The Babcock Institute
University of Wisconsin

Introduction to Silage-Making

Dairy Updates

Introduction

Silage-making is a management tool that allows producers to match feed resources (forages, crop residues, agro-industrial by-products, etc.) with feed demand for a dairy herd. The basic function of silage-making is to store and preserve feed for later use with minimal loss of nutritional qualities.

The need to store feed for use by cattle is not a novelty. The Naples museum in Italy displays Egyptian paintings dated 1000-1500 BC showing storage of fodder in what look like stone silos (Vanbelle, 1985).

In modern animal agriculture, hay-making of excess pasture preceded silage-making as the primary method of preservation on the farm; however, silage-making has progressively replaced hay making as the technique of choice in some parts of the world. Silage making is less dependent than hay-making on good weather conditions and can be extended to a great variety of forage crops (corn, sorghum, immature cereal grains, etc.) and locally available agro-industrial by products (sugar beet pulp, brewers grain, etc.). Actually, the practice of silage making evolved in parallel with the success of corn as a high yielding crop that is preserved extremely easily in a silo. Difficulties arose when silage making was extended to other forage crops that are less easily preserved as silage, in particular legumes.

Silage making has become an important tool for producers to manage crop production and dairy herd feeding programs in many production systems around the world. However, silage making requires considerable capital and labor investments on the farm; it also demands a fairly high level of technical expertise. The understanding of how ensiling works to preserve a crop by fermentation is important. This knowledge is key to making the best management decisions for minimizing the inevitable losses that occur when fresh feed resources are ensiled and preserved for long periods of time in a silo.

Thus, the objectives of this presentation are: (a) to briefly discuss how silage making fits in various dairy production systems, (b) to explain some of the biological principles of silage preservation, and (c) to provide a set of practical recommendations for the preparation of high quality silage.

The Role of Silage in Various Production Systems

One of the main features that distinguishes dairy production systems from each other is the strategy used by producers to supply feed to the dairy herd. For simplification, let us look at two systems that are commonly found in various parts of the world:

1) In grazing systems, the strategy is to rely on minimum inputs. Cows utilize natural or improved pasture directly. These systems are found in parts of the world where climatic conditions allow pasture to grow during most of the year;

2) In some land-based, capital-intensive systems, the strategy is to use the land to grow crops for forage production and store the forage with the objective of balancing dairy cow rations and maximizing milk production per cow throughout the year.

The need to preserve pasture or forage for dairy cattle varies considerably between the grazing and the capital-intensive production systems. Nevertheless,

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silage making plays an important role and contributes significantly to the efficiency of both systems.

◆ Role of silage-making in capital intensive systems

Forage preservation as silage is a key component of high input (zero-grazing) systems. It has allowed producers to intensify the productivity of the land and the productivity of the cows independently from each other. As silage making allows storage and preservation of feed resources for months, if not years, producers can focus on two separate objectives:

1) To maximize yield of digestible nutrients (energy, protein, etc.) per hectare of land;
2) to maximize milk production per cow throughout the year.

Although separate, these two objectives remain interrelated as the production, harvest and preservation of high quality forages are key elements of designing a feeding program that improves cow performance.

Thus silage making gives producers a feed inventory that can be used to plan a detailed feeding program for the herd. If feed analyses are performed, diets can be formulated specifically to meet cow requirements and improve nutritional status at all stages of lactation. Thus, despite the fact that silage making represents high costs and/or capital investments, benefits accrue from higher cow productivity.

Capital intensive production systems are most suited to parts of the world where the growing season is short, either because of long winters (northern latitudes of Europe and North America), or extended periods of drought (sub-tropical latitudes).

◆ Role of silage-making in grazing systems

Grazing systems are more suited to regions of the world with clement climates in which pasture growth is almost uninterrupted throughout the year. These climates can be found in parts of New Zealand, Argentina, and Ireland.

