# PREPARING HIGH QUALITY ALFALFA SILAGE

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## INTRODUCTION

Alfalfa is an important component of dairy rations in the northern and western United States. It is the major source of crude protein and fiber in the ration. In order to achieve high milk production levels, farmers need to feed alfalfa of high quality. This means harvesting alfalfa at the right stage of maturity and preserving that quality until the alfalfa is fed.

In dry climates, alfalfa can be preserved as dry hay. Hay made and stored at less than 20% moisture is very stable biologically, and the majority of losses and changes in quality occur during harvesting. Unfortunately in moister climates, harvesting alfalfa as hay involves substantial risk of rain damage during field drying. This risk along with the ease of mechanized handling of a chopped forage has caused many farmers to move to ensiling alfalfa.

Alfalfa has long been known as a difficult crop to ensile. This has been because of two factors. First, alfalfa has a relatively low sugar content compared with other forages. Second, alfalfa has a high buffering capacity or in other words, a high resistance to a drop in pH. More recently, we have become aware of a third problem, much of the true protein in alfalfa may be degraded to soluble nonprotein nitrogen during ensiling. This can have an impact on balancing rations for high producing dairy cows.

Because of these problems, it is important to know how ensiling works to preserve a crop. With that knowledge, the keys to making high quality alfalfa silage will become more apparent. Also you will be able to make better management decisions when harvesting does not go as you plan due to weather or other circumstances.

### Preservation by Ensiling

In ensiling, a moist crop is being preserved. The crop has a variety of enzymes that are still active when the crop is ensiled. Some of these enzymes are beneficial whereas others have a detrimental effect on feeding value. A wide variety of microorganisms (bacteria, yeasts and molds) are on the crop and capable of consuming the most digestible portions of the crop. A successful job of ensiling seeks to minimize the actions of both plant enzymes and microorganisms that will reduce crop quality.

In order to preserve a crop by ensiling, two conditions need to be achieved: an anaerobic (or oxygen-free) environment and a low pH. Both are necessary because each performs a different role in preserving crop quality during storage.

The anaerobic environment is attained by sealing the silo well with plastic. It plays two important roles. First, an anaerobic environment is needed for lactic acid bacteria to grow efficiently, dominate the other microorganisms on the crop, and produce fermentation acids that lower pH. Second and more importantly, an anaerobic environment is the only means of stopping the growth of many of the spoilage microorganisms on a crop. Most yeasts and molds and some of the aerobic (oxygen-requiring) bacteria that may spoil a silage are not killed by pHs of 3.6 to 4.0, the lowest pHs found in silages. Fermentation acids may slow these microorganisms but will not prevent their growth. In fact, many spoilage microorganisms grow very nicely on fermentation acids. Consequently, an anaerobic environment is crucial to preventing microbial spoilage.

A low pH in silage is created by the growth of lactic acid bacteria. These bacteria primarily consume sugars in the crop and produce lactic acid and some other products such as acetic acid and ethanol. Lactic acid is a stronger acid than acetic, but both lower pH. Low pH has two primary functions in crop preservation. First and foremost, it stops the growth of detrimental anaerobic bacteria. Second, it reduces the activity of protein-degrading (proteolytic) plant enzymes.

The two groups of anaerobic bacteria that one wants to stop are clostridia and enterobacteria. Clostridia grow on sugars, lactic acid and amino acids. Sugars and lactic acid are converted to butyric acid and carbon dioxide, resulting in a significant loss of dry matter. Amino acids are converted to ammonia and amines. Clostridial silages (those having butyric acid contents of 1% dry matter (DM) or more) are unpalatable, and so intakes are reduced. Enterobacteria convert sugars primarily to acetic acid and carbon dioxide. This is less detrimental but results in DM loss and an inefficient lowering of pH.

