PennState Extension

Troubleshooting Silage Problems

Practical information for evaluating silage quality and feeding management to determine its potential role in production or health problems on the dairy farm.

ARTICLES | UPDATED: FEBRUARY 15, 2016

Introduction

Ensiled forages are the most common feeds used on the dairy farm. Silages are used primarily due to their potentially lower harvest and storage nutrient losses. Silages also allow for greater flexibility in moisture content of feed at harvest. This is primarily of importance in areas of the country where weather patterns do not allow for easy feed drying to make good hay. The ensiling process (Table 1) is an anaerobic microbial fermentation of water-soluble sugars to lactic acid, lowering the pH to a point that inhibits further microbial fermentation. The goal is a rapid pH drop to minimize fermentation losses of feedstuff nutrients, especially protein. However it must be remembered silage is never static; it is a potentially dynamic feed that can dramatically change for the worst given the right circumstances, such as the addition of oxygen. The objective of this document is to provide practical information by which silage quality and feeding management may be evaluated to determine its potential role in production or health problems on the dairy farm.

Table 1. Six phases of silage fermentation and storage.

Phase	Active Process	Temperature	pH	Comments
I	Aerobic fermentation of forage	↑ 69 to 90°F	6.0 to 6.5	Produces H_2O, CO_2, heat; Continues until all O_2 is gone; Minimized by proper management
II	Heterofermentative fermentation (Acetic acid and lactic acid bacteria)	↓ 90 to 70°F	↓ to 5.0	Beginning of anaerobic fermentation; Lasts 24 to 72 hrs; Heat tolerant organisms; Inactivated by low pH; Acetic and Lactic acids, ethanol produced
III	Homofermentative fermentation	Stabilizes near 65 to 70°F	↓ to 4.5 or 4.0	Lactic acid production by Lactobacillus spp.; Lasts 10 d to 3 wk; Inoculants stabilize in 3 to 4 d
IV	Homofermentative fermentation			
V	Material storage	Stable	Stable	Stability dependent upon: air penetration; remaining soluble sugars; fermentation acids present; presence of yeasts and molds
VI	Unloading/Feeding	Stable to slight increase	may ↑ to 7.0	Yeast and mold activity; Potential for aerobic decomposition, heat damage
Table adapted from Holland, C and Kezar, W (eds). Pioneer Forage Manual: A nutritional guide. Pioneer Hi-Bred International, Inc., 1995.				

Assessing Quality of Ensiled Feeds

Although silages are the most commonly used feeds, they are the most variable feeds on the farm. As a result, they are often the source of feeding-based problems. Based on the desired goals for high quality silage (Table 2), we can use these parameters as critical measures of assessing silage quality. Like other feeds, quality

can be assessed on three different levels: sensory evaluation, chemical composition, and physical characteristics. Each of these methods of evaluation will be discussed with their interpretation relative to silage quality.

Table 2. Six goals for stable silage.

1	Rapid pH decline to optimum level
2	Proper spectrum of fermentation acids
3	Conservation of water soluble carbohydrates
4	Minimize protein degradation
5	Control fermentation temperature
6	Minimize aerobic activity upon feed out

Sensory Evaluation of Silage

One can gain significant insight as to the quality of silage, corn or hay-crop, by its smell, sight, and feel. Sensory evaluation may suggest the need for further chemical or physical characterization of the feed should a problem be identified. Sensory evaluation of silage would include the following.