In grazing systems, the primary objective is usually to maximize milk yield per hectare of pasture at minimal cost. As grazing systems intensify, producers adopt low-cost strategies such that pasture growth (kg dry matter/ hectare/year) meets dairy herd requirements (kg dry matter/hectare/year) as closely as possible. Although these systems tend to minimize capital investment, they also tend to require high levels of management and decision-making skills to optimize both pasture growth and cow nutrition. The challenge for the producer is to avoid both excess and deficit of pasture cover (kg of dry matter available per hectare), as pasture growth (yield and quality) and cow requirements change continuously and simultaneously throughout the year. Managing grazing systems is thus particularly challenging as pasture production is inherently variable and depends heavily on weather conditions (drought). The common management tools used to manage intensive rotational grazing include:

- Manipulation of stocking rate (cows/ hectare) by purchasing or selling animals;
- Manipulation of grazing area by renting pastures from or to neighbors;
- Altering the sequence of grazing by various animal groups (lactating cows, dry cows, heifers);
- Adjusting calving dates to match cow requirement curves with pasture growth curves (seasonal calving), etc.

An additional tool used to maintain adequate nutrition of grazing cows is the purchase of locally available feed (concentrates or agro-industrial by-products). However, silage making is also an alternative that can be used to improve grazing management and control risks and variability associated with pasture growth. Silage making permits transfer of pasture from the period of excess cover in early spring to the period of deficit cover in fall and winter.

◆ What does silage-making allow a producer to do?

Silage making is a tool for producers to achieve whole farm management goals. Silage making has some distinct advantages compared to grazing or hay-making. For example, silage making allows:

- Intensification of forage production (i.e., increased yield of forage per hectare);
- Minimization of risk factors associated with weather conditions (rainfall losses) when trying to harvest high quality forages. For example, compared to hay-making, silage making shortens the time between cutting

and storage—completion is possible in a wider range of weather conditions, and risk of dry matter losses due to rainfall is minimized;

- Improvement of the producer's control over cutting dates and optimal stage of maturity at harvest;

- Minimization of loss of leaves and other small plant parts of high quality in the field (compared to hay-making);

- Storage of non-forage feeds that cannot be preserved as hay, such as agro-industrial by-products (brewers' grains, sugar beet pulp, etc.);

- Storage of an inventory of forage of constant nutritive value, which makes it possible to balance rations of dairy cows accurately (as opposed to trying to balance rations of grazing cows ingesting pasture that has variable nutritive value).

◆ **What are the difficulties and drawbacks of silage making?**

Silage making also has some limitations or drawbacks that need to be accounted for when assessing the costs of adopting this technology:

- Silage making requires high capital investment (or direct cost for custom harvest) and heavy reliance on fossil fuel. Harvesters are needed to chop the forage, tractors or other heavy equipment are used to pack the silage, storage facilities (silo structures) may be expensive, and additional equipment may be required to remove silage from a silo;

- The management of silos is sometimes difficult on the farm because once a silo is opened, silage should be removed on a daily basis (to minimize loss of nutritive value). Adjusting the number of silos and their dimension to the expected feed out rate for a given herd size is difficult. Usually, only large herds can afford to feed out of different silos of varying forage qualities for different groups of animals on the farm (heifers, dry cows, lactating cows, etc.);

- Once silage is removed from a silo, it becomes unstable (because of exposure to oxygen) and tends to spoil within a day or two (especially in warm weather conditions with silages that are well-preserved);

- Silage cannot be marketed easily (difficult to transport long distances compared to hay);

- Loss of nutrients during storage in a silo is <u>unavoidable</u> and may be high if the silage is not prepared properly. The major losses associated with silage making include:
  1) The potential loss of highly digestible dry matter due to soluble sugars in the effluents ("juices") when silage has a low dry matter content;
  2) The inevitable loss of protein quality (especially with certain legumes such as alfalfa) as protein peptides and amino acids are converted to soluble nitrogen (e.g., amino acids and ammonia) during the fermentation process;
  3) The inevitable loss of energy as sugars are converted into organic acids, carbon dioxide (and other gases) and heat.

Principles of Silage Preservation

◆ **What is silage?**

As a forage crop is cut, harvested and stored, loss of dry matter (quantity) and nutritional quality inevitably occur. These losses are due to enzymes[1] that degrade the plant after it has been cut. Enzymes may originate from the dying plant itself or from bacteria and other micro-organisms. Thus the goal in silage making is to stop enzymatic reactions and minimize loss of energy, protein and other nutrients. Thus silage-making can be defined simply as a method of forage preservation in which most of the energy, protein, and other nutrients that were in the original plant remain in a form that can be efficiently utilized by cows. A more technical definition follows in the gray box below.

