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SILAGE MAKING AND SILAGE ADDITIVES

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Introduction

Silage formation should be considered a "self-preservation" of a feedstuff by fermentation of some of its nutrients by enzymes present in and/or organisms already present on the feedstuff. The resulting product has been defined as "a feedstuff resulting from anaerobic fermentation of moist forage or other feedstuff and by preservation with the formation of acids." Even under ideal conditions of silage formation, nutrient losses will occur during the fermentation process.

The discussion which follows will include suggestions and criteria for making high quality silage with minimum loss of nutrients.

Fermentation Process

The progression of events from fresh or partially dried forage to the completion of the fermentation process can be predicted. Losses can be estimated with reasonable accuracy when type of material, moisture content and storage conditions are known.

Step 1. Both microbiological and biochemical changes begin immediately as life processes are disrupted when the fresh plant is harvested. Reports suggest that increases in dry matter yield may occur for a short time in the wilting process that follows harvesting because photosynthesis results in carbohydrate storage which can continue for as long as 3 days. Usually, however, such an increase is of no real significance, and a net loss of 1 to 2% dry matter will occur during a 24-hour wilting period as plants continue respiration with utilization of energy. If weather is not favorable for drying during the wilting period, dry matter losses can exceed 10%.

Step 2. Just after the fresh forage enters the silo, fermentation begins with a rapid increase in the bacterial population. If the forage has been properly chopped 1/2 to 3/4 inch (1 to 2 cm) and packed sufficiently to exclude air, the bacterial population will shift to anaerobic (without air) bacteria such as lactobacilli. The continued respiration by the plant cells depletes oxygen that is trapped in the compacted forage and thus contributes to the desired anaerobic condition in the forage mass. Readily available nutrients from the plant cell fluids serve as an energy source for the microbial population. Other than a small amount of hemicellulose sugars, cell wall components (such as cellulose) do not become actively involved in the fermentative activity. Production of organic acids (lactic, acetic and butyric) by microbiological fermentation further restricts the bacterial population to those organisms which are able to tolerate the lower pH (increased acidity). If air has been excluded and anaerobic conditions persist within the fermenting forage, dry matter losses from bacterial activity and plant respiration could be as low as 5 to 6%.

Fermentation is greatest a few hours after the material enters the silo but may continue for a week or more depending on the acidity, compaction, available carbohydrates, moisture level, oxygen present and other factors.

Step 3. Silage will enter a stable phase. During this phase, organic acids produced by fermentation preserve the silage and prevent losses of nturients as long as anaerobic conditions are maintained. The forage mass becomes a palatable feed with good texture and a pleasant odor.

Step 4. If proper silage making practices are not followed, a secondary fermentation by such organisms as clostridia (butyric acid bacilli) may occur which utilize the lactic acid produced in the earlier phases of fermentation. Also, proteins of the forage will be denatured or partially changed to certain nonprotein forms which may not be well utilized by animals. Secondary fermentations may also create undesirable silage odors and possibly toxic nitrogen compounds as well. The temperature of the silage may rise during this secondary fermentation with an accompanying loss of dry matter (as high as 50%). If excessive air enters the mass, yeasts and molds will also use up the acids causing a rise in pH as well as temperature. Animal ingestion of yeasts, high levels of ammonia and mycotoxins from mold activity may present additional hazards. The final result is very bad silage which will not stabilize during storage but will continue to ferment and deteriorate. In addition to serious dry matter losses, such silage will contain more butyric acid, less lactic acid and has been shown to have reduced protein digestibility and energy content than so-called "normal silage."

Characteristics of good silage may be summarized as shown in table 1.

Table 1. Characteristics of Good Silage

Parameter	
pH (acidity)	4.2 - 4.5 or below
Lactic acid	3 - 5%[a]
Butyric acid	0.1%
Ammonia (% of total N)	10%
Temperature	30-38° C[b]

[a] Corn and other grain-type silages will usually have higher lactic acid levels than forage-type silages such as alfalfa silage.