The proteolytic enzymes in the plant are stored in portions of the plant cell so that they do not come in contact with other proteins in the plant. However, as the plant cells die, the proteolytic enzymes do mix with the other plant proteins, permitting the breakdown of protein nitrogen to soluble nonprotein nitrogen (NPN). Soluble NPN consists of free amino acids, peptides, ammonia, and some other compounds. The pH for maximum activity of these enzymes is 5.5 to 6.0, typical pHs of the standing crop. At pH 4.0, proteolytic activity is 15 to 35% of the maximum rate. Another important factor related to this protein loss is time. Most of the protein degradation occurs in the first 24 to 72 h of ensiling. After 3 d, the enzymes lose their activity. Consequently, a rapid drop to a low pH is needed to significantly reduce the amount of protein breakdown.

### Key Concerns for Ensiling Alfalfa

As indicated earlier, alfalfa has several problems related to ensiling. Table 1 indicates typical sugar contents and buffering capacities for various forages. Alfalfa ranks low in sugar content and high in buffering capacities. The practical result is that alfalfa ensiled under the best conditions rarely gets a pH lower than 4.5. Typical pHs range from 4.5 to 5.0 and may be even higher if sugar levels are particularly low or if ensiled at high DM contents (>50%). This means that alfalfa is particularly susceptible to a clostridial fermentation. This also implies that anything in the ensiling process which reduces the sugar content of the crop could have a very negative effect on alfalfa silage quality and intake potential.

Protein breakdown during ensiling may be another area of concern if the silage will be fed to high-producing dairy cows. As shown in Fig. 1, alfalfa silage has the highest level of protein breakdown during ensiling of any of the legume forages that have been studied. If one is to minimize the loss of true protein in the silage, one needs to guarantee a rapid drop to a low pH. This suggests the importance of efficiently converting as much of the sugars in the standing crop into lactic acid. It also suggests that the addition of lactic acid bacteria to the crop to ensure a rapid fermentation high in lactic acid may be of value.

## Specific Issues of Ensiling

*Maturity:*

The stage of maturity at which alfalfa is cut has the biggest effect on the digestibility and nutrient content of the resulting silage. Maturity at cutting also may affect the life of the stand, yield, and ensilabililty of the crop. Stand life is reduced by consistently cutting alfalfa at immature stages (mid-bud and earlier). Yield is maximized by cutting at the full flower stage. However by that stage, forage digestibility is nearing a minimum value.

The ensilability factors of sugar content and buffering capacity change with maturity in a parallel manner. The sugar content of the crop generally decreases as alfalfa gets more mature (Fig. 2). Fortunately, buffering capacity decreases as the crop matures (Fig. 3) so that less fermentation (and thus less sugar) is required in more mature alfalfa to reach a given pH.

Because of the relatively similar ensilability of alfalfa over a range of maturities, the prime consideration for when to cut alfalfa will be the type of animals being fed. If you are feeding high-producing dairy cows, then you should harvest some alfalfa at a more immature stage such as mid- to late-bud so that you will have alfalfa silage of high digestibility and crude protein content for them. Animals not requiring an energy and nutrient rich diet such as dry cows can utilize alfalfa of later maturity. Consequently, a range of maturities on a given farm can be used if the varying maturities are kept separate so that they can be used most effectively.

*Mowing:*

Many farmers wonder what is the best time of day to cut alfalfa for making silage. Unfortunately, there are many opinions on this but few data to support a particular opinion. In the standing crop, sugar and starch concentrations vary with the time of day and the amount of sunshine. Sugar and starch levels in the standing crop are lowest in the early morning and increase throughout the day (Fig. 4). Sugar contents are also highest in sunny weather. What is in the crop at mowing is not always a good indicator of what may be available when the crop enters the silo. When the crop takes approximately 24 h to reach 35% DM, the levels of total nonstructural carbohydrates (sugar plus starch) at chopping vary much less with time of mowing than the levels immediately after mowing (Fig. 4). This is because the alfalfa mowed early in the day dries down further before nightfall than that mowed in the early evening. The alfalfa still respires sugar after mowing and respiration rate decreases as DM content increases. Thus the alfalfa mowed earlier in the day respires less sugar than that mowed late in the day, which is wetter entering the nighttime hours. Overall, afternoon mowing consistently produced the lowest pHs in alfalfa that was wilted 1 d and ensiled at 35% DM. I suspect that the optimum window will vary by the speed of drying.