As a bunker silo is filled, each load of freshly chopped forage is packed to expulse as much air as possible from the growing mass of silage. The absence of oxygen allows lactic acid bacteria to grow by converting sugars (simple sugars and starch) into lactic acid, a strong organic acid.[2] As lactic acid bacteria grow, lactic acid accumulates in the ensiled mass and the acidity increases, that is, pH[3] drops. As pH declines, the degrading actions of plant enzymes and undesirable bacteria (clostridia and enterobacteria), yeast and molds are slowed. When pH is sufficiently low (pH of 3.8-4.2 in corn silage and pH of 4.2-4.7 in alfalfa silage)

> Silage is a method of feed resource preservation...
>
> ... which is based on the removal of air (oxygen) from a mass of feed...
>
> ... to promote the fermentation of sugars into lactic acid by lactic-acid bacteria...
>
> ... causing an increase in acidity (a reduction in pH)...
>
> ... which inhibits further silage degradation by:
>
> - plant enzymes (primarily protein degrading enzymes);
>
> - undesirable bacterial species (enterobacteria, clostridia), yeast and molds;
>
> - and the lactic acid bacteria themselves.

most degrading enzymes are inhibited and the growth of lactic acid bacteria is also inhibited.

Thus the goal in silage-making is to exclude oxygen from the forage mass in order to promote the fermentation of sugars by lactic acid bacteria and drop the pH as rapidly as possible to stop all forms of degradation activity.

◆ The "aptitude" of a forage to be preserved as silage

The chemical composition of a forage crop or agro-industrial by-product plays an important role in determining the ease with which lactic acid fermentation can take place; and thus the ease with which a particular feed can be preserved as silage. It is easier to ensile forages that have:

- A high level of fermentable sugar;
- A low level of protein;
- A low buffering capacity;[4]
- An "ideal" dry matter content at ensiling time (see "wilting green forage" below).

As indicated in Table 1, corn is preserved as silage more easily than grasses or alfalfa because of its high sugar content, low protein content and low buffering capacity. In contrast, alfalfa is more difficult to ensile well because of its low sugar content and high buffering capacity, which is due in part to its high protein content. Thus the higher the quality of alfalfa, the more challenging it is to ensile successfully.

◆ Silage fermentation: A battle between "good" and "bad" bacteria

As indicated in the above definition, silage is essentially a battle between "good" and "bad" micro-organisms. The outcome of the battle, that is, whether a silage is well preserved or poorly preserved, depends not only on forage characteristics (Table 1), but also in great part on the practices followed during the ensiling process. Before discussing these practices, we will describe the fermentation process that takes place in a silo. A better understanding of the principles of silage fermentation will help producers make the best decisions in developing a silage-making strategy adapted to their particular situations. The desirable processes that take place in a silo may be described by a sequence of four phases:

Phase 1: Respiration,[5] which degrades plant nutrients in the presence of oxygen (1 to 2 days);

Phase 2: Early fermentation, which produces acetic acid, formic acid and other organic acids as a result of the growth of facultative aerobic bacteria such as **enterobacteria**, which can live in the presence (aerobe) or absence (anaerobe) of oxygen (1 to 2 days);

Phase 3: Lactic acid fermentation by **lactic acid bacteria** that are strictly anaerobic, that is, they can only grow

Table 1: Chemical composition and buffering capacity of typical forage crops

	Water soluble carbohydrate (g/kg DM)	Crude protein (% DM)	Ratio wsc/cp	Buffering capacity (mEq/kg DM)	"Aptitude" for silage preservation
Corn	80 - 300	80 - 100	1.0 – 3.0	150 - 300	High
Grasses	35 - 300	100 - 160	0.4 – 1.8	250 - 550	Intermediate
Alfalfa	20 - 150	140 - 200	0.1 – 0.75	350 - 650	Low

and multiply rapidly in the absence of oxygen (14 days);

Phase 4: Stabilization phase due to the presence of lactic acid, which inhibits further degradation (indefinite period).

Two other undesirable phases can also take place and cause important loss of dry matter and forage quality in a silo:

1) Butyric acid fermentation by **clostridia** (or butyric acid bacteria), which may occur if lactic acid fermentation (Phase 3) fails to produce enough lactic acid to stabilize the silage (Phase 4);

2) Aerobic deterioration caused by **molds** and **yeast** that develop rapidly when a well preserved silage is exposed to oxygen after opening a silo.

Phase 1 - Respiration

Once a plant is cut and cells lose their structures, they continue to consume oxygen according to the equation at the bottom of the page.

