How to Optimize Corn Silage Quality in Florida

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Introduction

Silage accounts for 30 to 40% of the diet of dairy cattle in over 90% of the dairies in the Southeast. Corn silage is the main silage fed to dairy cattle in Florida and it plays a vital role in supplying digestible fiber and energy to dairy cows. The fiber supply from corn silage is also necessary for stimulating salivation and buffering microbial acid production in the rumen, thereby minimizing the risk of acidosis and a displaced abomasum. Ingestion or inhalation of mycotoxins from bad silages pose health risks for producers and can severely limit feed intake and milk production in cows. Therefore, optimization of silage quality is crucial for ensuring the viability and profitability of dairies. This paper will describe the characteristics of good quality corn silage, discuss management practices necessary for optimizing silage quality and highlight the unique challenges faced by silage producers in the southeast that necessitate adoption of excellent silage management practices.

Characteristics of good and bad silages

Kung (2002) reviewed the physical characteristics of good and bad silages. High quality corn silage has a greenish brown appearance, and a light, fresh smell. This is because the lactic acid that is produced from the most efficient or homolactic fermentation pathway is odorless. Alcohol or sweet smelling corn silage is undesirable because it reflects ethanol accumulation which is indicative of dry matter (DM) losses due to yeast proliferation. Rotten, fishy smells usually indicate butyric acid accumulation due to clostridial fermentation and significant losses in nutritive value. Musty, stale smells indicate aerobic spoilage and DM losses while slight tobacco odors reflect heat-damaged protein. A strong vinegar smell indicates acetic acid accumulation and a heterolactic fermentation. If this smell occurs in corn silage that was not inoculated with *Lactobacillus buchneri*, a less efficient, heterolactic fermentation probably occurred. However, if the vinegar smell occurs in corn silage inoculated with *L. buchneri*, the vinegar smell should be expected as it suggests that the inoculant is effective, and aerobic stability should be enhanced. A brownish green appearance, and vinegary smells are typical of good quality, bermudagrass silages because of dominance of acetic acid in the fermentation products.

Since physical assessments of silage quality can be subjective and sometimes misleading, it is of paramount importance to analyze silage samples chemically. Ration formulation is only worthwhile when analytical results on representatively sampled silages are available. The first step in accurately analyzing a silage sample chemically, is to representatively sample the entire forage and send the sample to a reputable forage analysis laboratory. Remember that the laboratory may only use 1 g of the sample sent for analysis. Therefore, if representative sampling is ignored, the analytical results will be worthless. Representative samples of silages can be collected by taking several cores (at least five) from different locations on the silo face, or along the length of an Ag bag, and mixing the samples properly. About 1 pint to 1 quart of the mixed sample should be kept in an airtight, sealed, labeled plastic bag and sent to the laboratory on the day the samples are taken by next-day delivery. Any holes in the plastic created during sampling should be immediately sealed with waterproof, silage tape.

Optimal concentrations of key nutritive value indices in corn, sorghum and Tifton 85 bermudagrass silages are given in Table 1. Since the main reason for including forages in livestock diets is to supply fiber and energy, some of the most important indices of forage nutritive value include the total fiber or neutral detergent fiber (NDF) content and the NDF digestibility. Each percentage increase in NDF digestibility of corn silage can increase feed intake by 0.38 lb /d, and a 2% increase in NDF digestibility can increase daily milk production by about 1.13 lb/cow (Staples, 2005).

Table 1. Target levels of key nutritive value indices in good quality silages.

Item	Corn Silage	Forage sorghum silage	Tifton 85 bermudagrass silage
Crude protein, % DM	≥7	≥8	≥10
IVOMD, [1] % DM	≥75	≥65	≥50
Total digestible nutrients (TDN), %	≥65	≥54	≥53
Starch, % DM	>25		
Neutral detergent fiber (NDF), % DM	≤47	≤64	≤75
NDF digestibility[2] @ 30 h, %	≥50	≥50	
NDF digestibility[2] @ 48 h, %	≥60	≥57	≥44
Fermentation products			
pH	3.7 - 4.2	3.8-4.2	3.8-4.3
Lactic acid, % of DM	≥5	≥5	≥3
Acetic acid, % of DM	1 - 3	1 - 3	4-5
Lactic:acetic % of DM	>2	>2	>0.5
Propionic acid, % of DM	< 0.1	< 0.1	< 0.1
Butyric acid, % of DM	0	0	0
Ethanol, % of DM	<2	<2	<3
Ammonia-N, % of total N	≤ 7	≤7	<10