Under heavy crops or poor drying conditions requiring two days and perhaps more to reach 35% DM, mowing earlier may be favored. Under excellent drying conditions (e.g., chopping the day of mowing), alfalfa mowed late in the day may produce the best silage.

*Wilting Losses:*

Alfalfa plants continue to respire after mowing. Respiration uses oxygen and converts sugar to carbon dioxide and water and releases heat. This process represents the majority of dry matter loss in wilting under good drying conditions. In a crop such as alfalfa this loss is particularly important because sugars normally are a limiting factor for fermentation. Typical dry matter losses are approximately 1 to 3% per day, but this can vary even more depending on temperature and dry matter content of the crop.

*Rainfall Losses:*

Rainfall during field wilting is potentially damaging to the quality and ensilability of alfalfa. Rain does two things to the crop: shatter leaves and leach soluble nutrients from the crop. Both of these are detrimental to forage quality, but the latter is probably more important relative to the ensilability of the crop. The leachate from alfalfa and other forages consists largely of sugars, soluble NPN, salts and other soluble compounds in the plant. As a result, water soluble carbohydrates are twice as susceptible as crude protein to be lost from the crop by rainfall leaching. Somewhat surprisingly, leaching losses have generally not been found to be related to swath density, maturity of the crop or soluble nutrient content of the crop. The two most important factors appear to be the amount of rainfall and the dry matter content of the crop when rain occurs. Losses increase with increasing rainfall and increasing dry matter content. McGechan (1989) found that dry matter losses from rainfall leaching were reasonably predicted by the following equation:

$$l_{leach} = r_r (DM - 10)/70 \qquad [1]$$

where $l_{leach}$ = % DM loss; $r_r$ = runoff rainfall, mm; DM = dry matter content, %

This equation indicates that the losses at 30% DM from a given rainfall are double those at 20% DM. Consequently, a rainfall shortly after mowing is much less damaging to ensilability than one close to the time of chopping.

*Dry Matter Content at Chopping:*

One of the most important factors in making good alfalfa silage is the dry matter content of the harvested crop. It affects the potential for effluent production from the silage, how easily the crop is packed, and foremost with alfalfa the potential for a clostridial fermentation. In order to prevent a clostridial fermentation, the silage pH needs to reach a particular level to completely inhibit clostridial growth. The critical pH varies by both the dry matter content of the crop and the type of crop (Fig. 5). As the dry matter content goes up, a higher pH and less fermentation are sufficient to keep clostridia from growing. Also, you can see that alfalfa does not require as low a pH as grass and corn silage to prevent clostridial growth. This is related to the high buffering capacity of alfalfa. From experience and based on Fig. 5, well-managed alfalfa silage in a bunker or bag silo normally can be ensiled safely at 30% DM with little risk of clostridial fermentation because there is usually sufficient sugar to drop pH to 4.5 to 4.7. In overly mature alfalfa or in rain-damaged alfalfa or under poorer management, one may need to ensile at a higher DM content to prevent a problem with clostridial fermentation. In limited work with wrapped round bale silage, we have found that bale silage does not drop as far in pH as comparable forage ensiled in bunkers or bags. As a result, 30% DM is too wet to reliably ensile alfalfa in wrapped round bales. We believe that a minimum DM for good wrapped bale silage is approximately 40% DM. Overall we recommend the following DM contents for ensiling alfalfa:

| | |
|---|---|
| Bunker or bag silos: | 30 to 40% DM |
| Tower silos: | 35 to 50% DM |
| Wrapped round bales: | 40 to 50% DM |

The minimum values for all but the bale silages are also needed to prevent effluent losses, which will be discussed in more detail in my talk on corn silage. The maximum values are determined from packing considerations which will be discussed under the corn silage talk as well.

