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Proper ensiling is a controlled fermentation, which converts perishable wet forage plant material to a stable, stored feed energy source. Good ensiling management is required for high silage quality and dry matter (DM) recovery. To guide silage management practices, it is important to understand the biological and chemical processes that occur during ensiling, their effects on silage quality, and how these processes can be managed to help produce a more consistent feedstuff.

The ensiling process

There are four phases during the ensiling process: Aerobic phase or the pre-seal management, fermentation phase, stable phase, and the feed-out phase.

Aerobic, pre-seal phase

During the aerobic phase, forage is cut, chopped, moved to the site of ensiling, packed, and sealed. Management practices at each step will influence the success of the final ensiling. The management goal(s) during the aerobic phase is to store the chopped forage and create an anaerobic environment as soon as possible. In the presence of oxygen, plant and microbial respiration dominates, causing changes and nutrient losses from the chopped crop. Respiration is a necessary step, because it uses the oxygen trapped in the chopped forage material, but at the same time is a wasteful process, because it uses some of the plant sugars needed for further fermentation, thus, wasting some energy and dry matter (DM).

An important, first step is to harvest the forage crop(s) at the proper time. In making this decision, several plant maturity-related and livestock needs factors must be considered. Table 1 provides descriptive harvest maturities for several commonly used forage crops. When harvested at these stages, there is generally a good compromise for yield and nutritive quality. Some of these corps can be chopped directly as a standing crop at these stages, some may require cutting, windrowing and wilting to a more appropriate whole plant moisture content before chopping.

Table 1. Maturity stages at which commonly used forage crops are chopped for silage

Crop	Stage of maturity
Corn	Proper 'whole plant moisture'; or kernels at ¼ to 2/3 milk- line
Sorghum, grain and forage	Kernels at mid- to late-dough
Cereal grains	Late boot to early-flowering, or kernels at mid- to late-dough stage
Alfalfa	Late-bud to early-bloom
Red Clover	Late-bud to early bloom
Summer annual grasses	Late vegetative to late-boot
Grass mixtures, orchardgrass, smooth bromegrass, and timothy	Boot to early-heading
Legume - grass mixtures	Grasses at boot early-heading

The next important practice during pre-seal management is to chop the forage at the proper particle length. The recommended cutting length is 3/8 to 1/2 inch. Forage chopped in this particle size range packs well. When forage is too coarsely chopped, it is difficult to pack tightly, maintains excess trapped air, and allows respiration to continue for an extended period. Chopping too finely wastes fuel and may adversely affect the normal rumen function of cattle that eat the silage. Forage chopper knives are adjusted to cut at 3/8 to 1/2 inch, however, there will be some longer particles, which are actually useful in ruminant feeding.

To further reduce respiration losses during the aerobic phase, fill the silo or silage bag quickly, pack the chopped forage well, cover and seal the chopped material as soon as possible. If managed well, the aerobic phase will last about one day.

The heat produced as a product by respiration raises silage temperature and increases the rate of microbial processes, both good (fermentation) and bad (respiration). A noticeable increase in temperature is normal, and it is not uncommon for 50 and 70 percent moisture forage to reaches a temperature as high as 115°F during ensiling. Forage chopped and stored at moisture contents lower than 50 percent is more difficult to pack, thus providing more oxygen for a longer period during this initial, aerobic phase. More oxygen generally results in temperatures above about 120°F which can lead to an undesirable high-temperature reactions that causes heat-damage-browning, and decreased silage protein and DM digestibility. Silage producers can reduce excessive respiration losses by chopping the forage crop at the appropriate (60 to 70 percent) moisture content. The appropriate moisture content is the same for all crops, but each forage crop being used will require slightly different growth stages or management to achieve the desirable moisture content.

Fermentation phase

During the fermentation phase, the goal is for desirable bacteria to ferment sugars and carbohydrates to lactic acid, and to lower the pH of the ensiled forage to around 3.8-4.2, a level normally required for good quality silage.