[1] In vitro organic matter digestibility; [2] NDF digestibility is measured by incubating the silage in rumen fluid for 30 or 48 h. Different labs use different methods, therefore only values for silage samples analyzed at same laboratory with the same incubation duration should be compared.

Caution is required when comparing NDF digestibility values of different corn samples or hybrids, because different laboratories use different methods for the analysis. Some labs incubate the silage sample in rumen fluid within test tubes, while others incubate the samples in porous bags within fistulated cows. Another key difference is the rumen fermentation duration which ranges from 24 to 48 h. Therefore it is only valid to compare NDF digestibility results if they are obtained using the same method, i.e. from the same lab. and with the same digestion duration.

The length or physical effectiveness of fiber particles is an important determinant of saliva production and hence, buffering of acid production in the rumen. The Penn. State particle separator is a box consisting of sieves with different screen sizes that is used to evaluate fiber 'effectiveness'. When fed as the sole forage, corn silage should account for at least 8, 65 and 40% of the forage retained in the upper, middle and lower screens of the Penn. State separator, respectively. If the corn silage is not fed as the sole forage, the corresponding values should be at least 3, 45 and 30%, respectively (Heinrichs and Kononoff, 2002).

Other important measures of digestibility and energy content of the feed are the in vitro digestibility (IVDMD or IVOMD) and the total digestible nutrient (TDN) concentration. The quality of the fermentation can be assessed by evaluating the fermentation product concentrations in silages, and the target values for southeastern silages are shown in Table 1.

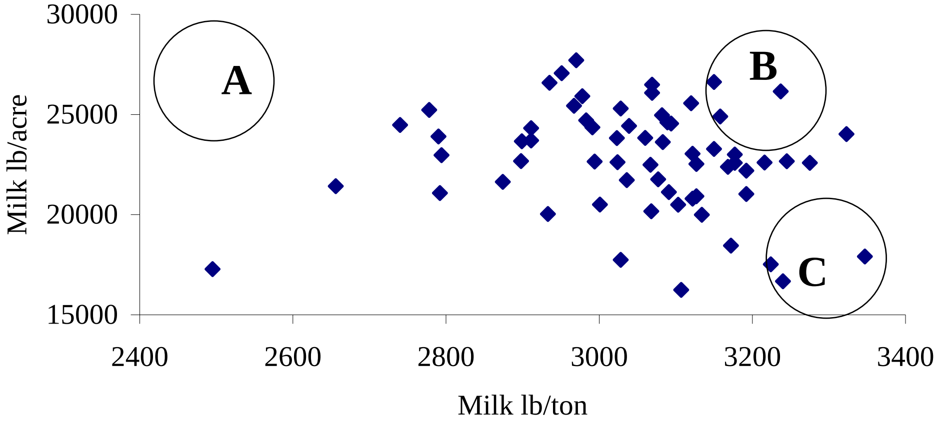
Making excellent quality silage

An important prerequisite to making good quality silage is to realize the importance of excellence in every step of the silage production process from hybrid selection to feedout. This is particularly important for silage producers in the southeast who face unique challenges that will be discussed later.

1. Hybrid selection

Proper hybrid selection is crucial for quality silage production, and time spent carefully researching the performance history of a hybrid can pay off greatly. Traditionally, attention was paid to traits such as pest and disease resistance, yield, leafiness, standability, relative maturity, drought tolerance, staygreen ranking and drydown rate. While such agronomic traits are important, several nutritional traits such as the NDF content, starch content, NDF digestibility and IVOMD are equally significant. The Milk 2000 spreadsheet (available at http://www.uwex.edu/ces/forage/articles.htm#milk2000) is a tool that calculates potential milk production per ton, and milk production per acre from silage hybrids. It therefore combines several nutritional and agronomic traits into numbers that can be used to make informed choices among hybrids. Figure 1 shows corn hybrids ranked according to their Milk 2000 scores. There were no hybrids in area A, which reflects hybrids with low nutritive values, but high milk production per acre due to their high forage yield potential. Such hybrids would be ideal for replacement heifers. Hybrids in area C have high nutritive values,