[b] Most researchers suggest that silage temperatures should not exceed 38° C (100° F) to avoid browning and protein denaturation. Abnormal silages may reach temperatures in excess of 45° C.

Factors Affecting Silage Quality

Many of the problems of silage making can be avoided by proper planning for harvest, fermentation and storage. Properly harvested and prepared silage is an excellent feed known for its palatability. Factors such as moisture content and stage of maturity appear to be rather specific for the crop being ensiled.

Maximizing nutrient yield is the goal of any cropping system. In terms of quantity, this refers to dry matter harvested per acre. For example, corn, when harvested for silage, yields more dry matter per acre than many other crops. In terms of maximizing quality, yield refers to harvesting a crop at the correct stage of maturity to obtain a feed with the greatest amount of energy and protein per pound of feed harvested. A good stand of alfalfa will produce high yields of protein per acre.

Harvesting a crop as silage increases the yield of nutrients from the crop as compared to dry hay or forage. In grain crops such as corn or oats, harvesting only the grain leaves 40 to 50% of the available nutrients in the field. Field losses normally associated with dry hays are reduced when harvested for silage. Alfalfa hay, for example, may have field losses of available nutrients in the range of 20 to 30%, whereas field losses of alfalfa silage are less than 10%.

One of the most important keys to making good silage is harvesting the crop at the proper stage of maturity. Crops intended for silage when harvested at the correct stage of maturity will assure maximized yields of digestible nutrients per acre while minimizing field and storage losses.

The following discussion deals with the stage of maturity and moisture content of various ensiled crops to maximize plant and animal production.

Corn Silage

The proper time to harvest corn for silage is at physiological maturity or when all kernels are fully dented. At physiological maturity, growth ceases and the corn plant yields more dry matter than at any other time in its growing phase. Harvesting after maturity results in leaf loss, dropped ears, stalk breakage and possible weather and insect damage. The whole plant should contain about 30 to 35% dry matter (65 to 70% moisture) which is ideal for compaction within the silo.

The following guidelines will be helpful in determining the time to harvest corn for silage:

1. Start filling the silo when kernels are glazed to hard dent. This usually occurs between 50 to 55 days after silking. By noting when about one-half of the field is in silk one can anticipate ahead of time when harvesting should occur.

2. Use the "black layer" test. At physiological maturity a black layer of cells forms along the tip of the corn kernel. To detect the black layer, remove some kernels from the middle of the ear, split the kernels lengthwise and look for the black layer near the tip. If present, the corn is ready for harvest.

3. Check moisture level in the grain with a moisture tester. Grain will be 65 to 70% dry matter (30 to 35% moisture) when the whole plant is 30 to 35% dry matter.

4. If large tonnages are to be harvested, plant varieties of different maturities. Early maturing varieties should be planted first followed by later maturing varieties. This allows silage harvesting to be spread over a longer period of time and enables the harvesting of all corn at the most correct stage of maturity.

Alfalfa Silage

The recommended time to cut alfalfa for silage is late bud to early bloom stage. At this time leaves make up about half of the dry matter of the plant. Leaves contain greater percentages of protein and energy and less fiber than other plant parts. Cutting at late bud to early bloom results in greatest animal intake, digestibility and annual nutrient yield.

Alfalfa is one of the most difficult crops to ensile successfully. Alfalfa is low in soluble carbohydrates, the substrate required for lactic acid production, and is high in protein and minerals which act as buffering agents to neutralize silage acids and prevents the drop in pH necessary for preservation.

Moisture level is important in making good quality alfalfa silage. Too much moisture (greater than 70%) results in seepage, high levels of butyric acid and protein losses in silage. Too little moisture (less than 45%) results in silage that packs poorly and suffers from heat damage that greatly reduces protein and to a lesser degree dry matter digestibility.