Processes during this phase occur under anaerobic (oxygen-free) conditions and should be dominated by growth of lactic acid-producing bacteria. This period lasts for two to four weeks. During the first days of ensiling, however, plant enzymes and acetic acid producing bacteria compete with lactic acid bacteria for sugars and proteins. Plant enzymes also break down some plant proteins to soluble non-protein nitrogen (NPN). Protein breakdown is highest during the first day after sealing and decreases rapidly as oxygen is used up. Very little protein breakdown occurs after one week under proper ensiling conditions. After ensiling, NPN in the silage can range from 20 percent to as much as 85 percent of total N.

Fermentation is carried out by two main groups of lactic acid bacteria are homofermenters, which produce only lactic acid from sugar; and heterofermenters, which produce carbon dioxide, ethanol, acetic acid, and lactic acid. The homofermenters are the most desirable because their activity does not cause DM loss as do heterofermenters. High levels of less desirable acetic acid and ethanol reduce the palatability of silage and, thus, animal intake.

Large numbers of lactic acid bacteria, and other types of bacteria, occur naturally on plants and grow under warm, humid conditions. As a result, corn and other forage crops, chopped at appropriate moisture contents, finish fermenting within 2 to 3 weeks. Fermentation occurs faster at silage mass temperatures between 80° and 100°F, but may require several more weeks if the chopped forage is < 50°F.

Stable phase

When lactic acid bacteria have reduced the silage pH sufficiently to stop their growth (pH 4.0 - 4.2 or lower), the stable phase begins. As long as the silo remains sealed and anaerobic, little biological activity occurs during this period.

Feed-out phase

After the silo is opened and during feed-out, the surface is reexposed to oxygen where yeast, mold, and aerobic bacteria can again degrade the silage. These organisms convert remaining plant sugars, lactic acid, or other energy-rich nutrients in the silage to carbon dioxide, water, and heat. In addition, residual plant proteins can be converted to ammonia. Because fermentation acids can be broken down during aerobic spoilage, silage pH can increase to levels sometimes exceeding 7.0. Heating and a yeast aroma are the most common symptoms of aerobic deterioration of silages. Thus, feed-out spoilage causes increased DM losses, degraded feed, and a higher risk of toxic organisms and their spoilage products.

When good feed-out management is practiced, aerobic feed-out losses are minimal. Recommended management is to remove a minimum of 2 to 3 inches of silage per day in the winter and 4 inches of silage per day in the summer from tower silos. For bunker silos, it is best to remove at least 4 inches per day in the winter and 6 to 10 inches per day from the silage surface in the summer. Also, feed silage to the livestock in small amounts two to four times per day instead of in one large feeding.

Silage additives

Producers hear and read advertisements and promotions about products to help make better silage. To determine whether to use a silage additive or which one is best, it is important that you know how the additive influences silage fermentation. Remember that an effective additive may help make good silage a bit better, but it will not make poor silage good. The most commonly used silage additives can be divided into five categories: bacterial inoculants, non-protein nitrogen (NPN) sources, and sugar sources.

Bacterial inoculants

These are the most common silage additives in the United States and are primarily homofermenter lactic acid bacteria. Effectiveness of the applied inoculant depends on the natural lactic acid bacterial population, the sugar content of the crop, and strains of bacteria in the inoculant. The inoculant must provide at least a tenfold increase in the lactic acid bacteria numbers in the silo to be economically practical.

Currently there is no method for quick determination of natural lactic acid bacteria numbers on the chopped crops. A common recommendation for the addition of inoculant lactic acid bacteria is to add a minimum of 100,000 colony-forming units (CFU) of lactic acid bacteria per gram of fresh forage. Inoculants are most consistently effective when the chopped forage has low numbers of naturally occurring bacteria, or when the chopped forage has low concentrations of fermentable sugars and carbohydrates, as is more often the case with chopped forage grasses and legumes, particularly when chopped at 70 percent moisture or higher.

Some strains of a bacterial species have been selected for use on particular crops. Therefore, buy the inoculant product that is selected for the crop you are ensiling. If that is not possible, try a product for a similar crop within the same classification (i.e. legumes and grasses).