and low yield potential such as some brown mid-rib hybrids, and these may be ideal for cows in early lactation. Hybrids in area B combine high yield potential with high nutritive values, and are therefore the most ideal overall choice.
However, it is pertinent to note that Milk 2000 scores only predict potential hybrid performance, and actual performance will depend on actual yield and nutritive value at harvest as well as fermentation quality and aerobic stability.



A= Area representing corn hybrids with high milk/acre values

B = Area representing corn hybrids with high milk /acre and high milk/ton values

C = Area representing corn hybrids with high milk/ton values

Figure 1. Milk 2000 scores of corn hybrids in the 2004 Florida corn silage hybrid performance trial.

When evaluating corn hybrids, only those that consistently have high Milk 2000 scores and nutritional values, and good agronomic traits over several years should be chosen. The hybrids should have been grown at locations with similar climatic and soil conditions to those at the producers' farm. These guidelines also apply to selection of sorghum hybrids, which vary more in their phenotypic attributes.

A seed company representative recently concluded a presentation to corn growers and dairy producers by stating that for every minute spent in corn hybrid selection, which is well worth the investment, an hour should be spent in ensuring good silage management practices. This is because excellent corn hybrids can end up as bad silages if proper silage management is not ensured. Silage production is a multifaceted process that requires excellence in hybrid selection, as well as each of the stages described in the following sections.

2. Predicting the harvest date

Traditionally, the kernel milk line was used to predict harvest dates for corn silage; however, this index is no longer suitable for current corn hybrids. Rather, producers should rely on analyzing the moisture content of plant samples. This can be done by placing representative samples of the forage in an oven set to 212°F (100°C) for at least 16 h, or using a Koster silage moisture tester which has a ± 3% error margin. A recent study at the University of Florida that compared the nutritive value and fermentation quality of corn silage harvested at DM contents of 26, 34 and 39% (corresponding to moisture contents of 74, 66 and 61%), revealed that nutritive value and fermentation quality were optimized at 34% DM (66% moisture; Arriola et al. (2005). Therefore corn silage should be harvested at 30 – 35% DM (or 70 – 65% moisture). Harvesting too early can lead to problems of excess effluent production and DM losses, while late harvests can predispose the plants to disease problems. These problems also occur with sorghum hybrids and they can be avoided by harvesting sorghum hybrids at the late dough stage when the DM at harvest is 30-35%. Harvesting at the milk stage results in lower yields and wetter forage, while harvesting at the hard grain stage results in lower energy value (Bolsen and Bolsen, 2004).

3. Harvesting and processing

Harvesting should be planned for dry days because even 1.5 inches of rainfall can compromise silage quality (Adesogan and Kim, 2005). Precision-chop forage harvesters with sharp knives should be used to achieve a chop length of ¼ -⅜ inch for unprocessed corn silage, and ¾ inch for processed corn silage (Shaver, 2003). Processing ensures proper utilization of the energy in the corn kernel. Processing is advised for flint corn or hybrids with high drydown rates, high staygreen rankings, high vitreousness or hard kernels, and whenever whole kernels appeared in the feces in the previous season. Processing increases starch digestibility by about 5 percentage units leading to over 1 lb of extra milk produced per day (Satter, 1999; Shaver, 2003). The roll clearance of processors should be set to 1 - 3 mm since inadequate processing is inefficient, while excessive processing can reduce fiber digestibility and predispose cows to acidosis.

Table 2 shows the effect of processing and chop length on the extent of kernel breakage. Proper processing should ensure that over 95% of kernels are cracked or split, and no cob fractions are greater than half an inch.

Processing forage sorghum hybrids before ensiling has not shown consistent benefits in research trials. However, wilting sorghum hybrids overnight is advisable, particularly if they are harvested at or before the milk stage when DM contents are lower than 30%.