Some steps to follow in making good alfalfa silage are:

1. Cut at proper stage of maturity--late bud to early bloom
2. Wilt to proper moisture level--45 to 70%
3. Chop fine and uniform (1/4 to 3/8 inch theoretical cut)
4. Provide tight silo (especially around doors)
5. Fill silo rapidly and evenly
6. Weight the top of the silage with high moisture material to seal
7. Seal with a cover if not used immediately

Small Grain Silage

Small grains are used extensively for silage in the upper midwest, especially in areas where the growing season is too short for corn. The time to harvest small grains for silage is more critical than for any other crop. Grains mature rapidly after heading, declining in dry matter digestibility at a rate twice that of perennial forage. Data concerning the effect of stage of maturity on voluntary intake and milk production are inconsistent. Higher dry matter yields are obtained with later stages of maturity such as hard dough. However, protein content declines with maturity. Greatest yields of protein per acre occur when harvested at late milk and early dough stages. Seepage is not a problem and sufficient carbohydrates are available for fermentation. Silage from small grains should be chopped fine and evenly distributed in the silo to assure adequate fermentation of the hollow stem.

Sunflower Silage

Sunflowers are becoming a major crop for part of South Dakota. Much of the sunflowers grown are for seed but can be used for silage. The whole sunflower plant may be 75 to 80% moisture or greater at maturity. One should wait until the plant is approximately 70% moisture before harvesting for silage. Any attempt to wait longer will cause a loss of leaves and possible damage to the heads by birds.

Silage Additives and Aids to Fermentation

Many attempts have been made to alter, assist or even replace some of the basic steps involved in silage formation by silage additives. For the sake of a more organized discussion of such additives, they will be discussed as belonging to the nutritive or non-nutritive material or as a fermentation inhibitor.

Nutritive Additions

Molasses. Molasses provides readily fermentable sugars and has found best use with forages that are high in moisture (55 to 88%) and protein (e.g., alfalfa). Molasses has been shown to increase lactic acid content and lower pH, free ammonia and butyric acid content when added (1 to 5%) to grass silages. Molasses also has a drying effect when added to high moisture silage but cannot be expected to stop leeching with the levels of molasses being used. It should not be expected that molasses-treated silages would increase feedlot performance or milk production much above untreated silages. Usually it would not be economical or necessary to add molasses to crops having an adequate level of available carbohydrate such as corn.

Grains. Grains serve a similar function as molasses, although grains do not contain as high a level of simple sugars as molasses. Grains would be higher in dry matter and starch than molasses. Grains such as corn, barley, oats and milo have been added (10 to 20%) to increase fermentable carbohydrates, increase dry matter of wet crops or increase the energy content of the silage. Additions of grains to silage will increase the labor, time required and costs of silage making.

Dried Beet and Citrus Pulp. Dried beet and citrus pulp are not readily available in many areas and are difficult to handle as a silage addition because of the bulky nature of the material. Up to 37% of these materials have been added to silage to increase the dry matter of high-moisture forage. The effect on intake and milk production is small, with only a limited advantage on retention of initial silage dry matter or lowering of silage pH. Pulps could be expected to have less available carbohydrates to increase fermentation as compared to molasses or grains.

Whey. From 1 to 10% dried whey has been added to corn and grass silage with no detrimental effects. In some cases greater digestibility and milk production were obtained by the addition of whey. It has been used as a replacement for molasses with high-moisture forages to assist in greater production of acids. Fresh whey finds less usage since most silages have sufficient moisture content. Some promise is indicated in using whey and low levels of urea to improve milk production when feeding silage. More research is needed to study the value of whey as a nutritive material in silage.

Limestone. Limestone is a very economical additive to silage and can be used to correct the calcium deficiency of corn silage. Limestone may also extend the silage fermentation time and therefore increase the organic acid content. Animal gain and feed requirements may not be benefited by limestone additions. Additions of 0.5 to 1.0% may assist the fermentation somewhat by increasing acid production, especially lactic acid. Minerals of this type, however, can be conveniently provided to animals in mineral supplements rather than by additions to silage.