This equation indicates that respiration converts sugar into carbon dioxide (a gas), water (a liquid), and heat. Thus respiration results in a loss of dry matter and available energy. In addition, the heat released by respiration raises the temperature of the forage. Temperatures greater than 26-32°C may cause significant loss of nutrients. Research indicates that the rise in temperature is not as high in well packed silos as it is in poorly packed silos (Pitt, 1983). The rapid expulsion of oxygen is desirable because it decreases both the length of the respiration phase and the associated nutrient losses.

Normally, respiration continues for one to two days, but takes place only as long as oxygen is present in the silage. Thus, compacting silage to remove as much air as possible as rapidly as possible will curtail respiration losses.

Phase 2 - Enterobacteria fermentation

This phase has sometimes been described as the lag or dormancy phase by some authors. Whatever it is called, the fate of silage depends a great deal on the outcome of this critical fermentation phase.
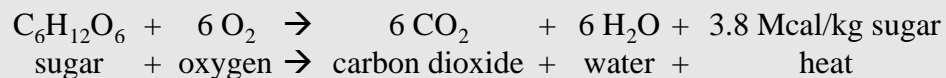
There are some 10^7 to 10^{10} micro-organisms per gram of forage freshly harvested, and most of them are undesirable for the process of silage preservation. Most of these organisms require oxygen to grow (strict aerobic bacteria). Thus a decrease in oxygen in the silage as it is packed results in a "natural selection" and a decrease in the type of bacteria that require oxygen to grow.

As oxygen is removed and fermentation begins, the bacteria that become predominant are those that have the ability to live either in the presence or in the absence of air (facultative aerobic bacteria). This group includes the enterobacteria, which convert sugars into a variety of organic acids (formic acid, acetic acid, lactic acid and sometimes butyric acid), carbon dioxide (CO_2) and hydrogen (H_2). These acids are responsible for the early decrease in pH in the silo.

As fermentation proceeds, enterobacteria become less competitive because they are particularly sensitive to decreasing pH. The growth of enterobacteria is inhibited when the pH falls below 4.5, which usually occurs within a few days of ensiling. However, enterobacteria tend to persist for longer periods in silage where pH decreases slowly, as is the case with wilted silage (see below).

Phase 3 - Lactic acid bacteria fermentation

Lactic acid bacteria begin to dominate the fermentation process after silage pH drops to 5.5 – 5.7 (from 6.5 - 6.7 at ensiling time). A few species of lactic acid bacteria can live in the presence of oxygen, but most are strictly anaerobic, meaning that oxygen is toxic to them. The reaction describing lactic fermentation is simple; one unit (molecule) of sugar is broken down into two units (molecules) of lactic acid:

$$C_6H_{12}O_6 \rightarrow 2\,C_3H_6O_3$$
$$\text{sugar} \quad \rightarrow \quad \text{lactic acid}$$
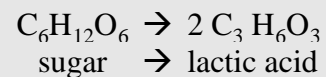
Some species of lactic acid bacteria produce only lactic acid (as indicated in the above equation), they are called "homofermentative" bacteria. However, other species of lactic acid bacteria, called "heterofermentative" bacteria, produce lactic acid and other end products such

$$C_6H_{12}O_6 \;+\; 6\,O_2 \;\rightarrow\; 6\,CO_2 \;+\; 6\,H_2O \;+\; 3.8\text{ Mcal/kg sugar}$$
$$\text{sugar} \;+\; \text{oxygen} \rightarrow \text{carbon dioxide} \;+\; \text{water} \;+\; \text{heat}$$

as acetic acid, alcohol (ethanol) and carbon dioxide. Homofermentative species are preferable in silage because they produce more lactic acid, which is stronger and reduces pH more than acetic acid. Actually, as pH drops, lactic acid becomes the predominant end product of fermentation. Proper lactic acid production depends on the following three factors:

- The number of lactic acid bacteria present at the time of ensiling;
- The presence of a sufficient amount of fermentable sugars;
- The absence of oxygen in the silage.

The number of lactic acid bacteria present at ensiling time can vary from less that 1,000 to about 20,000,000 per gram of fresh forage (Muck, 1988) and cannot be controlled easily with management decisions. Nevertheless, the count of lactic acid bacteria tends to increase when wilting time is between 24 and 48 hours, as compared to less than 24 hours, and when temperatures during wilting range from 22-25°C, as compared to 18-22°C.

