MISSISSIPPI STATE UNIVERSITY EXTENSION SERVICE

Understanding Silage Making Process and Utilization

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There are different ways to store forages for winter feeding when pasture production is limited. Hay is the most popular storage method because it stores well over long period of times, but sometimes silage is more suitable when curing the hay is difficult due to the type of forage being harvested or to weather conditions. Silage production is a very controlled process used to achieve optimal preservation of nutrients through fermentation. The goal of an optimum fermentation process is to quickly and effectively facilitate the conversion of carbohydrates into the desirable organic acids, especially lactic acid. There are several requirements to achieve a good fermentation: (1) an anaerobic environment (lack of oxygen), (2) optimum moisture content, (3) adequate amount of nonstructural carbohydrates (water-soluble), (4) adequate population of lactic acid producing bacteria, (5) good buffering capacity of the forage, and (6) the type of silo.

Producers should understand the ensiling process and what steps are needed to preserve the forage crop and its nutrient value. Silage fermentation can be divided into 4 phases (**Table 1**):

Phase 1 (Aerobic Phase): Forage should be chopped and packed tightly. Freshly harvested undergoes respiratory losses due to aerobic bacteria consuming soluble carbohydrates. This phase is undesirable since the respiration process produces water and heat in the silage material. Excessive heat build-up could greatly reduce digestibility of nutrients, especially proteins. During this process proteins can be broken down into amino acids and then into ammonia and amines. Up to 50% of the total plant protein can be broken down during this phase. Protein breakdown is dependent on the rate of pH decline in the silage until the acid environment inhibits the enzymatic activity of the bacteria responsible for protein degradation. Under idea conditions, phase 1 should only last a few hours.

Phase 2 (Lag Phase): This phase begins when the oxygen in the ensiled material has been depleted by the anaerobic bacteria. In this anaerobic environment, the generation of acetic-acid producing bacteria occurs to ferment soluble carbohydrates and produce acetic acid. Acetic acid initiates the reduction in pH to set up phase 3 of the fermentation process. As the pH drops below 5.0, the growth of the acetic bacteria is inhibited. This indicates the end of Phase 2 and it should last no longer than 24 to 72 hours.

Table 1. Phases of silage fermentation.

Phase	Silage Age (days)	Activity	Temperature (°F)	pH change	End-product
1	0 - 2	Cell respiration	69 – 90	6.5 – 6.0	CO_2, heat and water
2	2 - 3	Production of acetic and lactic acids and ethanol	90 – 84	6.0 – 5.0	Acetic acid and lactic acid bacteria
3	3 - 4	Lactic acid bacteria	84	5.0 – 4.0	Lactic acid
4	4 – 21	Lactic acid bacteria	84	4.0	Lactic acid

Source: Schroeder, J.W. 2004. Corn Silage Management. Pub. AS-1253. NDSU Coop. Ext. Serv. Pub. AS-1254.

Phase 3 (Fermentation Phase): As the pH drops below 5.0, this enhances the development of the acid lactic-producing bacteria. Lactic acid is the most desirable acid of the fermentation process. It should be comprise more than 60% of the total silage organic acids produced to ensure efficient preservation of the silage. Lactic acid is also utilized by cattle as an energy source. This phase is the longest of the ensiling process and it continues until the pH is low enough to inhibit the growth of all bacteria. At that point, the forage in a preserve state.

Phase 4 (Stable Phase): The final pH of the ensiled forage crop will depend on the type of forage being used and their condition at the time of ensiling. Haylage should reach a final pH close to 4.5 while corn silage should be near 4.0. The pH of is alone is not a good indicator of the quality of the silage or type of fermentation process. The end products of silage fermentation are often monitored to assess silage Quality. The composition of different silage types is presented in **Table 2**. Producers should be aware that numerous factors may affect silage composition.

When to harvest silage? Silage can be made from many different crops, although limited at times. Corn, small grains (wheat, oats, and barley) and grain sorghum have been used extensively for silage. Other warm-season annual grasses such as forage sorghum, sudangrass, pearl millet, sorghum-sudan hybrids, grasses and legume-grass mixtures are also used for silage, but they require wilting to reduce moisture content and allow proper ensiling. These crops can produce high yields with high-energy feed per acre, they are very palatable, and can be stored directly at time of cutting when plant reaches the desired maturity. Forage crops should be harvested at the correct maturity and dry matter percentage (**Table 3**). Forages should be chopped at the correct length (approximately 1/4 to ½ inch long) to ensure good packing, eliminate excess oxygen, prevent butyric acid accumulation, and minimize spoilage losses. Corn silage should be harvested at ½ to 2/3 milk stage and about 35% dry matter (DM). Grasses should be harvested at the boot stage and approximately 35 to 45% DM. Small grains (wheat, rye, and oats) should be harvested between the boot and dough stage and at approximately 30 to 40% DM. By harvesting forage crops at the right maturity, it could optimize the nutritive value and dry matter content.

Table 2. Concentration of common fermentation end-products for various silage types.

End-Product	Grass (25 – 35 %)[2]	Legume (30 – 40%)[2]	Legume (45 – 55%)[2]	Corn (30 – 40%)[2]	HMC[1] (70 -75%)[2]
pH	4.3 – 4.7	4.3 – 4.7	4.7 – 5.0	3.7 – 4.2	4.0 – 4.5
Ammonia N, % CP	8 – 12	10.0 – 15.0	<12.0	5 – 7	<10
Ethanol, % DM	0.5 – 1.0	0.5	0.5 – 1.0	1.0 – 3.0	0.2 – 2.0
Acid, % DM					
Acetic	1.0 – 3.0	2.0 – 3.0	0.5 – 2.0	1.0 – 3.0	<0.5
Butyric	<0.5	<0.5	0.0	0.0	0.0
Lactic	6.0 – 10.0	7.0 – 8.0	2.0 – 4.0	4.0 – 7.0	0.5 – 2.0
Propionic	<0.5	<0.1	<0.1	<0.1	<0.1

[1]HMC = High moisture corn; [2]Dry matter basis. **Source:** Kung, L. 2008. A review on silage additives and enzymes. Univ. of Delaware.