1. **Observe the contour of the bunker face.** Ideally the face should be very smooth and straight. This minimizes oxygen exposure to the silage. Bunker silos with irregular and uneven faces have greater surface area exposed to oxygen and thus a greater chance at increased microbial activity. As silage is reintroduced to air, mold and bacterial spores present in the silage can begin their metabolism again. This metabolic activity will result in silage heating as well as alterations in acids and sugars available in the feed. This metabolic activity suggests unstable silage and can contribute to depressed feed intake and feed refusals. This secondary heating is usually not sufficient to cause significant heat damage to the silage. The true value of bunk face management is not well known and is related to the density of the silage, the season of the year, and the amount of silage face that is removed each day.
2. **Silage color** can indicate potential fermentation problems (Table 3). Silages with excessive acetic acid will have a yellowish hue, while those with high butyrate will have a slimy, greenish color. Brown to black silage usually indicates heating from

fermentation and moisture damage. These silages have the highest potential for molding and are unacceptable feeds. White coloration of silage is usually indicative of secondary mold growth.

3. **Silage odors** can also be used to evaluate fermentation (Table 3). Normal silage has minimal odor due to lactic acid. If acetic acid production is high, then silage may have a vinegar smell. High ethanol content from yeast fermentation may impart an alcohol odor to silage. Clostridial fermentation results in a rancid butter smell. Propionic acid fermentation results in a sharp, sweet smell and taste. Heat-damaged silages will have a caramelized or tobacco smell. No silage should have a musty, mildew or rotten smell due to molding. Remember if the silage smell is really unpleasant to you, most likely it will be refused by the cow or cause reduced intake.

Table 3. Odor and color evaluation of silages.

Odor	Color	Cause
Vinegar	Yellowish	Acetic acid production (Bacillus)
Alcohol	Normal	Ethanol production (Yeast)
Sharp sweet	Normal	Propionic acid production
Rancid butter	Greenish	Butyric acid production (Clostridium)
Caramel/Tobacco	Dark brown to black	High temperature, Heat damaged

Chemical Composition of Silage

The following are chemical composition analyses that are important in evaluating silage quality. All analyses should be available from most commercial feed analysis laboratories.

- **Moisture** measures the amount of water in silage and is the most variable measure. How the sample was handled and processed will impact the final result from a lab. Moisture content will vary across the face of the bunker and through the pile. The reason moisture is such an important measure is that it determines the amount of dry matter. If the silage you are feeding is wetter than you think, you are feeding less dry matter. If it is drier, then you are feeding more dry matter. These differences may account for intake problems as well as not meeting expected

nutrient composition of the TMR. Ideally, all farms should have moisture testing capabilities for use on the farm (microwave, Koster tester®) to monitor weekly changes in moisture. Diets that are excessively wet or dry may limit intake. Excessively wet or dry silages often result in inadequate fermentation and unstable products. Suggested moisture guidelines are shown in Table 4.

Table 4. Suggested silage moisture levels based on silo structure.

	Corn Silage	Alfalfa Silage	Grass Silage	HM Shell Corn	HM Ear Corn
Bunker/Pile	67 to 72%	65 to 70%	67 to 72%	26 to 32%	34 to 40%
Stave/Bags	63 to 68%	60 to 65%	63 to 68%	26 to 32%	32 to 38%
Oxygen Free	50 to 60%	50 to 60%	50 to 60%	22 to 28%	30 to 36%

- **Crude Protein** content of a feed is often a measure of quality, mainly due to the high cost of providing additional protein supplements in the diet. Forages containing higher protein values are of higher quality since they are in early phases of growth. Sufficient dietary protein is necessary to facilitate rumen microbial fermentation and if deficient, reduced dry matter intake will result. Excessive rumen degradable protein results in high milk urea nitrogen (MUN) values, especially when rumen fermentable carbohydrates are limited. Unbalanced rumen protein results in lower nitrogen utilization efficiency, increased nitrogen excretion and potentially reproductive inefficiency. As a result, partitioning silage crude protein into rumen soluble, degradable, and unavailable fractions can be more enlightening in evaluating silage quality.
- **Soluble Protein** measures the total nitrogen in silage that potentially can be used by rumen microbes for microbial protein production. Utilization efficiency is dependent upon available fermentable carbohydrate in the rumen. Excess soluble protein will be absorbed and detoxified by the liver and excreted as urea. Silages with excessive proteolysis or that have been treated with ammonia or urea will have large amounts of soluble protein (>60%). These silages may be associated with reduced intake and poor bunk stability. A goal is to maintain protein solubility within a range of 40 to 60% of total crude protein.
- **Ammonia Nitrogen** measures the nonprotein nitrogen (NPN) component of the soluble protein fraction. One goal of silage is to minimize proteolytic activity from plant respiratory enzymes or microbes, primarily Clostridium. Amounts of NPN compounds increase greatly with proteolytic activity. This will buffer and increase

