Western Beef Resource Committee *Fourth Edition*

Cattle Producer's Handbook

Nutrition Section 320

Principles of Successful Silage Management

Tianna Fife and Mireille Chahine
University of Idaho

Harvesting forages for hay is the most common means of preserving forage for feeding the beef herd; however, silage is an alternative method of preserving forage that may offer advantages for some beef producers. In particular, preserving forage as silage does not require extended time for field drying; therefore, silage is a likely alternative when wet, inadequate climate conditions do not permit field drying to conserve the forage as hay. Likewise, when harvesting forage as silage losses in the field are lower as compared to harvesting it as hay because processes such as respiration, shattering, leaching, and sun bleaching are reduced.

Compared with hay, silages are also typically more palatable with more digestible fiber and may have a higher energy and protein content. On the negative side, silages require more attentive management to prevent dry matter and nutritional losses during storage and feeding. Therefore, these aspects and the costs of production, storage, and feeding need to be evaluated for each situation.

Phases of Silage Making and How Harvest Affects It

The ensiling process allows forage to be preserved at a moisture content that would typically be unsatisfactory for storage. Forages are preserved as silage by an ensiling fermentation process that produces acids to inhibit spoilage. It is important to understand the phases of ensiling fermentation in order to properly manage the forage at both the time of harvest and at feeding. The process in which forages are ensiled has two steps—aerobic and anaerobic.

Aerobic Phase

The aerobic (with oxygen) phase lasts a relatively short period of time; ideally less than 2 days. After the wet forage is packed into a silage structure, whether it be a bunker, upright silo, or a plastic bag, some residual oxygen remains in the forage, despite even the best management efforts of the producer. Before the ensiling process can proceed, this oxygen must be completely eliminated from the structure. This happens by respiration. In the presence of oxygen, respiration converts soluble carbohydrates ($C_6H_{12}O_6$) present in the forage to carbon dioxide (CO_2) and water (H_2O) (Fig. 1). A byproduct of the reaction is heat.

$$C_6H_{12}O_6 + O_2 \longrightarrow CO_2 + H_2O + \text{Heat}$$

Fig. 1. Chemical reaction involving respiration of plant carbohydrates.

Importantly, the aerobic phase is detrimental to the feeding value of the silage for two reasons: (1) the soluble carbohydrates lost are an important digestible energy source in the forage, and (2) the heat produced may damage or denature the protein contained in the forage (Fig. 2). For this reason, it is critical to eliminate as much air from the silo as possible when packing and

Fig. 2. Wet, unpacked silage quickly produces heat from respiration, as evidenced by the rising vapors. This extensive respiration will reduce the energy value of the silage and will result in lower nutritive values since the heat will denature, or damage, the protein.

keeping the structure completely sealed. An important principle of making good quality silage is ***getting the air out and keeping it out!***

Anaerobic Fermentation Phase

Once the oxygen has been eliminated from the stored forage by respiration, anaerobic (without oxygen) fermentation can begin. Forage is preserved (and protected from deterioration) by acids produced from bacteria during the anaerobic fermentation phase. After oxygen is eliminated from the silo, anaerobic bacteria can begin to grow and produce organic acids.

Initially, the predominant species of bacteria thriving produce acetic acid (much like the bacteria thriving in the rumen of the cow), but by at least day 3 the environment within the silo begins to favor lactic acid producing bacteria (LAB). Lactic acid production during this phase is very favorable and growth of LAB should be encouraged in the following ways:

1. LAB thrive on soluble carbohydrates, therefore, the forage should be harvested at an early stage of maturity to assure active production of lactic acid.
2. The forage should be of proper moisture content, less than 70 percent and preferably between 60 and 65 percent, depending on the forage crop and the silo (forage sorghum generally with a higher moisture content compared to others, such as alfalfa, grass, corn, and cereal silages).

Within 21 days sufficient lactic acid and other organic acid have been produced to lower the pH of the forage to 3.5 to 5.0 (again, depending on the forage crop with legume silages generally being of the higher pH vs. grass silages vs. corn silage being of the lower pH). At this pH anaerobic bacteria are no longer thriving and the ensiling process is complete. If everything has gone properly, the acid content is sufficiently high (and the pH sufficiently low) that growth of any microorganism, including undesirable molds and yeasts, is retarded and the forage is stable. Therefore, it is safe at this point to begin feeding the ensiled forage.