Table 3. Stage of growth and moisture recommendations for different silage types at time of harvest.

Forage Crop	Maturity	Silo Type: Bunker	Silo Type: Trench	Silo Type: Sealed	Cut Length
		---------- Moisture (%) ----------			(inches)
Corn	Milk stage	67 – 72	65 – 68	50 – 60	3/8 – ½
Small Grains	Milk to soft dough				----------
Grasses	Boot stage or early head				¼ - 3/8
Clovers	¼ to ½ bloom				
Forage Sorghum	Grain medium to hard dough	70 - 75	65 – 70	50 – 60	3/8 – ½

Source: Schroeder, J.W. 2004. Corn Silage Management. Pub. AS-1253. NDSU Coop. Ext. Serv. Pub. AS-1254.

Forage producers should also keep in mind that it is important that silos should be filled and sealed quickly to reduce losses from respiration and prevent the growth of undesirable aerobic microorganisms. It is important that silage is tightly packed to prevent air flow and spoilage (**Table 4**). Make sure that silage covers are kept away from sharp objects and make sure that the silos are free from leaks. Allow the silage crop to ferment for at least 14 to 21 days.

Table 4. Effect of compaction level (bulk density) and dry matter content on temperature rise in a tightly sealed silo.

Dry Matter Content (%)	Bulk Density (lbs/ft^3): 20	30	40	50	60
	-------- Temperature Increase (°F) --------				
20	4.8	5.3	6.0	7.8	9.0
30	2.5	2.8	3.2	4.3	5.0
40	1.4	1.6	1.9	2.5	3.0
60	0.7	0.8	1.0	1.5	1.8
70	0.2	0.3	0.5	0.8	1.0

Source: Coblentz, W. 2005. Principles of Silage Making. Univ. of Arkansas Coop. Ext. Serv. Pub. FSA-3052.

How to determine if the forage was properly ensiled? The ensiled material should look similar to or slightly darker in color than the material before ensiling. If the color is very dark or brown, this indicates that excessive heating caused to the material to caramelize. Caramelization usually reduces protein digestibility. If molds are present in the material, this is an indication that insufficient lactic acid was produced.

There are also several odors that indicate issues with the fermentation process. If a putrid or rancid odor is detected, this indicates the presence of butyric acid from *Clostridium* bacteria. This odor usually is found in silages that are ensiled too wet or do not reach a pH below 5 due to insufficient lactic acid production. A vinegar odor usually indicates a high level of acetic acid and this will odor will discourage intake by livestock. A burnt odor indicates that the silage was exposed to excessive heat.

Temperature is also an indication of poor fermentation. A temperature of more than 20ºF above the air temperature when the forage was ensiled indicates poor fermentation and excessive dry matter losses. Microbial activity usually raises temperature in the silage. The greater is the rate of micro-organisms in the temperature, the higher the temperature. As temperature increases, the rate of acidification in the silage is greater allowing for an earlier onset of fermentation. Higher temperatures encourage the growth of Clostridia (undesirable bacteria) which results in increased formation of butyric acid and ammonia. Silage temperature should not exceed 86 ºF. High temperature can also cause heat damage in the silage and reduce true protein digestibility from 90% to 30% or less (**Table 5**).

Table 5. Percent protein digestibility as affected by temperature and ensiling time.

	Temperature (ºF)		
Ensiling Time (Days)	**110**	**135**	**160**
	Digestibility (%)		
0	69.7	69.7	69.7
3	68.7	65.8	60.2
9	68.4	64.4	50
18	65.2	58.6	35.8
30	65.4	49	30.1

Source: Anonymous. 2007. Ensiling. Alberta Agriculture and Rural Development. Online (verified 18 July 2010).

How to feed silage? Feeding silage is also an important part of the process. Silage should be ready for feeding three to five weeks after it is stored. A silage sample should be collected and analyze to determine the quality of the silage. This will allow calculating the level of supplementation needed according to the type of animal and it nutritional requirements. Data has shown that approximately 50% of the dry matter losses occurs from secondary anaerobic while silage is exposed to oxygen when in storage or in the bunk. This usually can lead to production of high populations of yeast and mold. An average daily removal rate of 6 to 12 inches from the face of the silage should prevent heating and spoiling of exposed silage. The distance to which oxygen can penetrate is usually determined by how well the silage was packed.

Summary

Optimum fermentation is dependent upon decisions and management practices implemented before and during the ensiling process. Good quality silage is achieved when lactic acid is the predominant acid produced. Lactic acid is the most efficient fermentation acid and will drop the pH of the silage the fastest. The faster the fermentation is completed, the more nutrients will be retained in the silage. Keep in mind that good silage depends on the stage of maturity of the forage at time of harvest, the type of fermentation that occurs during the ensiling process, and the type of storage used for the fermentation process. Attention to details such as moisture content, length of chop, silage distribution and compaction can greatly impact the fermentation process and storage losses.

Upcoming Events:

August 24-25: Pasture and Forage Short Course. Starkville, MS.
Visit http://msucares.com/crops/forages/shortcourse/index.html for registration information and agenda.

November 17: Mississippi Forage and Grassland Conference, Starkville, MS