Urea. Urea is usually added at the 0.5% level (fresh basis) to silage to increase the nitrogen level (protein content) of low protein silage materials such as corn silage. Higher levels may reduce feed intake. The fermentation period may be extended by urea additions to corn silage, but the pH may be higher because of the basic ions formed from urea. Most studies indicate small but beneficial effects on rate of gain, feed efficiency or milk production. Less protein supplementation will be needed with urea-treated silage. If urea and limestone are added together, some claim of associative effects has been suggested over addition of either material alone.

Other Nonprotein Materials and Minerals. Other forms of nitrogen besides urea can be used such as ammonia or ammonia-molasses and mineral suspensions. The response may be similar to urea additions. The choice will depend on which is most convenient to the feeder at the time the silage is made and the cost comparison.

Silages which serve as the only ration--"all-in-one silages"--including nitrogenous additions can be prepared which are customized for a certain feeding regime. Such silages are less flexible once prepared but are more convenient at feeding time. All-in-one silages can be used in automated systems but are more difficult to prepare at ensiling because of the numbers and kinds of materials to be handled. No advantage is realized over supplementing silage as it is fed.

Non-nutritive Silage Additives

A number of products categorized as "aids to fermentation" are available commercially for addition to forage at the time of ensiling. The function of such aids is to alter the rate or enhance the degree of fermentation and thereby retain a higher proportion of one or more nutrients in the silage dry matter. Although some non-nutritive additives have been the subject of considerable research, others have not been extensively studied under carefully controlled conditions.

This group of additives includes bacterial and yeast inoculants, enzymes, flavorers and antioxidants. The discussion which follows will deal with how they affect fermentation, palatability, preservation of nutrients and animal performance.

Bacterial and Yeast Cultures. The chemical changes observed during the ensiling process result from fermentation by microorganisms which exist naturally on the plant material. These microbes live and grow in an atmosphere of air but, when placed in an oxygen-limiting environment of the silo, some types will disappear. Other microbes will find conditions favorable for growth and will increase to enormous populations. The crushed plant tissue provides an excellent nutrient food for various microorganisms which produce organic acids such as lactic, acetic and propionic acids. The acid fermentation serves to crowd out spoilage producing organisms and aids in the preservation of the silage.

Responses to bacterial inoculants have been variable and somewhat inconsistent. Research has been conducted with wilted or direct cut forages, with forages differing in stage of maturity and with additions of readily fermentable carbohydrates such as molasses, whey or grain. This complicates the evaluation of microbial additives and has created confusion as to their usefulness in silage making.

Investigations with forages inoculated with viable cultures of microorganisms have shown a more rapid decline in pH and a lower pH at the completion of fermentation than untreated forages. Higher titratable acidity has been reported in inoculated silage with increased concentrations of lactic acid and lower levels of acetic and butyric acids. Lower levels of soluble and ammoniacal nitrogen and soluble carbohydrates have been observed.

In terms of preservation, limited research has shown inoculated silages often have a more pleasant aroma with less spoilage than untreated silages. Lower temperatures and improved dry matter and protein preservation have been reported. However, some investigators have found no clear evidence of improvements in these parameters.

The utilization of nutrients by ruminants fed treated forages ranges from small improvements in dry matter and protein digestibility to essentially no changes in utilization. Animal performance with treated and untreated silages has also been variable. Lower intakes of treated silage have been observed with no improvement or only slight improvement in daily gains and feed conversion. Milk production has also been similar for treated and untreated silages. An increase in the fat content of milk has been shown with inoculated forage.