When the structure (bunker, bag, or upright silo) is opened, the forage is once again exposed to air/oxygen and the forage is susceptible to deterioration through the aerobic reactions. An important principle to remember is that the better the anaerobic fermentation, and the more lactic acid that was consequently produced, the more resistant the ensiled forage will be to aerobic decay during feed-out.

Management for the Best Quality Silage

Understanding the process of ensiling forage will help the producer appreciate best management practices for silage making. Below are four management rules that apply to the understanding of the silage-making process:

Rule 1. Get the air out and keep the air out. As described earlier, any oxygen in the system will allow undesirable aerobic microorganisms, such as molds and yeasts, to metabolize the soluble carbohydrates in the forage with the result being the loss of digestible energy due to the formation of carbon dioxide and water. Producers may misjudge the importance of this management rule because the end products of aerobic decay are difficult to observe. Carbon dioxide is invisible and odorless, and the additional water produced is difficult to observe in the already moist forage.

This rule can be applied as early as harvest time. Rapid filling and subsequent sealing of the forage is essential to prevent aerobic loss. Forage should be packed into the silo as soon as it is chopped and delivered from the field.

On the other hand, if the forage is being stored in a bunker, the filling of the bunker should not exceed the rate at which workers can thoroughly pack the forage with the packing tractors. When the bunker becomes full and forage is packed, the system should be sealed to prevent reintroduction of oxygen.

For bunker and drive-over silos, the top must be covered with plastic sheets and firmly anchored to the surface of the packed forage; ***no exceptions!*** There are few management practices that are more cost effective than covering a bunker immediately after filling.

Rule 2. Harvest forage at the proper stage of maturity. As previously described, the ensiling bacteria (LAB) that preserve the forage require soluble carbohydrates (sugars), which are characteristic of those found in early maturity forage. If the forage is allowed to mature, more of the carbohydrates will be in the form of fiber compared to simple sugars where the LAB will thrive.

This rule means that alfalfa should be harvested mid-bud to 10 percent bloom, perennial grass should be harvested at early seed head emergence, cereal grains should be harvested before soft dough, and corn should be harvested at or before the time that the kernels have developed to 3/4 milkline. These maturities will not only aid proper ensiling fermentation but will also provide high energy forage for the beef herd.

Rule 3. Harvest at a proper moisture content and chop length. This management rule provides for proper, air-limiting packing of the forage. Actually the proper moisture content and chop length depend on the forage crop and the silo structure used for storage. In general, forages should be cut at a 1/4- to 3/8-inch length. Because corn silage packs and ensiles very well, it can be chopped to a length up to 1/2 inch if the kernels have not advanced beyond a 3/4 milkline stage of maturity. If the corn is more mature than this the crop should be processed (passed through rollers) before packing to break the cobs and kernels.

For most forages to be preserved as silage, a moisture content of about 65 percent is usually optimal for packing and for good growth of LAB. If the forage is being stored in an upright silo or in plastic bags, the forage may be stored drier (60% or slightly less) as forage will pack and ensile extremely well in these types of silos. Upright silos have the benefit of gravity as forage is stored vertically and the downward pressure of the forage's weight almost assures a tight pack and oxygen-limiting storage. Forage is mechanically pressed into plastic silo bags at an extremely high pressure, which also results in a tight pack and an ensiling environment with a limited amount of oxygen.

Rule 4. Feed an adequate amount of the silage daily. Just as it is important to limit the exposure of the forage to oxygen packing into the silo, it is likewise important to limit exposure to oxygen as the silage is being fed. This rule might be a deciding factor as to whether storing forage as silage is a logical choice for many beef cow-calf producers. For most silages, stored in most types of silos, at least 12 inches should be removed from the feed-out face each day to prevent aerobic spoilage. This rule obviously eliminates many of the smaller producers who do not feed an adequate amount of silage daily.

Because most feeding of the beef herd occurs in the winter months when mold growth is inhibited by temperature, some exceptions to this rule can exist. However, it is important to understand that oxygen will likely penetrate as much as 3 feet in from the feed-out face giving aerobic molds adequate time in a warm, well insulated environment to decay the silage if the feed-out rate is not adequate (Fig. 3). This rule is also an incentive for producers to apply maximal management as silage with greater concentrations of lactic acid will be more stable during feed-out.

