n=205)	
	Mean	**SD**	**Mean**	**SD**
DM	31.6	4.7	34.1	5.3
ADF[1]	24.5	3.4	20.9	4.0
NDF[1]	44.6	4.7	40.4	5.5
Lignin	3.3	0.6	2.2	0.6
Protein	8.0	0.96	7.6	0.88
Ash	6.1	1.1	3.7	1.1
Lact:Acet	2.76	1.7	3.08	1.45

[1]ADF and NDF were not done following the Van Soest methodology.

A desirable lactic:acetic ratio is greater or equal to three. The lactic to acetic ratio was 2.76 for California corn silage and 3.08 for Wisconsin corn silage. Differences in ambient temperature between states may help in part to explain this observation. Ensiling involves microbes and enzymes and their biological activity is affected by temperature. Laboratory research studies, with mini silos (Kim and Adesogan, 2006), indicated that ensiling at 104 vs. 68 F results in:

- Higher pH (low pH is more desirable as it inhibits undesirable microbial growth).
- Lower lactic to acetic acid ratio.
- Higher dry matter (**DM**) losses.

OPPORTUNITIES TO MINIMIZE ENSILING DRY MATTER LOSSES IN CALIFORNIA

To maximize crop production and minimize ensiling losses, dairy producers need to trust the services of growers, pest control advisors, custom harvesters and nutritionists. An efficient communication among these different groups of people needs to be nurtured. Poor communication may have a direct impact on the quality and quantity of the ensiled forage. Therefore, to get the most out of the ensiled crops, dairy producers should invest time facilitating and leading the silage team that grows, harvests, stores and feeds the silage crop.

This section will focus on three important silage management practices that are in the control of the dairy producer and the silage team. These are: 1) targeting the proper DM at harvest, 2) achieving a high packing silage density, and 3) properly managing the feedout face. It is important to mention, however, that good corn silage starts with a high quality crop standing in the field. Cultural practices, weed and pest management, irrigation, and fertilization should not be overlooked to ensure crop quality and quantity.

Harvesting at the right moisture

One of the most challenging management decisions of corn silage production is to decide when to harvest to achieve the proper moisture. The interactions between forage yield and quality, genetics and environment make it difficult to properly time harvest. The optimal time to harvest is when the crop reaches 30-36% DM. **Figure 3** represents the distribution of corn silage DM from samples collected at the silage structure (CA n=130; WI n=203). In California the median DM was 30.7% whereas in WI was 33.9%. Corn silage chopped too early (too wet) will have lower starch and greater seepage losses. Wet silages undergo a poor fermentation that results in greater production of fermentation acids and a low lactic:acetic ratio. This may impact intake. On the other hand, wet silages are less susceptible to aerobic spoilage and are highly digestible. Corn chopped too late (too dry) undergoes a limited fermentation and it is harder to pack; both factors make silage more susceptible to aerobic deterioration during feedout and in the feedbunk. Moreover, fiber and starch digestibility in mature forages can be low.

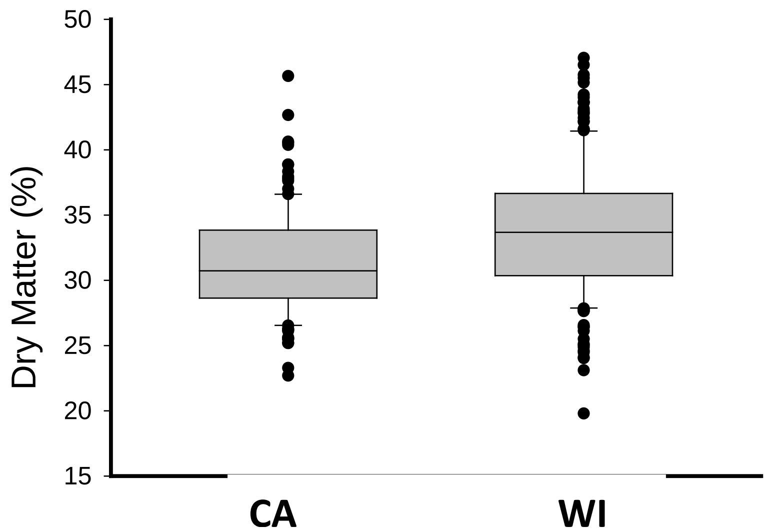

Figure 3. Corn silage DM at harvest in California (n=130) and WI (n=203), for the 10th, 25th, 50th, 75th, and 90th percentile.