Table 2. Effect of processing and chop length on corn silage kernel breakage. (Jirovec et al., 1998).

	Control		Processed	
Chop length, inches	3/8	3/4	3/4	3/4
Roll spacing, mm	-	-	1	3
Kernel breakage, %	63	50	100	91

4. Inoculants and additives.

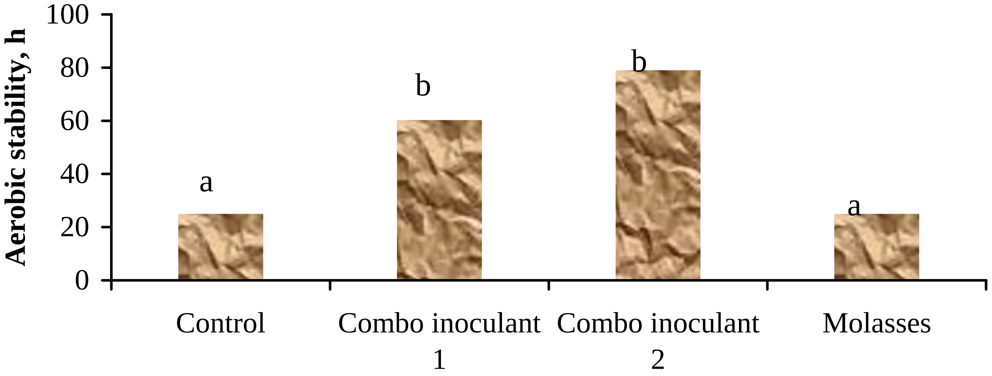
Most of the guidelines for inoculant usage on corn silage are also applicable to forage sorghum silage. Muck reviewed the literature on the use of traditional homolactic inoculant effects on corn silage fermentation and recommended them for alfalfa and grass silages, but not for corn silage (Muck and Kung, 1997). This is because corn silage has a higher concentration of the bacteria that grow naturally on plants, and are necessary for starting and maintaining fermentation than the other forages (Andrieu & Gouet, 1990). Also many corn hybrids have sufficient sugars for optimal microbial growth during ensiling. However after a frost or under conditions of excess moisture or dryness, such inoculants may be useful for improving the fermentation. Furthermore, some silage hybrids have low sugar contents which compromise the ensiling process. Recent results from the 2004 corn hybrid performance evaluation at the University of Florida revealed that about 20% of the hybrids tested had sugar contents that were less than the 5% of DM that is considered to be needed for proper fermentation.

Unfortunately, sugar contents of hybrids are not usually displayed in the hybrid brochures. Though the addition of molasses at ensiling can increase the sugar content, it is risky and not recommended because the potential for yeast proliferation and aerobic deterioration is greater in molasses-treated corn silages (Figure 2).

One of the limitations of using homolactic inoculants on corn silage is that they may not reduce the incidence of aerobic spoilage, which occurs more readily in hot and humid climates. However, heterolactic inoculants containing *Lactobacillus buchneri* have been shown to increase the bunk life of corn silage in several studies (Muck and Kung, 2001). It is therefore advisable to use such inoculants to increase the aerobic stability of corn silage in the southeast. Propionic acid is an equally effective alternative for enhancing aerobic stability of silage.

Novel 'combo' inoculants which contain both homolactic and heterolactic *L. buchneri* bacteria aim to enhance the both the fermentation process and aerobic stability. Recent studies have confirmed their effectiveness on corn silage produced in the southeast (Figure, 2; Adesogan et al., 2005). However, recommendations that inoculant application rates should be doubled for the southeast because of the climatic and environmental challenges have been disproved (Kim and Adesogan, 2005).

Silage producers should only use inoculants with a track-record proven through independent research and that contain > 90 billion live bacteria per ton (> 100,000 colony forming units (CFU)/g). Those containing *L. plantarum* should be used for fermentation enhancement, while those containing *L. buchneri* are for bunk life enhancement. Price should never be the only factor determining the choice between inoculants. Inoculants should be applied through the forage harvester rather than at the bunker, and they should be stored in a cool, dry place and used within 24 h of dilution.