*Cutting Length:*

The cutting length set on the forage harvester varies considerably within countries and even more so across countries. In Europe, longer cutting lengths of 20 to 100 mm are common. In the United States, cutting lengths tend to be much shorter, 6 to 25 mm. What is the optimum? Actually that is a difficult question to answer because the cutting length affects not only ensiling but animal performance. We know that cattle need enough long fiber in their diet for good health, but the amount needed in a particular silage may vary based on the proportion of silage in the diet and the characteristics of the other components. For ensiling, shorter is better. Shorter particles are easier to pack, resulting in higher densities. That in turn makes for a less porous silage that should be less susceptible to spoilage losses. McGechan (1990) found that increasing cutting length from 20 to 100 mm reduced density by 20% in grass silages in bunker silos. In studies at our center, we found that initial bunker silo capacity was reduced 14% going from 9 to 25 mm in alfalfa. There also appeared to be greater spoilage losses using the longer cut. Somewhat surprisingly, fermentation in farm-scale silos normally is not affected much by cutting length. The exception is at very long cutting lengths. The 100 mm cutting lengths from forage pickup wagons used in parts of Europe and Canada sometimes result in reduced fermentation. As indicated earlier, less fermentation occurs in wrapped bale silages. The low dry matter losses reported in many wrapped bale studies (5 to 10% DM loss) suggest that the reduced fermentation is more due to some of the plant sugars not being available to the bacteria rather than due to excessive loss of sugars from plant and microbial respiration. Given all this, what is the best cutting length? I would suggest the smallest value that provides enough long fiber for good animal health. Depending on the circumstances, that most likely is in the range of 10 to 20 mm.

*Speed of Filling:*

Speed of filling is likely to be more important in ensiling alfalfa compared with other crops. During the filling process, oxygen is present in the top 30 to 50 cm of crop in a silo. The plant respiratory enzymes are still very active. Consequently, slow filling uses up valuable sugars needed for fermentation and produces heat that may cause excessive damage to protein. Ruppel (1993) in a survey of alfalfa silages in 30 bunker silos found that shorter filling periods led to silages with lower pHs. Also the level of acid detergent insoluble nitrogen (as a percent of total nitrogen) increased on average 0.84 percentage units for each day of filling, indicating greater heating from slow filling. Susceptibility to heating and spoilage at feedout is an additional problem caused by slow filling. Slow filling permits the growth of spoilage microorganisms at the beginning of ensiling. Ruppel found that slowly-filled silos produced silages that heated more rapidly at feedout.

*Covering:*

Doing a good job of covering a silo is an absolute essential to producing high quality silage. As stated earlier, fermentation alone will not produce a good silage. A well-maintained seal is necessary to prevent microbial spoilage. Large dry matter losses from silos are normally due to a poor job of covering (or no cover) and/or failing to feed out of a silo at a fast enough rate. In alfalfa, failing to cover the silo generally results in more than spoilage. Frequently below the moldy layer is a zone which looks all right from a distance but has a high pH and has undergone a clostridial fermentation. Thus the farmer is faced with discarding not only the moldy layer but also the zone below it which is unpalatable.

What is the value of covering a bunker silo? It is one of the most profitable jobs on the farm! We have a computer model of a dairy farm which allows us to evaluate various practices on the farm. The model indicates that covering bunker silos returns on average a profit 6 times the cost of the plastic and labor to put the cover on and off. Holmes (1997) has calculated the value of a good cover another way: how much could I afford to pay someone to cover and uncover my silo and still breakeven? His answer: $60 to 100 per hour. Anyway you look at it, covering is an important task that will reward you greatly.

*Feedout Rate:*

As mentioned earlier, this is an important issue regarding dry matter losses from any type of silage. However, this will be dealt with under the corn silage talk.

*Additives:*

A variety of additives may be used on alfalfa. The most common in the United States is the bacterial inoculant, which guarantees a high number of lactic acid bacteria. The purpose is to ensure a fast and efficient fermentation. By improving fermentation, ammonia levels are generally reduced. Because inoculants compete with the natural lactic acid bacteria, they are not always successful. Under Wisconsin conditions, they are successful approximately two-thirds the time on alfalfa, and we have developed guidelines so that farmers will know the conditions when such products are most likely to be profitable. Another speaker will address their use under your conditions.