Dry matter is a critical piece of information in silage making. It can be estimated by looking at the canopy and the kernel milk line. However, based on research from the University of Wisconsin (Laurer, 2006), dry matter estimates are poor predictors of measured dry matter (R^2=0.63). Determination of DM ensures that the crop will be harvested at the right moisture and this is beneficial to 1) dairy producers because they will get the most out of their investment and 2) custom harvesters because they will avoid situations where they need to back off fields when the crop is too wet. Required tools are a machete, a chipper shredder, a koster tester or microwave oven, and a scale. Plants (10 to 20) should be collected from different locations to represent the field. The guidelines for dry matter determination of the corn silage crop are described in **Appendix I**.

Timing harvest at the right DM requires the joint effort of all the members of the silage team. Once the team agrees on the targeted DM, several factors need to be taken into consideration:

a. Variation in whole plant moisture from plant to plant within the same field and hybrid. Differences within a field in soil type, fertilization, and irrigation may explain this variation and help to define a representative sample size for that particular field.

b. Large scale farming in California.
   Harvesting a large field may take several days, and during the heat of the summer, DM may increase in 0.5 to 1.0% DM units a day.

c. Timing of last irrigation.
   From the last irrigation it may take 10 to 20 days before the harvesting equipment can enter the field. The soil type, the field length, and the ground preparation of the field are factors that affect irrigation time. Furthermore, growers and dairy producers relying on scheduled ditch water may find it more challenging to time harvest with the desired crop DM.

Kernel Processing and Theoretical Length of Cut

In California, most corn harvested for silage is processed. However, there are still dairy producers harvesting without kernel processes. This clientele represents up to 5 to 15% of the custom harvesters accounts (Collar and Silva-del-Río, 2010). Processing improves the whole plant value by breaking all the corn kernels and reducing the presence of large cob pieces. This has a positive impact on handling and packing, reduces feed sorting, and increases rumen availability and total tract digestibility of starch, fiber utilization and feed intake. However, excessive processing may negatively impact rumen health by decreasing effective fiber and favoring rapid fermentation and ruminal acidosis. On the other hand, little processing increases sorting and kernels lost in feces, and the silage is more difficult to pack.

Several factors affect kernel fragmentation during processing: processor roll clearance, length-of-cut, machine throughput and the maturity of the corn. Adequate processing will result in more than 90-95% of the kernels cracked and 70% of the kernel particles smaller than ¼ of a kernel. It is recommended to evaluate the extent of kernel fragmentation at the silage structure. A bucket of water can be use to help separate the fodder from the kernels that sink. Some labs are equipped to evaluate the physical form of the corn silage (corn silage processing score) and infer ruminal and total tract digestibility. This method includes a series of sieves that quantifies the starch in kernel particles smaller than ¼ of a kernel. This lab procedure is described by Mertens (2005).

Corn silage particle length should be long enough to provide effective fiber and adequately short to ensure good packing. The theoretical length of cut (TLC) may need to be adjusted depending on the DM of the harvested crop. Corn harvested for silage too dry should be chopped finely to improve packing. However, if corn is the only roughage source at the dairy, it is recommended to chop long. Measuring forage particle length using the NASCO Penn State Particle Separator continues to be a popular way to objectively evaluate if forages have optimal particle length on the farm. General recommendations can be found at: http://www.das.psu.edu/research-extension/dairy/nutrition/pdf/evaluating-particle-size-of-forages.pdf

Dr. Mike Hutjens, the Dairy Extension Specialist from the University of Illinois, has developed some guidelines on the theoretical length of cut and the roll clearance based on whole plant maturity (http://www.livestocktrail.uiuc.edu/dairynet/paperDisplay.cfm?ContentID=615):

- DM < 33%: TLC should be 0.75 – 0.90 in. and the rollers open.
- DM 33-38%: TLC should be 0.75-0.90 in. and rollers with 0.12.
- DM 38%: TLC should be ½ in. and the rollers should be close.