Bars with different letters are different ($P<0.05$)

Figure 2. Effect of treating corn silage with molasses or two commercial 'combo' inoculants companies on aerobic stability (hours, Adesogan et al., 2005).

5. Packing and sealing.

Although practical considerations may interfere, it is imperative to plan to pack the forage and seal the bunker on the day of harvest. The quality and bunk life (aerobic stability) of silage can be seriously reduced by delayed sealing, and prolonged delays can render inoculants ineffective (Table 3).

Another crucial determinant of silage quality is packing density. Silage shrinkage (DM losses) increases as packing density decreases (Figure 3), and poor packing density can also reduce the effectiveness of silage inoculants (Table 4). A target packing density of 14 lb DM/ft^3 (43 lb fresh forage/cu ft) is required to minimize shrinkage and this can be achieved by aiming for a packing time of 1- 4 min/ton and using delivery rates of about 30 tons/h (Bolsen and Bolsen, 2004). Delivery rates of over 60 tons/h will lead to packing times less than 1 min /ton (Bolsen and Bolsen, 2004), which will compromise packing density. High delivery rates that leave unpacked silage overnight should be avoided. A spreadsheet for properly managing bunker filling is available at www.uwex.edu/ces/crops/uwforage/storage.htm.

Table 3. Effect of delayed sealing for 48 hours on corn silage fermentation (Uriarte *et al.,* 2001).

	Control		Inoculant-treated	
	Instant seal	Delayed seal	Instant seal	Delayed seal
pH 4 days after opening silo	3.6	8.0	3.7	8.2
Lactic acid 4 days after opening silo, % of DM	4.4	0.3	3.9	1.5
Yeasts, log cfu/g	4.9	5.7	5.0	5.5
Aerobic stability (bunk life), h	113	65	137	89

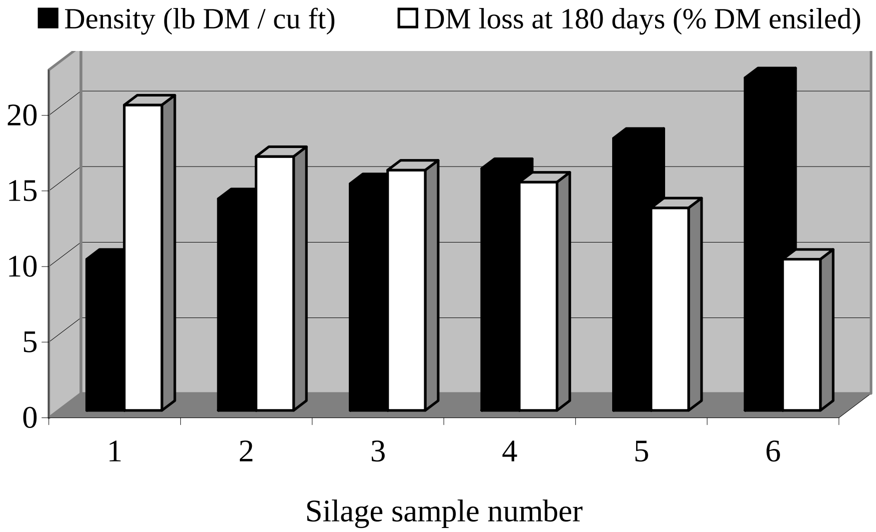


Figure 3. Effect of density on silage DM loss (Ruppel et al., 1995).

Additional factors that are important for achieving the right packing density include using the heaviest tractor for packing, filling in a progressive wedge design (Figure 4) and packing no more than 6-8 inches of forage at a time (Kung, 2000).