Research has focused on inoculation of silage with strains of lactic acid bacteria. When applied, a silage inoculant should provide at least 100,000 bacteria/gram of ensiled alfalfa to be effective. The best chance for benefiting from this investment may be with first and last cuttings of alfalfa, since cooler and shorter wilting conditions (of early spring and early autumn) lower the naturally occurring lactic acid bacteria (Satter et al., 1988).
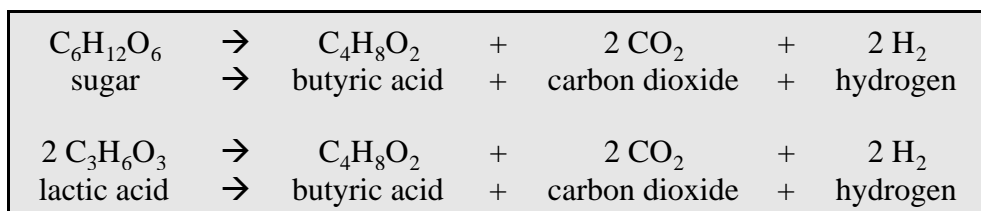
Phase 4 – Stable silage

After about 14 days of fermentation, a well preserved grass silage contains 1.5 to 2% lactic acid, and pH may range from 3.5 to 4.2. In legumes such as alfalfa, however, the pH rarely drops below 4.5, even under the best conditions. The strong acidity created during Phase 3 leads to a sort of "semi-sterilization" of the silage mass in the sense that all bacterial growth is paralyzed, and eventually the growth of the lactic acid bacteria themselves is inhibited. This stable phase may last for months (if not years) as long as the silo remains closed and protected from oxygen. Thus, it is important to cover a silo with a good plastic sheet that is well sealed and has a low level of aire permeation. Large dry matter losses can occur due to a poor covering (see aerobic deterioration below).

Undesirable fermentation due to Clostridia (butyric acid bacteria)

These bacteria grow in the absence of oxygen (anaerobic) and are normally found in soil and manure. The fact that clostridia live in the absence of oxygen and resist pH as low as 4.2 allows them to compete with lactic acid bacteria even after the pH drops below 5.0. Essentially, clostridia dominates the fermentation when lactic acid bacteria do not produce enough lactic acid to drop pH to a stabilization value fast enough. When silage is contaminated with dirt (e.g., from a soiled tractor wheel) or manure, the risk of clostridial fermentation increases. Clostridia tend to growth faster at a temperature of about 35°C (a higher optimal temperature than most previously discussed bacteria). Thus this type of undesirable fermentation happens when extensive respiration and enterobacterial fermentation occur and silage temperatures rise in the early phases of the fermentation process. Some species of clostridia ferment sugars and change the lactic acid produced by lactic acid bacteria into butyric acid, carbon dioxide and hydrogen (H_2) (see box at bottom of page).

Production of carbon dioxide and hydrogen gas indicates a loss of digestible energy. The breakdown of lactic acid into butyric acid, which is a weaker acid, means that the pH of silage going through clostridial fermentation will tend to rise. Butyric acid has a strong, repulsive smell. Trace amounts of butyric acid suffice to decrease voluntary intake by cows. Also, some species of clostridia ferment amino acids, leading to the formation of toxic substances such as cadaverine and putrescine. A silage spoiled by clostridia is easily recognizable due to its strong odor, a pH above 5.0, ammonia nitrogen greater than 10% of total nitrogen, and more butyric acid than lactic acid.

$C_6H_{12}O_6$	→	$C_4H_8O_2$	+	$2\,CO_2$	+	$2\,H_2$
sugar	→	butyric acid	+	carbon dioxide	+	hydrogen
$2\,C_3H_6O_3$	→	$C_4H_8O_2$	+	$2\,CO_2$	+	$2\,H_2$
lactic acid	→	butyric acid	+	carbon dioxide	+	hydrogen

Fortunately, many clostridia are more sensitive to high acidity and high osmotic pressure[6] (high levels of dry matter content) than lactic acid bacteria. Thus clostridial fermentation can be avoided by:

- Ensiling at more than 30% dry matter content;
- Packing the silo as densely as possible to reduce increases in temperature due to respiration;
- Avoiding soil contamination;
- Ensiling forages with the highest possible sugar content;
- Using proper ensiling techniques that favor maximum fermentation to the lowest possible pH as soon as possible.