Results of a recent custom harvester survey (Collar and Silva-del-Río, 2010), indicates that the settings of the roll clearance opening ranged from 0.5 to 3.0 mm (0.02 to 0.12 inches). and the theoretical length of cut from 10 to 21 mm (0.4 to 0.8 inches). Research needs to be conducted to evaluate the particle length and kernel processing of California silage and its impact on quality.

Packing Density

The single most critical factor affecting the efficiency of forage preservation is the rapid removal of entrapped air within the forage mass (Woolford, 1990). During silage fill out, the presence of oxygen maintains the respiration of the fresh plant material and the activity of obligate and facultative aerobic microorganisms (i.e. yeast, molds, enterobacteria, lactic acid bacteria). This results in dry matter losses and delays the growth of the desired lactic acid producing bacteria. However, most of the aerobic spoilage takes place during storage and feedout. Air can infiltrate on the top, sides and face of poorly packed silage structures resulting in important DM losses. Nevertheless, aerobic spoilage can be minimized if the forage is well compacted and the silage structure is sealed without delay.

Researchers from Cornell University (Ruppel, 1992) studied the relationship of packing density and dry matter losses in alfalfa silage stored for an average of 96 days: DM loss (% = 29.1 – 0.936 x DM density (lbs DM/ft3). This relationship is shown in **Table 2**.

Table 2. Dry Matter loss over an average of 96-day storage as a funtion of storage dry matter density

Density (lbs DM/ft3)	DM Loss (%)
10	10.4
12	8.0
14	7.6
16	6.2
18	4.8
20	3.4

Corn silage is an expensive commodity. Therefore, dairy producers should devote time and effort to ensure their forage is tightly packed. There are many factors that affect packing density and some can be controlled by the silage team and/or dairy producer. Among those factors are:

a. Forage maturity or DM at harvest - wet forage is easier to pack.
b. Theoretical cut length and processing – smaller particle length is easier to pack.
c. Forage delivery rate – should be appropriate to match packing capacity.
d. Tractor weight and number of packing tractors.
e. Packing layer depth – the recommendation is six inches depth.

Responses from recent survey (Collar and Silva-del-Río, 2010), indicates differences in harvesting and packing practices across custom harvesters that may have an impact on packing. The impact of those practices on silage quality should be addresses in future research. Further information on the controllable management factors and the expected effect on packing density can be obtained through the Extension Services from the University of Wisconsin (www.uwex.edu/ces/crops/uwforage/storage.htm).

This section includes information from the corn silage packing density survey conducted by **Mr. Caley Heiman**, Sales Representative with Alltech, on California's Central Valley dairies during the spring and summer of 2010. A total of twenty-five silage structures were studied (22 piles, 2 drive over piles, 1 bunker). The height of the silage structures ranged from 14 to 30 ft. Density samples were collected in three different locations (right, medium, and left) at six ft from the bottom of the silage structure. Fifteen silage structures were also sampled at six ft from the top of the silage. The top samples were intercalated within the bottom samples.

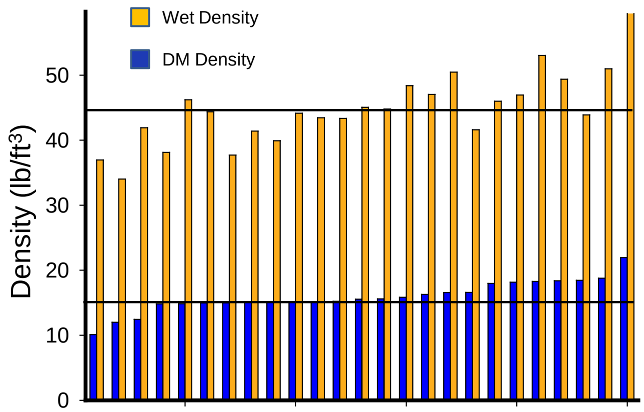

Figure 4. Overall wet and dry silage density.