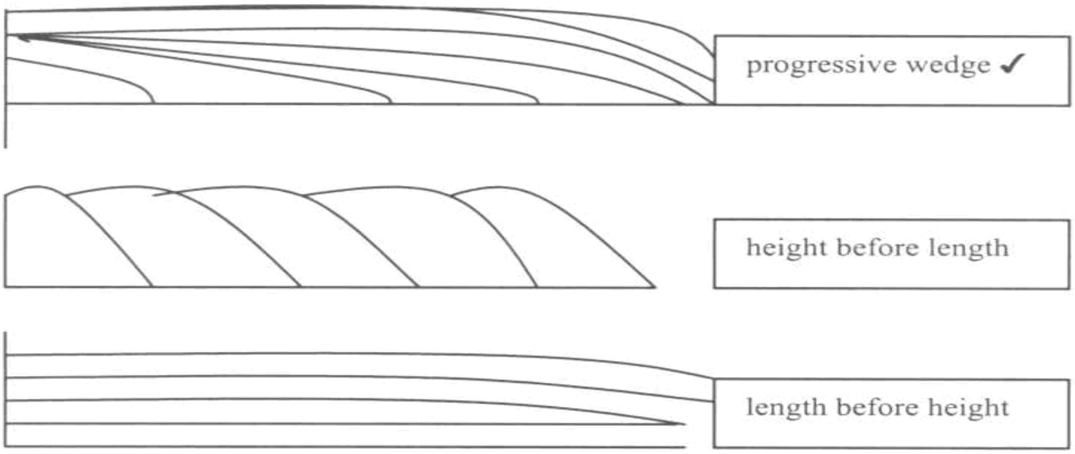


Figure 4. Bunker filling methods (Kung, 2000).

Table 4. Effect of packing density and *L. buchneri* inoculant treatment on silage quality and aerobic stability (Antoniali et al., 2004).

	Loose (12 lb/ft^3)		Tight (14 lb/ft^3)		
	Untreated	Buchneri	Untreated	Buchneri	Effect [1]
Lactic acid, % of DM	4.64	4.29	4.41	4.53	
Acetic acid, % of DM	1.69	2.23	1.60	2.08	I, P
Yeasts, log cfu/g	3.92	2.7	4.05	1.66	
Molds, log cfu/g	3.97	2.57	3.73	1.81	I
Aerobic stability, h	27.5	34.5	31.0	60.0	I

[1] Significance ($P<0.05$) of packing density (P) or inoculant (I) effects.

6. Sealing, storage and unloading.

Bunkers and bags must be sealed on the day of harvest with 6 mil plastic to prevent subsequent spoilage and quality losses. To avoid heating and spoilage, bag and bunker plastic integrity should be examined frequently, and any holes or splits found should be immediately sealed with proper waterproof silage tape. Tires (that are touching) should be used to weigh down the plastic and exclude air from the silo.

Furthermore, at least 6 inches of forage should be removed daily during unloading in the winter, and 10 to 12 inches should be removed in the summer in the southeast to minimize spoilage. Removal should be from the bottom of the silo face rather than the top, and the aim should be to minimize silo face disturbance. Care should be taken to avoid tearing the plastic when unloading from Ag bags, and the face of the silage in Ag bags should be covered with plastic after unloading.

This paper has emphasized the management practices that must be ensured at each of the key stages of silage production in order to make excellent quality silage. Since different individuals are often involved in handling each of these stages, the dairyman needs to ensure that all those involved realize that their contribution plays a vital role and can determine the quality of the silage. This is particularly necessary because of our hot, humid environment.

Unique challenges faced by silage producers in hot, humid regions.

A recently completed research project at the University of Florida was aimed at determining the effects of temperature and simulated rainfall on the quality of corn silage (Kim et al., 2005). A corn hybrid was grown in four replicated plots and after half of each plot was harvested, the other half was sprinkled with sufficient water to simulate 1.5 inches of rainfall and then harvested. Samples of dry or wet forage from the four plots were either stored at 105^{o}F in an incubator or at 85^{o}F in an air conditioned room for 82 d. Wetting the corn silage increased protein degradation during ensiling and made the fermentation less efficient or heterolactic. Ensiling at the higher temperature reduced DM digestibility and decreased the extent of fermentation as shown by a higher pH. The higher temperature also increased protein degradation and damage. These results are similar to those of other researchers who concluded that “in warm climates, or under high temperatures, silages are more susceptible to poor fermentation and aerobic deterioration” (Weinberg et al., 2001).

These factors indicate that while silage producers in cooler, drier regions may succeed with mediocre silage management practices, producers in the southeast need to aim for excellence in silage making to overcome the unique challenges posed by our climate.

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Notes