Enzyme products or inoculants with enzymes included have been marketed for alfalfa. The majority of enzymes are cell wall degrading enzymes such as cellulases and hemicellulases. Amylases that breakdown starch are sometimes included. These products have a dual purpose. One is to provide extra sugars for fermentation. The other is to reduce fiber content such that a more mature forage feeds like a more immature one. Unfortunately, these products as a group have not been as effective in alfalfa as one would expect. A recent survey (Muck and Kung, 1997) found that while neutral and acid detergent fiber fractions (NDF and ADF) were reduced in approximately 90% of grass silage trials, NDF and

ADF were reduced in less than half the alfalfa trials. Silage pH was lowered in just over half the alfalfa trials. The most surprising result was an improvement in DM recovery in two thirds of the alfalfa trials, averaging 7 percentage units. Increases in animal performance have occurred in approximately a third of all trials across all crops. In general, enhanced animal performance has been less frequent and at a lower rate than that observed with inoculants. Enzymes should not be used on crops that are too wet as they will increase silage effluent. They are also less effective in drier silages (>45% DM). Overall, improved DM recovery in 30 to 40% DM silages appears to be the most consistent benefit of these products.

A final group of additives that might be used on alfalfa would be acids like formic or sugars like molasses. In both types, the main goal is to guarantee a low pH. In the case of an acid, crop pH is immediately lowered to some point, typically 4.7 to 5.0. Then natural fermentation continues to lower the pH of the silage. The addition of sugar supplements those sugars naturally present in the crop. Acids and sugars are normally used in ensiling when wilting is impractical because of frequently rainy conditions such as in northern Europe. They are rarely used in the U.S., where wilting can generally be done with little or no rain damage. Acids may prove useful in the future however. An immediate drop in pH can help reduce protein breakdown by proteolytic enyzmes in the plant. However, the levels required to subtantially improve protein protection in alfalfa do not appear to be cost effective.

**Summary**

Alfalfa can be a difficult crop to ensile because it has a low sugar content and a high buffering capacity. These factors make alfalfa potentially susceptible to a clostridial fermentation, producing butyric acid and amines that will make the silage unpalatable. These problems can be overcome by wilting the crop to at least 30% DM (40% DM in wrapped bale silage) and practicing good ensiling techniques during harvesting and storage that will minimize the loss of sugar. The breakdown of protein to soluble nonprotein nitrogen is another problem in alfalfa silage. This can be slightly reduced by silage inoculants, but currently there are no cost effective means for making major improvements in protein preservation.

TABLE 1. Typical ranges of water soluble carbohydrates and buffering capacities in different forages.

| Crop | Water Soluble Carbohydrate, g/kg DM | Buffering Capacity, mEq/kg DM |
|---|---|---|
| Alfalfa | 20 - 150 | 350 - 650 |
| Grasses | 35 - 300 | 250 - 550 |
| Corn | 80 - 300 | 150 - 300 |

FIGURE 1. Soluble nonprotein nitrogen in legume silages of varying tannin content (Abrecht and Muck, 1991).