The overall density for each of the silage structures was calculated by averaging all the density samples collected and expressed as DM density and wet density (**Figure 4**). All the silage structures but three met the benchmark of 15 lb/ft^3 of overall DM density, whereas when expressed as wet density, 11 silage structures did not meet the benchmark of 44 lb/ft^3. Wet density reflects porosity which is the pore space relatively to the volume occupied by the forage mass. Forages that are densely packet at higher moisture will have less pore space and will be more resistant to air penetration. Therefore, to account for porosity we will report results based on wet density.

The percentage of samples below the benchmark of 44 lb/ft^3 in each of the different sample locations is represented in **Figure 5**. Among the 25 silages studied, 22 had at least one density sample below 44 lb/ft^3, and 15 had a least one density sample of less than 35 lb/ft^3. The overall wet density of bottom samples was 47.6 lb/ft^3 and top samples 36.6 lb/ft^3.

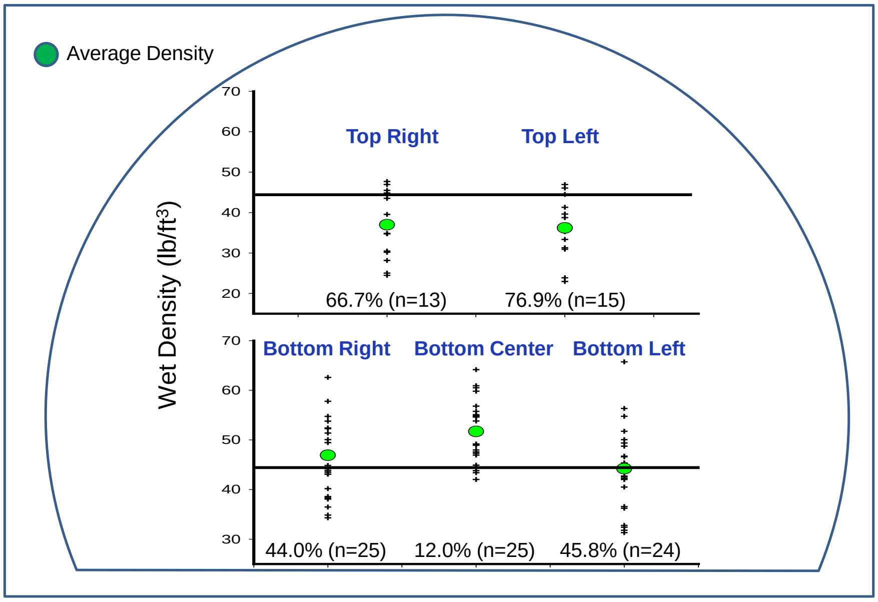

Figure 5. Percentage of wet density samples below 44lb/ft^3 for each of the sample locations.

A total of 15 silage structures were sampled at both locations: bottom and top. The average wet silage density by location (top and bottom) is summarized in **Figure 6**. Blue bars represent the average density of samples collected at the top and the red bars the average density at the bottom. Four out of the 15 silages studied meet the desired density benchmark of 44 lb/ft^3 for both locations: the bottom and the top. Density of the bottom samples were correlated with silage height (r=0.38, p-value =0.05) but not the top density samples.

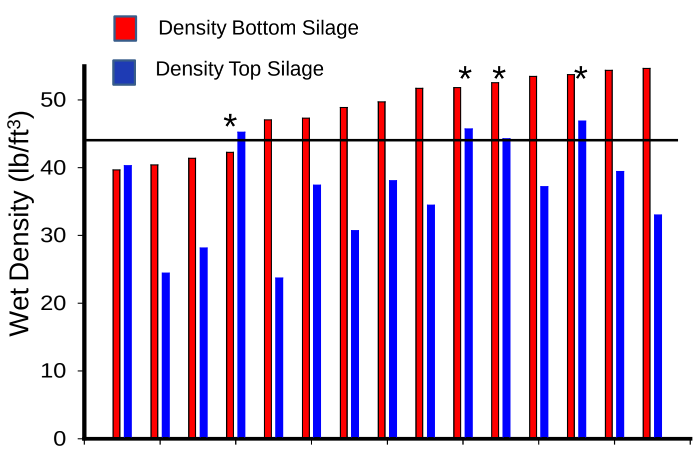

Figure 6. Packing Density in the Top and Bottom of Silage Piles

Packing density is critical to prevent dry matter losses associated with aerobic spoilage. Most of the surveyed silage structures were well packed at the bottom. This may be partially due to the compaction force that the upper forage mass exerts on the bottom. However, there is an opportunity to improve silage on the top of the silage structure. The dry matter losses associated with poor packing should be a great incentive for dairy producers to achieve the highest standards in packing.