The addition of bacterial inoculants appears to offer little advantage when generous amounts of readily fermentable carbohydrates are present in the silage. Studies with corn silage treated with microbial additives show no effect on weight gain or feed conversion under conditions where increased energy and protein preservation have been observed. Legume or grass silages appear to be improved with the addition of readily fermentable carbohydrates such as sugar or molasses in conjunction with bacterial inoculations.

Enzymes. Enzymes such as proteinase, amylase, cellulose, lipase or crude mixtures of these compounds together with their co-factors have been considered as aids to the silage fermentation process. The mode of action of these additives appears to be their ability to increase the availability of nutrients through factors which stimulate microbial growth or utilization of nutrients by the microbes. The benefits to be obtained, however, depend upon the kind and amount of nutrient to be acted upon by the enzyme. Some investigators suggest that enzymes accelerate fermentation while lowering heat production and increasing the concentration of lactic and propionic acids.

Recent research results with enzyme-treated corn silage show an improvement in preservation and recovery of nutrients compared to untreated silage. However, steers fed the treated silage consumed more dry matter but gained only slightly faster and with only a small improvement in feed efficiency than steers fed the untreated silage.

An investigation of the addition of the enzyme cellulose resulted in an increase of acetic acid with a reduction in lactic acid production. Milk production was not affected in one experiment but was slightly higher in another trial with cows fed silage containing the enzyme.

Flavors. Flavors have been utilized for some time to mask undesirable tastes of feed ingredients or to enhance the aroma of the finished feed. Flavors contribute no nutritional value to a feed or silage. However, some investigators suggest that flavors may impart a desirable aroma to silage and improve feed intake by influencing palatability. However, differences in palatability are extremely difficult to measure. Silage prepared under optimum conditions would not be improved by flavor additions.

Antioxidants. Compounds such as ethoxyquin, butylated hydroxy anisole (BHA), butylated hydroxy toluene (BHT) and others are commonly added to livestock feeds to prevent oxidation of fats, fat-soluble vitamins and pigments. Antioxidants have been included in various additive mixtures for silage presumably to aid in the reduction of oxygen content. Elimination of oxygen in early stages of fermentation would allow bacterial and enzyme reactions involved with fermentative degradation to proceed with greater efficiency. Silage made at the proper moisture content and packed well in the silo would have most of the air removed.

It has been suggested by some investigators that antioxidants may be helpful in reducing heat damage in silage containing optimum moisture. If benefits are to be obtained from antioxidants, the response would occur in early stages of fermentation when organisms which grow without air are rapidly multiplying. Silage made with antioxidants does not appear to keep well with extended periods of storage.

Handling Non-nutritive Additives. The compounds discussed in this section are usually added to the ensilage mass upon storage in the silo. The additives of this group are recommended in very small quantities per ton of forage and therefore some problems of mixing are likely to occur. A quantity such as 1 pound of additive per ton of fresh ensilage requires uniform application and sufficient mixing to insure adequate dispersion throughout the forage mass. Various commercial granular applicators are available which attach to the forage chopper to apply the inoculant near the chopper knives. Applicators may also be mounted on the feed table of the forage blower. Hand mixing may be used by mixing the inoculant with a small quantity of ground corn and then applying the mixture over the top of each load of chopped forage. Storage of additives should be in a cool, dry place, preferably avoiding direct sunlight.

Fermentation Inhibitors

Another type of silage additive are compounds that inhibit microbial fermentation of silage. There are three classes of fermentation inhibitors: (a) organic acids, (b) mineral acids and (c) antibiotics. Acid addition at ensiling acts by lowering pH in an attempt to prevent microbial growth. Antibiotics have been proposed to selectively inhibit growth of putrefactive bacteria.

Organic Acids. Much of the research on organic acid additions to silage has involved propionic acid, formic acid and formaldehyde as the additive. Formaldehyde is not an acid but acts very similar to formic acid in preserving ensiled material.

Propionic acid was first used as a preservative for high-moisture grain and has been shown to be an effective treatment of silage in terms of reducing silage temperature, top spoilage, mold growth and heat-damaged protein.