silage pH making it less stable. Also, some toxic NPN compounds such as amines can reduce feed intake. The goal is to have ammonia nitrogen less than 8% and 10% of crude protein for corn silage and hay-crop silages, respectively.

- **Acid Detergent Insoluble Nitrogen (Protein)** is the amount of crude protein bound to plant cell wall and found in the acid detergent fiber fraction. This generally represents heat-damaged protein, which is unavailable to both microbes and cow. The goal is to have less than 10 to 12% of total crude protein as bound protein.
- **Neutral Detergent Fiber (NDF)** content of a feed characterizes the amount of cell wall material and is inversely proportional to dry matter intake. Plant maturity is directly proportional to NDF content. High NDF feeds have lower potential intake, although feed processing (grinding) can improve intake potential.
- **Acid Detergent Fiber (ADF)** is a subset of NDF, measuring the amount of less digestible feed cell wall material and is an important measure of feed quality. Cellulose, lignin, heat-damaged protein and other resistant substances comprise the ADF fraction. As ADF content of silage increases within a given plant species, overall quality will decrease.
- **Lignin** is a most critical factor in feed quality, especially forages, but one not often determined. Lignin is a polyphenolic compound that is totally resistant to digestion or fermentation. Lignin acts as cement between outer and inner cell wall layers. As a plant matures, lignification of the cell wall increases. Cell wall lignification reduces fiber carbohydrate availability of the associated cell wall (NDF) fraction. This effect can be directly measured by NDF fermentability procedures.
- **Fermentation Profile** is a newer analytical process that determines amounts of each important volatile fatty acid (VFA) produced during the ensiling process (Table 5). Normally lactic acid should be the predominate (>60%) VFA in silage. Excessive amounts of acetic, propionic, or butyric acids as well as ethanol indicate a poorer quality fermentation process resulting from other microbes that are not exclusive lactic acid-producing bacteria. It is important to understand that the levels of VFA will vary tremendously based on the crop species, dry matter at harvest, natural and added bacterial populations, field respiration losses, weather and sunlight prior to harvest, and most importantly the sugar content of the crop once it reaches the storage structure.

Table 5. Fermentation (volatile fatty acid) profiles for ensiled feeds.

VFA	Wet Silage	Wilted Silage	HM Grains
Total VFA	10 to 14%	4 to 8%	2 to 4%
Lactic acid, Total	6 to 8%	6 to 8%	1 to 3%
Lactic acid, % of total	> 60%	> 60%	> 60%
Acetic acid	< 2%	< 2%	< 0.1%
Propionic acid	0 to 1%	0 to 1%	0 to 1%
Butyric acid, total	< 0.1%	< 0.1%	< 0.1%
Ethanol	0%	0%	0%