Silage Face Management

The goal of silage face management is to minimize silage exposure to oxygen. In the presence of oxygen, yeast can metabolize lactic acid, a strong acid that keeps the silage pH low. When pH increases, undesirable fungi and bacteria are able to grow and further spoil the silage. This spoilage is translated into dry matter (DM) losses that can be as high as 10% when face management is marginal. This section focuses on the importance of good face management practices to minimize DM losses and describes current silage management practices in California dairies based on a UCCE survey (Silva-del-Rio et al., 2010).

Maintain a smooth surface: The feedout face should be a smooth surface (with no cracks) and perpendicular to the floor. The advantages of a smooth and perpendicular face are reductions of:

- The surface area exposed to oxygen by up to 9%.
- The risk for avalanches.
- The water caught during the rainy season.

Dairy 1

In this dairy, silage face management is poor. The front loader lifts the silage from the bottom of the pile to the top, allowing oxygen to enter the face.

Dairy 2

This silage face is smooth and perpendicular to the floor. The face is carefully shaved across the width (from left to right as shown in the picture below).

Dairy 3

This dairy uses a face shaver. It is estimated that face shavers can reduce DM losses by 3% compared to front-end loaders. However, more research needs to be conducted.

Based on results from the UCCE corn silage management practices survey, most dairy producers considered that their silage faces were maintained smooth. However, only five of 109 producers used a face shaver.

Maintain a rapid progression through the silage face. The rule of thumb is to remove between 6-12 inches per day during the cold season and 18 inches per day during the warm season. Muck and Huhnke (1995) found that in well packet silages (density = 14 -15 lb DM/ft3) air moves 3ft into the silage pile. Therefore, with a removal rate of 6 inches per day the silage will be exposed to oxygen for a week before feeding.

A desirable removal rate can only be achieved if the silage pile is sized according to the herd needs. If the pile's face is oversized, it is recommended to work on removing small sections of the silage face at a time. Silage removal rate and width of the face removed in California dairies is represented in **Figure 7** and **Figure 8** respectively.

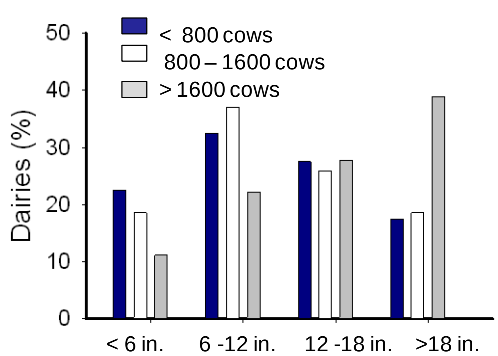

Figure 7. Depth of the corn silage face removed per day by herd size (Silva-del-Rio et al., 2010).

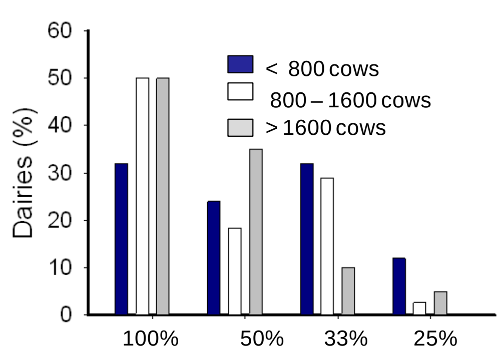

Figure 8. Width of the corn silage face removed per day by herd size (Silva-del-Rio et al., 2010).

Minimize the time the silage stays in the commodity area before it is added to the ration.