What About Silage in a Bale (Balage)?

Preserving grass or legume forage as silage in bales might be a compromise and an alternative to consider. Balage has many of the benefits of conventional silage (feeding value and allows harvest in cool, damp climates) and can be harvested with the same equipment used to make hay. Forage that is baled wet can be stored in sealed bags or tubes, or can be stretch-wrapped in plastic to create silage in a bale form (Fig. 4). This method of silage storage may fit better with the existing winter feeding operation of the cow-calf operation.

Preserving forage as balage reduces the importance of fast feed-out (Rule 4), as even the largest bales would usually be consumed in 1 to 2 days (Rules 1 to 3 are in effect for balage, however). On the negative side of the ledger, storage losses are generally a little greater (2 to 4% more spoilage) when forage is stored as balage, and extra caution must be exercised to make certain each bale remains sealed from oxygen—one small hole in the plastic from a bird or a rodent can ruin the better part of a bale (Fig. 5). Balage is not for everyone but may be worth consideration.

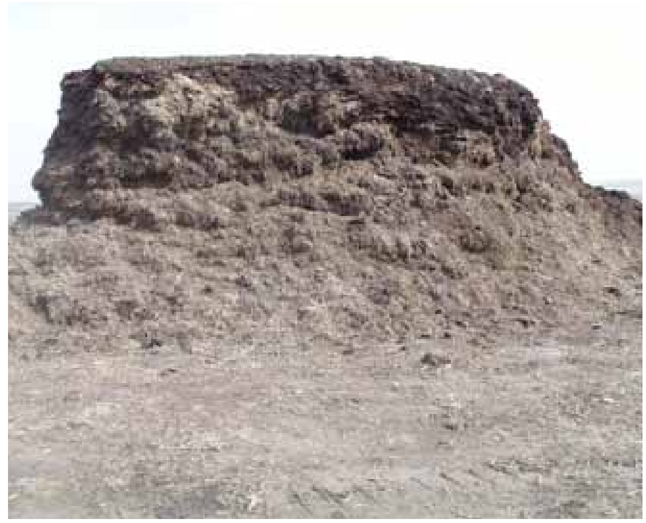

Fig. 3. Silage disaster is seen because Rules 1 and 4 were violated. The pile was not covered with plastic and feed-out was slow and from three sides, thus giving mold ample opportunity to destroy the silage.

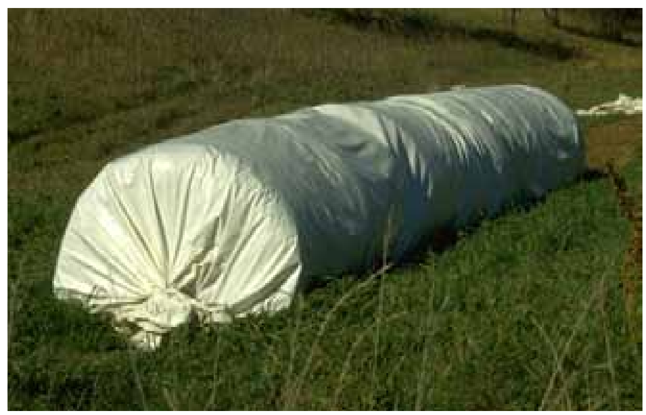

Fig. 4. Large, round bales of wet grass placed in a plastic tube to make "balage."

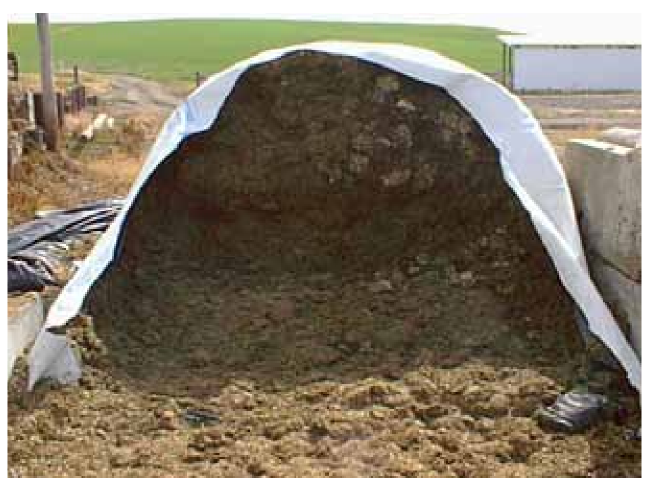

Fig. 5. Barley silage is ensiled in a plastic tube. The mold spoilage on the right was created by a single, small hole, which demonstrates the importance of thorough oxygen exclusion.