A relatively new approach in silage inoculant additives is to include an inoculant to direct the fermentation, aid in preventing spoilage during feed-out, and to improve 'feed bunk stability.' The bacteria *Lactobacilus buchneri* has been demonstrated to improve aerobic stability of silages by reducing the growth of yeasts. The beneficial impact of *L. buchneri* appears to be related to the production of some acetic acid in addition to lactic acid during fermentation. Aerobic stability is likely improved because acetic acid inhibits growth of specific species of yeast that are responsible for heating and spoilage upon exposure to oxygen as compared to untreated silages. Treating silage with inoculants including *L. buchneri* most likely would be beneficial under circumstances where problems with aerobic instability are expected. Corn silage, small grain silage and high moisture corn are more susceptible to spoilage once exposed to air than legume or grass silage, and therefore L. buchneri inoculation may be a benefit.

Non-protein nitrogen sources (NPN)

Both ammonia and urea are common additives for improving corn, sorghum, and other cereal silages with low protein concentrations. These additives are used to increase the total crude protein and NPN concentration of silage and to improve aerobic stability during feed-out. Application rates are typically 5 to 10 pounds of an hydrous ammonia or 10 to 20 pounds of urea per ton of fresh chopped forage. Addition of NPN can raise the pH of the crop, with ammonia having the greatest effect. Urea is preferred over ammonia because urea is safer and easier to handle since no special application equipment is required.

NPN must be carefully managed in ruminant animal diets. Its feeding value varies and must be balanced with the other constituents in rations

Added carbohydrate sources

Whey, molasses, and starchy cereal grains are sometimes used to improve preservation of low energy crops. Additions of 1 to 10 percent dried whey of fresh silage weight have been successful in improving fermentation of low sugar forage crops, such as alfalfa and grass. Molasses, applied at 2 to 5 percent of fresh silage weight, improves fermentation in high moisture (> 70 percent) crops and in crops with naturally low sugar content, such as alfalfa. The addition of molasses combined with an inoculant to a low sugar crop may improve conditions for fermentation of sugar to lactic acid.

When the ensiling process goes wrong!

Ensiling is usually successful. However when important steps are mismanaged, it can lead to undesirable results.

Plant material chopped too dry and inadequate packing can trap excess oxygen. As the aerobic phase stretches too long, some naturally occurring bacteria produce less lactic and more acetic acid and, This can also occur in the absence of enough sugars for proper fermentation. This condition can also occur when a silo is opened mid-way through the fermentation phase, as when a producer puts additional forage on the existing fermenting silage. Rexexposure to added oxygen can cause a gradual growth of undesirable bacteria, a reduction in lactic acid and increased acetic acid concentrations, reducing silage palatability

Clostridium bacteria and other undesirable bacteria that may be present on the chopped crop can convert already formed lactic acid to foul smelling butyric acid and produce ammonia from plant protein. This is called a secondary fermentation, and is characterized by butyric acid levels greater than lactic acid levels, ammonia-N levels greater than 10 percent of total N, pH above 5.0, and a “rancid butter” odor. Clostridial fermentation may sometimes dominate in silage with a moisture content above 70 percent.

Other problems can develop during the ‘stable phase’ if oxygen slowly enters through silo walls and through plastic covers. This can reactivate aerobic microorganisms. The growth of yeasts, molds, and other aerobic bacteria, including Listeria bacteria, grow in silage exposed to oxygen. Listeria can become a serious animal health concern.

Summary

To achieve good silage fermentation, the crop must be harvested at the proper moisture (60 to 70 percent) level. Silage that is too wet causes seepage losses from the silage and growth of undesired microorganisms, which result in a less palatable feed for ruminants. Too dry (< 50 percent moisture) silage, however, increases DM losses due to respiration and heating and reduces the opportunity for lactic acid bacteria to grow. The key for successful ensiling is to chop the forage to a minimum cutting length of 3/8 to1/2 inch, pack the forage tightly in the silo, and seal the silo well to prevent air passages through covers and walls.

When these conditions are met, silage quality can be further improved with silage additives. Bacterial inoculants can increase the number of lactic acid bacteria in the silage. The desirable lactic acid bacteria use sugar to produce lactic acid, which decreases pH to 4.0 to 4.2. A rapid pH drop results in stable, high quality silage. Fermentable sugar concentration can be raised with molasses, whey, or cereal grains. Non-protein nitrogen products are used in crops with low protein concentrations, such as corn and sorghum, to increase their crude protein level and to improve silage stability during feed-out.