Silage sitting in the commodity area, exposed to sun and oxygen, heats and undergoes secondary fermentation. In some dairies, the silage may need to be removed several times a day in order to avoid this. There should be little to no silage left at the base of the face after feeding is done for the day (**Figure 9**). Silage should not be removed prior to the time of feeding. This practice may save a small amount of time, but is detrimental to silage quality.

Figure 9. Loose silage sitting at the face exposed to oxygen and air.

Remove the cover as needed, discard spoiled feed and keep air out of the edges and seams.

No more than three days of cover should be removed at one time. This will prevent a prolonged silage exposure to oxygen and weather elements. Spoiled and moldy feed should be discarded as it decreases intake, digestibility and destroys the rumen forage mat. A total of 60% of dairy producers reported that they discarded spoil forage (**Figure 10**). The face should be kept tight to prevent air infiltration. Silage should be sealed on the edges with sand, gravel bags or other materials (**Figure 11**).

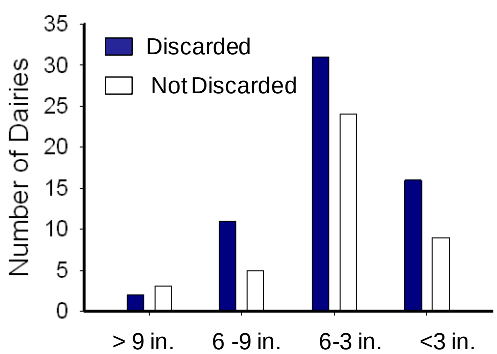

Figure 10. Dairies discarding spoiled forage from the Silage Surface (Silva-del-Río et al., 2010).

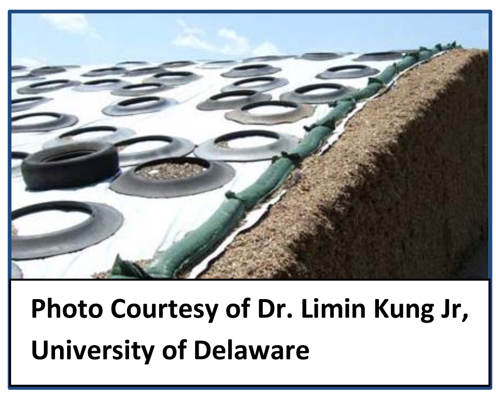

Figure 11. Gravel bags on the front and sides of the silage face help to prevent air infiltration into the silage mass.

SUMMARY

Corn silage is a valuable commodity. Dairy producers should invest time and effort to coordinate growers, pest control advisors, custom harvesters and nutritionists to work towards the same goal: maximizing quality and quantity of the crop harvested and ensiled. The key to minimize DM losses during ensiling is to rapidly achieve anaerobiosis, and minimize the exposure to air during silage feedout. Good management practices at harvesting, storing and feed out are required to ensure minimal DM losses.

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APPENDIX I.

Dry Matter Determination of the Corn Crop Prior to Harvest

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The dry matter of the crop standing in the field can be estimated by evaluating the greenery of the canopy, breaking down the stalk and examining the kernel milk line. But, how well does that relate to actual dry matter? We suggest you to take a new approach that may help you to more accurately determine the dry matter of the crop standing in the field.

Step 1. Take a representative sample of the field. **Select 10-20 plants** at different locations away from the head or tail of the field. Enter the field several rows from the edge. You can use a machete or pruning shears.

Step 2. Hand feed the plant to a **chopper** (you can use a chipper shredder).

Place a bag to collect the chopped material.

Step 3. Take a **representative sample**: *Method 1* (more accurate): divide your sample in quarters and discard two opposite quarters. Mix the other two quarters and repeat until you get a 1lb sample, or volume of 5-7 cups. *Method 2*: Mix the pile well and collect 5-7 cups of forage throughout the pile.

Step 4. Place your **sample in a plastic bag and keep on ice**. Take the sample quickly to a lab or to your dairy for dry matter determination. It is important to get the wet weight as soon as possible.

Step 5. Use approximately 100 g **for microwave method or 200 g for Koster** Tester (1lb = 454 g). You may also find a nearby lab where you can get timely results.