Undesirable aerobic deterioration

Aerobic deterioration in bunker silos occurs when oxygen is allowed to penetrate the mass of packed silage. This may occur (a) on the top surface of a silo that is not sealed with a plastic sheet; (b) locally, around a whole in the plastic covering, or (c) when less than 10-15 cm of silage is removed daily from the vertical front of a well preserved silo. Losses caused by not protecting a silo from oxygen at ensiling time (Table 2) are due to continued respiration and undesirable bacterial fermentation. However, aerobic deterioration can also result from the development of other microorganisms including molds and yeast.

Molds and yeast (and some aerobic bacteria) resist pH as low as 2.0, but remain dormant in stable silage at a pH of around 4.0-4.5. Molds require sugar and oxygen to grow and can resume their development rapidly once oxygen is present. Yeast, on the other hand, may grow with or without oxygen and can produce alcohol in silage that is rich in sugars, such as corn. More than 60 species of molds have been isolated from silage, but the risk of aerobic deterioration depends upon the type of forage ensiled. Paradoxically, the risk of development of these undesirable micro-organisms increases with the quality of silage preservation. The residual sugar in a well preserved silage is the ideal energy source for molds and yeast. In addition, a well preserved silage has little or no butyric acid, which is a strong inhibitor of mold and yeast growth. Thus, after a silo has been opened, a well preserved silage has a greater chance of mold and yeast deterioration than poorly preserved silage.

◆ Wilting green forage - Why is it important to ensile at the "right" dry matter content?

The dry matter content of silage strongly influences the type of fermentation that takes place in a silo. Losses of dry matter in effluents occur when silage dry matter content is less than 25%. Dry matter losses decrease from 7.2 to 1.6 and 0.4% from grass silage ensiled at 15, 20 and 25% dry matter respectively (Harrison and Fransen, 1991).

On the other hand, too much dry matter makes it difficult to pack and expulse the oxygen from the silage mass. The "ideal" dry matter content of the forage depends on the type of silo (which influences the mode and level of level of compaction that can be achieved). The recommended levels of dry matter in forages at ensiling are:

- 30 to 40% for bunker silos;
- 35 to 50% for tower silos;
- 40 to 50% for wrapped round bales.

Often, wilting a green forage for 24 – 48 hours to increase dry matter is highly desirable. <u>Why</u>? Essentially because wilted silage requires less lactic acid production and will stabilize at a higher pH level than silage that has a lower dry matter content (Table 3). This is the case because higher dry matter content increases the concentration of soluble dry matter in the silage, and the resulting increase in osmotic pressure (see endnotes) inhibits bacterial growth. Thus fermentation stops in wilted silage because of the high acidity, high osmotic pressure

Table 2: Average losses and quality changes in covered and uncovered bunker silos (Oelberg et al. 1983)

	Temp. (°C)	DM[a] Losses (%)	pH	Lactic acid (% DM)	CP[a] (% DM)	ADF[a] (% DM)	SP[a] (% CP)	ADIP (% CP)
Covered	36.7°	4	4.9	3.2	21	39	20	28
Uncovered	53.9°	32	6.8	1.7	22	47	16	37

[a] DM = dry matter; CP = crude protein; ADF = acid detergent fiber; SP = soluble protein; ADIP = acid detergent insoluble protein.[7]

Table 3: Effect of dry matter content and green forage type on pH required to avoid clostridial growth (Libensperger and Pill, 1987).

Dry Matter	Stable pH	
(%)	Grass	Legumes
20	4.16	4.26
25	4.26	4.45
30	4.43	4.60
35	4.63	5.04
40	4.90	5.56
45	5.14	--
50	--	--

combination (rather than high acidity alone in silage with lower dry matter content). Thus wilting has a "sparing" effect on the level of sugar and the level of fermentation needed to stabilize the silage. As a result, wilting is particularly important when the ensiled forage is a legume, which has a relatively low level of fermentable sugars as compared to grass or corn.

Wilting has additional advantages as well:

- Wilting tends to increase the number of lactic acid bacteria present at ensiling. This improves the likelihood of an early start of lactic acid fermentation and reduces the need for a commercial lactic acid bacteria inoculant;

- Wilted silage is usually more palatable, in part because of lower acid content. A 500 kg cows will ingest one additional kg of silage for every 5% increment in dry matter content above 20%.