- **Mold Counts/Mycotoxin Concentrations** can be determined at a number of laboratories. Common mold genera that cause problems include: Fusarium, Penicillium, Aspergillus, and Mucor. Moldy feed and mycotoxins should not necessarily be equated. Molds and fungi will grow under appropriate conditions and require moisture and heat. High humidity (>70%) and moisture content of feed in excess of 15% are conducive to fungal growth. Under the right conditions a fungal bloom can occur, which results in tremendous numbers of fungi contamination in feed in less than 24 hours. However, mold growth does not mean there are mycotoxins present. Conversely, mycotoxin problems may be present in the absence of visually obvious mold growth. Mycotoxins are very sporadic within a feed and often difficult to measure. Total mold counts can be determined for any feed. Expected mold counts for quality feeds are <300,000 cfu/g. Mold counts exceeding 600,000 cfu/g of feed are of concern. Extreme mold contamination may have mold counts exceeding 1,000,000 cfu/g of feed. If a single species of mold is identified at these higher levels, this would be considered significant, especially if it is a known mycotoxin-producing organism (i.e., Aspergillus, Penicillium, or Fusarium spp.). High mold counts with mixed species are less significant, but presence of mycotoxin-producing species would be of concern.

Physical Characteristics of Silage

- **pH** is a measure of acidity. High moisture silages are unstable with respect to pH and a wide range is found; good quality silages are associated with low pH. Corn silage should have a pH of 3.8 to 4.2, while hay crop silages have a slightly higher pH at 4.0 to 4.8. High pH at high water content is associated with proteolysis

(aberrant Clostridial fermentation) and low pH with lactic acid production. In high dry matter silages, pH is a less useful criterion of quality since deficiency of water restricts fermentation and acid production. This effect causes a negative association between water content and pH over the higher dry matter range.

- **Temperature** is a measure of the amount of heat generated. Temperature of silage can be easily measured with a compost thermometer placed at least 18 to 30″ into the bunk face. Other than initial respiration when the silage is first placed in the silo, there should be a fairly rapid return of silage temperature back to near ambient temperature. Elevated temperatures above ambient temperature suggest oxidative respiration by molds and fungi and feed instability. Temperatures in excess of 120°F suggest aerobic oxidation and potential for heat damage. Stable silages should not increase in temperature when removed from the silo and placed out in the feed bunk. Mold growth can often result in temperatures in excess of 100°F. Heating of silage in the feed bunk does not cause heat-damage of the feed, but it will decrease feed palatability.
- **Fermentability of NDF** in a feed can be determined at some laboratories by in situ or in vitro digestion techniques. This is a useful diagnostic test with corn and hay silages. One must be careful when comparing dNDF results tests across labs. The amount of time used for the digestion process must be consistent. Some labs are using 48 hrs while others are using 30 hr. NDF is a major component of ruminant feeds and its availability can greatly impact animal performance. NDF fermentability can range from 20% to over 60%. Plant maturity and lignification can greatly decrease NDF fermentability.
- **Particle Size** of fiber in the ruminant diet is important in maintaining proper rumen function and cud chewing activity. Insufficient effective fiber in the diet can result in ruminal acidosis and alterations in milk composition. Unfortunately, many times particle size of feeds or the rations are reduced as a result of improper harvesting, processing, or ration preparation. Effective particle size of feeds or the TMR can be estimated with a particle separation device (Penn State Particle Separator). Recommendations for particle size of forages, TMR, and grain are shown in Table 6.

Table 6A. Corn silage, haylage, and TMR particle size recommendations for lactating cows.

Screen	Pore Size (inches)	Particle Size (inches)	Corn Silage	Haylage	TMR

Screen	Pore Size (inches)	Particle Size (inches)	Corn Silage	Haylage	TMR
Upper Sieve	0.75	> 0.75	3 to 8	10 to 20	2 to 8
Middle Sieve	0.31	0.31 to 0.75	45 to 65	45 to 75	30 to 50
Lower Sieve	0.16	0.16 to 0.31	20 to 30	30 to 40	10 to 20
Bottom Pan		< 0.16	< 10	< 10	30 to 40

Table 6B. Particle size recommendations for corn grain.

Grain Type (Moisture content)	Sieve # 4 (4.75 mm)	Sieve # 8 (2.36 mm)	Sieve # 16 (1.18 mm)	Sieve # 30 (0.60 mm)	Pan
HM Corn (> 30%)	75	25	0	0	0
HM Corn (25 to 30%)	25	50	25	0	0
HM Corn (< 25%)	0	33	33	33	0
Dry Corn (< 15%)	0	0	30	50	20
Note: USDA standard sieve numbers.					