Ensiling Aids

The last management factor to consider is the use of ensiling aids to enhance the natural ensiling process. As would be expected, the better the conditions are for proper ensiling, the less benefit one would expect from the use of these additives. If the forage to be ensiled has abundant soluble carbohydrates, is chopped correctly, is of the proper moisture content so as to allow for optimal packing, and if the feed-out rate is sufficient, then these enhancers would not be as likely to be cost-effective.

Although ensiling aids will be more beneficial in less-than optimal ensiling conditions, they should ***never*** be considered as a substitute for proper silage management! The following are three common types of ensiling aids:

Bacterial Inoculants

Bacterial inoculants are by far the most widely used silage additives. They are live cultures of LAB organisms (typically organisms of the genus *Lactobacillus* and/or *Streptococcus*) that specialize in fermenting sugars to form lactic acid. When forages are preserved with inoculants the anaerobic fermentation phase may occur faster and more efficiently resulting in silage with a greater final concentration of lactic acid. These silages may also be more aerobically stable, especially during feed-out in warm weather.

It is extremely important for the product to contain hearty, highly viable organisms that have been selected to grow on the type of forage being ensiled. Too often dead or non-hearty LAB are added to forage, obviously resulting in no benefit. When deciding on an inoculant product to use, the producer should consider only products from reliable companies with substantial research validating the product claims.

Enzymes

Enzyme additives are also intended to increase the lactic acid content of the silage but accomplish this in a slightly different manner. Enzyme ensiling aids usually contain a combination of enzymes that breakdown complex carbohydrates (fiber and starch) into simple sugars. The production of simple sugars in turn inspires more active growth of the LAB, which ultimately results in greater lactic acid content and more stable silage.

Enzyme additives will obviously be most effective when soluble carbohydrates are in short supply and complex fibrous carbohydrates are in abundance. In other words, these products would be expected to enhance ensiling if the forage has been allowed to mature to an advanced stage.

Organic Acids

Organic acids can be added to forage when ensiling. These acids, primarily propionic and acetic acid, inhibit fermentation and acidify the silage, which preserves the sugars. These supplements are also effective in inhibiting aerobic mold growth. Consequently, organic acid products would likely prove most beneficial when feed-out rate is slow and/or when feeding is during warmer weather when molds will be more active.

Organic acids are the most expensive treatment of wet forage, but they are probably the most reliable. When uniformly mixed with the forage at the recommended level, organic acids will effectively inhibit mold growth. Some organic acid products may corrode equipment, however, most products today are buffered to protect against corrosion.

How You Know Whether You Have Successful Silage Management

Once the silage has been harvested and packed, how do producers know whether they have a high quality forage? It is important to take a representative sample of the silage and send it to a laboratory certified by the National Forage Testing Association. When the analysis is returned, various numbers are represented, but are they good? To help set some parameters, see Table 1 below for target values for corn silage.

It is important to use the results of the feed analysis to adjust current management and feeding, as well as for the following year's planting and harvesting. It is essential that the ration is meeting the requirements of the animals, but that it is also balanced and not causing digestive upsets. High quality corn silage and its economics are advantageous to cattle operations that have the overall management and means to feed it.

Table 1. Target values for corn silage in horizontal bunkers and piles (on a dry matter basis).

Nutrient	Target value	Reasoning
Dry matter (DM)	30-40%	Too wet or dry can cause spoilage and decrease the quality of the silage. Too dry is also usually associated with a reduced digestibility and energy content.
Crude protein (CP)	7-9%	High protein is desirable. Low protein may be caused by under fertilization, nitrogen losses due to rain, weed competition, or insufficient harvesting and/or storage.
Available protein	As close as possible to CP	The more that is available the better.

Table 1. (cont'd).