◆ Change in forage composition in a silo

Loss of soluble carbohydrates and proteins

As dry matter is lost during silage-making, forage composition also changes. The changes in dry matter composition are due primarily to the fact that the most valuable nutrients (soluble carbohydrates and proteins) are also the first to be lost during respiration and fermentation and in the effluents (juices). Fiber on the other hand remains essentially unaffected by the naturally occurring fermentation process in a silo. Thus the overall effect of these losses is to increase the proportion of fiber; the percentage of both the acid detergent fiber (ADF[8]) and neutral detergent fiber (NDF[9]) tend to be higher in silage than in freshly cut forage.

Changes in the protein (nitrogen) fractions

Silage-making change the protein fraction of forages. Respiration is responsible for protein breakdown. As plant cells die after cutting, proteolytic enzymes break down large proteins into smaller soluble compounds including: peptides, amino acids (the building blocks of proteins) and ammonia. In addition, enterobacteria have proteolytic enzymes that remain active even after the pH has dropped to 5.0. Thus most of the protein degradation that takes place in a silo occurs within the first 24 to 72 hours (Phase 1 and Phase 2 of silage fermentation). By the time pH is about 4.0, proteolytic enzymes have lost 65 to 85% of their activity. Consequently, a rapid drop in pH is desirable to reduce the amount of protein breakdown in a silo. Nevertheless, recent research indicates that as much as half of the total nitrogen in alfalfa silage may be in the form of non-protein nitrogen. The extensive breakdown of alfalfa protein in a silo may be a factor in limiting milk yield in high producing cows (Broderick, 1995). Some scientists have proposed the use of ammonia content as one indicator of adequate silage fermentation. For example, a grass silage containing less than 5% of total nitrogen in the form of ammonia might be classified as excellent. In contrast, a silage that undergoes clostridial fermentation might contain more than 35% nitrogen in the form of ammonia and thus would be classified as poor (Vanbelle, 1985).

Although limiting protein solubilization and ammonia production in a silo is desirable, one should realize that this process is relatively similar to what happens in the rumen of a cow after ingesting silage. Not all soluble protein and ammonia produced in the silo are necessarily lost. Ammonia and amino acids are needed for microbial synthesis in the rumen.

Another nitrogen transformation that may occur during hay or silage-making results from the browning reactions that take place when excess heat is produced (Table 1). Excess heat cause chemical reactions that combine amino acids with plant sugars (usually derived from hemicellulose) to form a compound resembling lignin.[10] This reaction results in increased levels of acid detergent fiber (ADF) and acid detergent insoluble protein (ADIP; Table 2). Excess heat

is an indication of aerobic degradation due to the presence of air (oxygen) in a silo. Again, these undesirable reactions can be avoided by compacting silage as much as possible immediately after unloading fresh forage into a silo.

- Set the harvester to obtain a theoretical length of cut (TLC) of 1.0 cm for green forages and 0.6 cm for corn silage. Short particle length enhances sugar availability for fermentation and facilitates silo compaction. However, at least 20% of the particles should exceed 2.5 cm in length to insure enough effective fiber in the silage.

- Filling a silo should be a continuous process with delays no longer than overnight. The last load of the day should always be packed particularly well to reduce oxygen penetration overnight.

- Avoid contamination of the silage mass with soil (from mud on tires), which tend to contain high levels of undesirable species of bacteria (clostridia).

- Pack the silage as much as possible to expel oxygen and favor the growth of lactic acid bacteria.

- Judiciously use additives to potentially improve fermentation patterns (optional).

- Seal the open surface of the silo with a plastic sheet to prevent oxygen from

reentering the silo; poor covering (or no covering at all) causes large losses of dry matter, undesirable fermentation and unpalatable silage. Plastic sheet should have a low level of permeation by air and be carefully placed and anchored to seal the silo completely. Holmes (1997) tried to quantify the value of feed saved (i.e., not spoiled) by using proper covering technique. He calculated that the time spent covering and uncovering a silo is worth $60-100/hour.

- Leave the silo close for at least two weeks for fermentation to reach its stabilization phase.

- Plan to build silos such that, upon unloading, 5 to 10 cm of silage can be removed daily (so that the rate of dry matter removal is greater than the rate of oxygen penetration in the silo's front).

- Use equipment that leaves a smooth surface to minimize exposure to oxygen and risk of secondary fermentation.

- When unloading a silo, remove only the amount needed for one meal (one day) and avoid spoilage of silage in feed bunks (mangers) by cleaning them every day before offering freshly unloaded silage to cows.

In summary, what are the best management practices for maximizing the quality of silage preservation?