Propionic acid (.5 to 2.0%) reduces the amount of heating that occurs in low-moisture alfalfa and the resulting silage has higher protein and dry matter digestibilities than untreated silage. Protein digestibility of propionic-treated alfalfa silage is improved by 5 to 8% over untreated silage. Animal intake as a percent of body weight is increased by 0 to 15% by treating with propionic acid. Although silage quality is improved by addition of propionic acid, animal performance in terms of rate of gain or milk production is not increased by treatment. The primary benefit of treating silage with propionic acid appears to be from increased recovery of dry matter from the silo.

Formic Acid and Formaldehyde. Formic acid and formaldehyde enjoy widespread use in Europe but are not approved by the Food and Drug Administration for use in the United States. Formic acid like propionic acid immediately reduces pH of the ensiled forage. Lactic acid-producing bacteria are relatively tolerant to this acidic condition, whereas other microbes (especially Clostridia) are sensitive to this lowered pH. Theoretically this would give the lactic acid bacteria an advantage to proliferate. Formaldehyde is bactericidal and limits fermentation.

Addition of formic acid or a mixture of formic acid and formaldehyde to legumes or grasses results in silages (direct cut or wilted) with lower pH, butyric acid and total acids, higher lactic acid and greater residual soluble carbohydrates than in untreated controls. Formaldehyde alone produces silage with a higher pH but less total acids than controls. Greater amounts of true protein and less ammonia were present in formic acid and formaldehyde-treated silage than in untreated silage.

Energy digestibility of silage treated with formic acid, formaldehyde or a mixture is similar to control. Nitrogen digestibility of formaldehyde-treated silage may be lower than that of untreated silage. Although digestibility is less, nitrogen utilization is improved for two reasons: (1) more nitrogen in forage present as true protein and (2) protein in formaldehyde-treated forages tends to by-pass rumen fermentation and be digested in the lower tract.

Animal performance, the best indicator of forage quality, is improved from 20 to 60%, feed intake is increased by 10 to 15% and feed efficiency is improved 50 to 80%.

Mineral Acids. Mineral acids (hydrochloric, sulfuric and phosphoric) when added to silage cause an immediate fall in pH of 3.8 to 4.0. At this low pH, the forage (this would not be a true silage) would be preserved almost indefinitely. One of the major problems with mineral acid silage is animal intake is extremely low. Use of mineral acids as a preservative cannot be recommended because of cost and its corrosive nature.

Caution in Handling Acids. Care must be taken when treating a crop with a product containing any organic acid. Acids are corrosive and look like water. They can easily be mistaken for water and used improperly. An acid product should be clearly labeled and, when using acids, have plenty of water and sodium bicarbonate (baking soda) near to clean up spills and accidents immediately. Wear protective clothing, especially goggles for the eyes. When finished, machinery should be washed and sprinkled with baking soda to neutralize any remaining acid.

Antibiotics. Work with antibiotics advanced on the theory that growth of selected microorganisms could be inhibited during early stages of fermentation while other more desirable microbes would grow and increase in numbers. Antibiotics such as tylosin, zinc bacitracin, tetracyclines and streptomycin have been used with little success in improving silage quality.

Summary and Conclusions

The production of high quality silage is a problem that is costly in terms of possible loss of nutrients, reduced palatability and a reduction of total feed available due to dry matter losses. The adherence to time-tested principles is still the best assurance of obtaining high quality silage that has an appealing color, pleasant smell and good texture. Good quality silage is most likely accomplished by:

1. Harvesting the crop at the correct stage of maturity.
2. Chop fine (1/4 to 1/2 inch) and keep equipment in top operating condition.
3. Make sure silo is in good repair. Doors are tight and do not leak.
4. Fill silo continuously if possible.
5. Distribute evenly and pack well.
6. For upright silos, make last loads wet to add extra weight for packing.
7. Cover the top of the silage.