Potential Uses of the Particle Separator

Assessment of particle size for individual feed ingredients or the ration can be evaluated to address a number of diagnostic situations.

- **Harvesting cut length.** First and foremost is the use of the particle separator to evaluate particle size of individual forages (corn silage, hay-crop silage) during the harvest process to ensure appropriate particle size to facilitate the fermentation and feeding out processes.
- **Particle size reduction during mixing.** Mechanical reduction of particle size during the mixing process is a common problem on many farms. Over mixing,

inappropriate ingredient mixing order or mismatch between feed ingredients and mixing unit can all contribute to nutrition and metabolic problems. The particle separator can be used to visually demonstrate differences in particle size distribution from samples collected after the mixing process and by hand mixing. For a visual comparison, have the producer mix a batch of feed and then weigh out individual ingredients and mix by hand/pitchfork. Separate a representative sample of each and lay out side-by-side to evaluate differences in particle size distribution. Or you can calculate the theoretical particle size distribution of the TMR using the TMR components' particle sizes and percentages in the TMR. This will give you the actual mixer particle size reduction.

- **Mixing consistency and ration uniformity.** Ultimately we want particle size distribution to be essentially equivalent from one end of the bunk to the other end. One can evaluate mixing consistency by collecting TMR samples at different points during unloading of the mixer wagon or along the length of the bunk. Determine particle size distribution within this collection of samples to determine variability. Minimal variation (<5%) within screen sizes should be expected if the mixing process is doing a good job. Particle size distribution exceeding expectations from the given feed ingredients might indicate mixing errors of inclusion possibly due to scale inaccuracies.
- **TMR sorting.** This is the most powerful use for the particle separator in evaluating a feeding program on the farm. Feed bunk samples are collected at feeding time and then at defined times after feeding. Typically 2 to 3 hrs following feeding is the second sampling time and this can continue at regular intervals until the next feeding. Particle size is determined in all samples and compared across time. Typically changes of more than 10 percentage units on any one screen are suggestive of change, particularly the bottom 2 trays of the Penn State particle separator. In most sorting problem herds, material retained on the top two screens will increase over time while material retained on the bottom trays will decline as a percent of total particles.
- **Dietary effective fiber content.** A primary focus of ration formulation is to ensure adequate intake of dietary fiber that can maintain rumen function and a healthy rumen environment. However, not all dietary fiber is capable of evoking this response and hence the terminology of effective and physically effective fiber has evolved. Different methods have been developed to estimate the "effective" fiber in the diet or dietary ingredients. Often particle size, as measured by the Penn State separator, is equated with a determination of effective fiber. Some specialists have stated the total retained material above the bottom pan is a measure of effective

fiber. Although the third screen aperture is similar in size to another methodology, values obtained by the two different methods cannot be equated as a result of differences in procedures. Shaking direction and using either dried or as fed feed samples will have tremendous effects on obtained values. Research is currently underway to develop translational models to predict "effective fiber" measured by one or more different methods.

Summary

Even if an extension educator or veterinarian does not feel comfortable with ration formulation, they can and should become involved in their client's ration program in a role of monitoring agent. Feed quality and feeding management issues account for the greatest percentage of feed-related problems on the farm. An extension educator or veterinarian with an understanding of feed quality and management diagnostics is a critical component in the diagnostic process. This paper covered a number of easy to use diagnostic tools that can become part of the diagnostic nutritional toolbox. Many of the concepts and diagnostic measures presented can be used not only to diagnose problems, but may be used to help producers in the process of making good quality silage. Monitoring should start with the first cut!

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This paper was originally published in the proceedings of the Mid-Atlantic Conference held May 26-28, 2008.