In summary, one should remember that the quality of silage depends primarily on the quality of the forage entering the silo. Dry matter losses and quality changes in silage cannot be entirely eliminated, but they can be minimized by using good management practices:

- Cut the green forage in the early morning if the anticipated period of wilting is several days, but cut the green forage late in the day if drying conditions are good and chopping is anticipated for the next day. Research has shown that afternoon mowing consistently produces the lowest pH levels in alfalfa that is wilted one day and ensiled at 35% dry matter (Muck, 1998).

- Enhance the rate of drying in the field (to reduce respiration losses) by using a conditioning mower or increasing exposure to sunlight (optional).

- Ensile the forage when it has the proper moisture content (depending on silo structure and forage crops, between 30 and 50% DM) to minimize effluent losses and maximize level of silage compaction.

◆ Set the harvester to obtain a theoretical length of cut (TLC) of 1.0 cm for green forages and 0.6 cm for corn silage. Short particle length enhances sugar availability for fermentation and facilitates silo compaction. However, at least 20% of the particles should exceed 2.5 cm in length to insure enough effective fiber in the silage.

◆ Filling a silo should be a continuous process with delays no longer than overnight. The last load of the day should always be packed particularly well to reduce oxygen penetration overnight.

◆ Avoid contamination of the silage mass with soil (from mud on tires), which tend to contain high levels of undesirable species of bacteria (clostridia).

◆ Pack the silage as much as possible to expel oxygen and favor the growth of lactic acid bacteria.

◆ Judiciously use additives to potentially improve fermentation patterns (optional).

◆ Seal the open surface of the silo with a plastic sheet to prevent oxygen from reentering the silo; poor covering (or no covering at all) causes large losses of dry matter, undesirable fermentation and unpalatable silage. Plastic sheet should have a low level of permeation by air and be carefully placed and anchored to seal the silo completely. Holmes (1997) tried to quantify the value of feed saved (i.e., not spoiled) by using proper covering technique. He calculated that the time spent covering and uncovering a silo is worth $60-100/hour.

◆ Leave the silo close for at least two weeks for fermentation to reach its stabilization phase.

◆ Plan to build silos such that, upon unloading, 5 to 10 cm of silage can be removed daily (so that the rate of dry matter removal is greater than the rate of oxygen penetration in the silo's front).

◆ Use equipment that leaves a smooth surface to minimize exposure to oxygen and risk of secondary fermentation.

◆ When unloading a silo, remove only the amount needed for one meal (one day) and avoid spoilage of silage in feed bunks (mangers) by cleaning them every day before offering freshly unloaded silage to cows.

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Endnotes

[1] Enzymes are proteins that accelerate reactions in living cells without being consumed in the process.

[2] Organic acids are acids that are produced by the normal functions of all living cells; common organic acids include formic acid, acetic acid, propionic acid, butyric acid, lactic acid, etc.

[3] pH is a measure of acidity or alkalinity. pH values range from 0 (most acid) to 14 (most alkaline). Water has a pH close to neutral (pH 7). A drop in pH indicates an increase in acidity.

[4] Buffering capacity is the resistance to pH drop and is often expressed as milliequivalent/kg of dry matter. Plants such as alfalfa, which contain high levels of salts of organic acids and proteins, have a high buffering capacity; which means that a given amount of acid will lower pH less than for plants that have a lower buffering capacity (corn). In other words, plants with high buffering capacity (e.g., alfalfa) require more acids to reach the same reduced pH than a plant with a low buffering capacity (e.g., corn).

[5] Respiration basically means to live in presence of oxygen and use it.

[6] Osmotic pressure reflects the concentration of substances in a solution. As dry matter content increases, osmotic pressure also increase. At high osmotic pressures, water is drawn out of bacterial and other living cells, which "die of thirst" because of lack of intracellular water.

[7] ADIP or acid detergent insoluble protein is a measure of the unavailable nitrogen in the feed, primarily as a result of heat damage.

[8] ADF or acid detergent fiber is correlated with the digestibility of a feed; the lower the ADF, the higher the digestibility.

[9] NDF or neutral detergent fiber is correlated with the level of dry matter intake by cows; the lower the NDF, the higher the level of intake.

[10] Lignin is an indigestible plant compound, which is deposited in the cell wall and is responsible for a decrease in cell wall carbohydrate (cellulose and hemicellulose) digestibility as a plant matures.