Nutrient	Target value	Reasoning
Acid detergent insoluble CP (ADICP)	<0.7%	This is CP that is not available for digestion. Higher levels indicate heat damage.
Soluble protein as % of CP	40-60%	This is the amount of the CP that is quickly degraded. Silage with greater soluble protein will have grain that is more fermentable in the rumen and may increase the risk of acidosis.
Degradable protein as % of CP	60-75%	Amount of CP that has potential to be degraded in the rumen.
Neutral detergent insoluble CP (NDICP)	1-1.6%	Amount of CP insoluble in neutral detergent solution, thus associated with the cell wall. It is slowly degradable in the rumen.
Neutral detergent fiber (NDF)	35-55%	Cellulose, lignin, and hemicellulose content. NDF values will generally increase with low grain silage, stress, or immaturity.
Acid detergent fiber (ADF)	20-33%	Cellulose and lignin content. High ADF content is for the same reasons as high NDF content.
Lignin	2.8-4.1%	A polymer content of the cell wall that provides structure to the plant. It is not digestible and can bind to other contents of the plant and make them indigestible. It increases as the plant matures and is inversely related to digestible NDF. Increasing lignin content reduces NDF digestibility and may reduce intake. Lignin values vary due to variety, temperature, and drought.
Non-structural carbohydrates (NSC) or non-fibrous carbohydrates (NFC) (starch and sugars)	23-43%	Lower NSC or NFC content indicates stress or improper maturity. Higher levels can decrease fiber digestion and cause digestive upset if rations are not formulated correctly.
Starch	>28%	Usually the greater the better (remember to account for this when formulating a ration because of the same reason as with higher NSC/NFC). Higher starch percentages are especially beneficial when dealing with high corn prices. If starch levels are <28% this usually indicates the silage was cut early or the crop was stressed.
Sugars	8%	Sugars are the carbohydrates that are fermented and reduce the pH, which stabilizes the silage.
Crude fat	2.8-3.8%	Energy source.
Ash	<6%	Greater levels of ash indicate contamination by soil, which is not digestible.
Total digestible nutrients (TDN)	67-74%	Amount of nutrients that are digestible. Could be used to express the energy value of the corn silage.
Net energy for maintenance (NEM)	0.67-0.78	Mega calories of energy for maintenance.
Net energy for gain (NEg)	0.4-0.5	Mega calories of energy for gain.
Ammonia	<0.9%	Greater concentrations of ammonia indicate CP degradation and loss of nutrients. It may also indicate clostridial fermentation and the pH did not drop fast enough.
Lactic acid	>4%	The more lactic acid the better. Higher levels of lactic acid indicate good fermentation and better preservation. Lower levels indicate the silage was not harvested at the correct moisture content, improper chop length, not packed fast enough, low density, or exposure to oxygen.
Acetic acid	<3%	Acetic acid is produced by yeast breaking down lactic acid. High levels may indicate the silage was not packed fast enough, was too dry, was not packed dense enough, or was not covered adequately and may reduce intake. Some inoculants can also produce acetic acid.

Table 1. (cont'd).

Nutrient	Target value	Reasoning
Butyric acid	<0.13%	Lower levels are better because higher levels indicate clostridial fermentation and can cause decreased intake and health problems.
Lactic acid/acetic acid ratio	1.5-4.0	Ratio of lactic acid to acetic acid, which signifies overall quality and preservation. However, if an inoculant, such as *Lactobacillus buchneri* has been added this ratio is not a good indicator.
Volatile fatty acid (VFA) score	>8.0	The VFA score takes into consideration the lactic acid to acetic acid ratio plus any negative ratio of butyric acid. This is an indicator of fermentation profile.

Issued in furtherance of cooperative extension work in agriculture and home economics, Acts of May 8 and June 30, 1914, by the Cooperative Extension Systems at the University of Arizona, University of California, Colorado State University, University of Hawaii, University of Idaho, Montana State University, University of Nevada/Reno, New Mexico State University, Oregon State University, Utah State University, Washington State University and University of Wyoming, and the U.S. Department of Agriculture cooperating. The Cooperative Extension System provides equal opportunity in education and employment on the basis of race, color, religion, national origin, gender, age, disability, or status as a Vietnam-era veteran, as required by state and federal laws.

Fourth edition; December 2016 Reprint