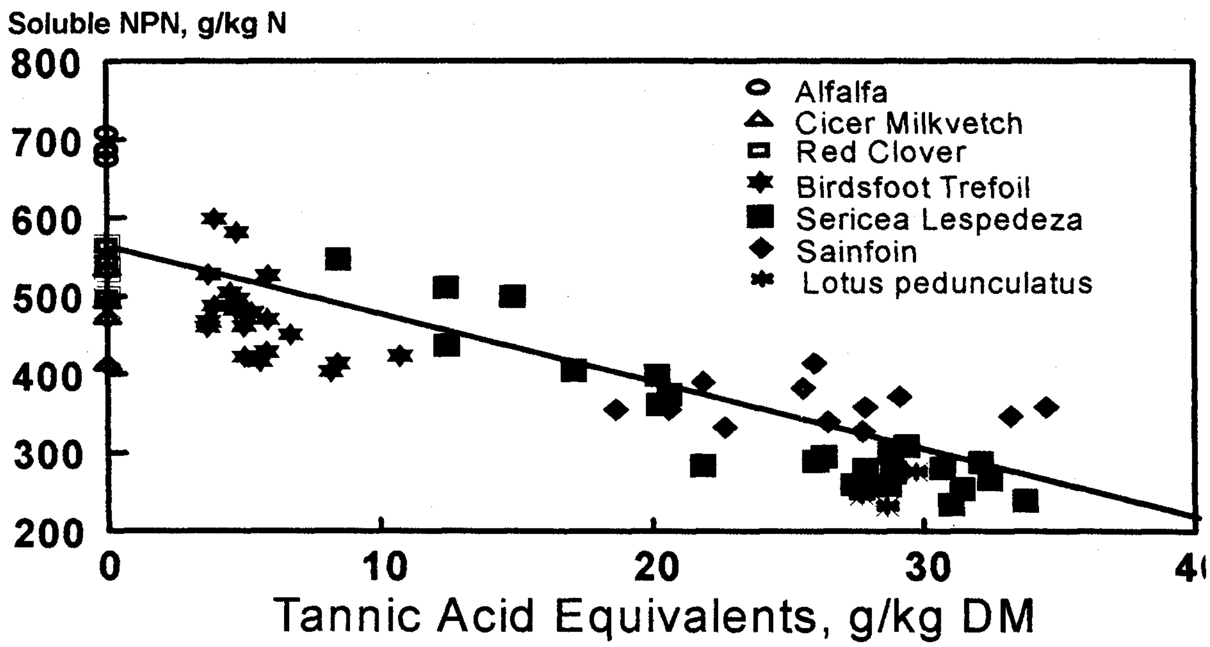



FIGURE 2. Sugar content of alfalfa harvested at different maturities (Smith, 1973).

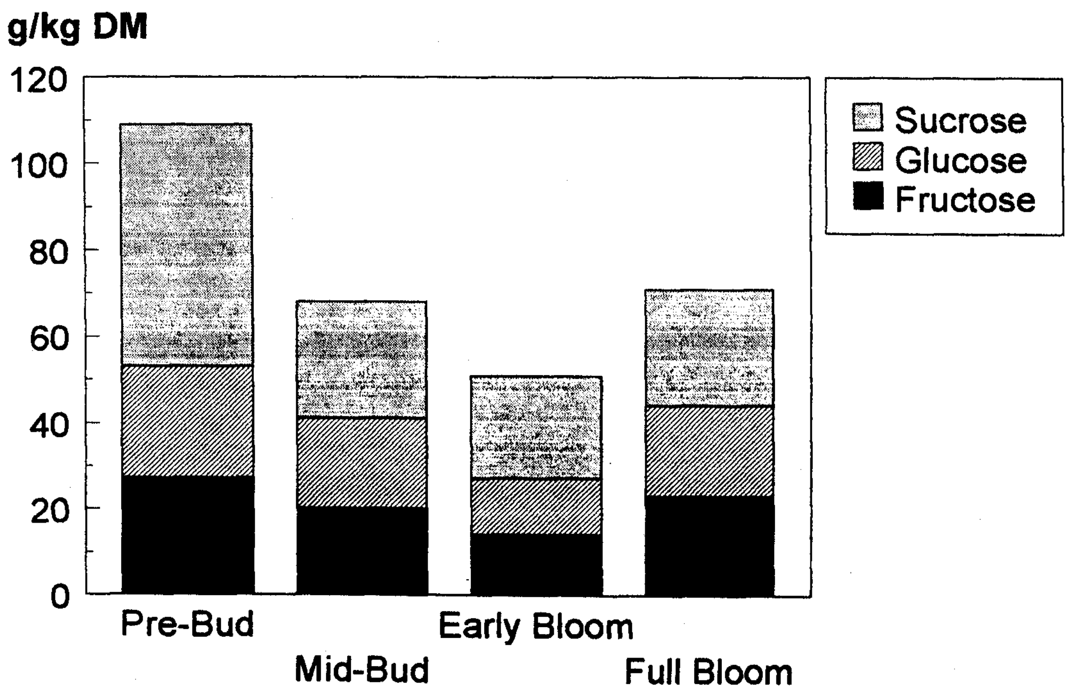


FIGURE 3. Effect of maturity on the buffering capacity of alfalfa (Muck and Walgenbach, 1985).

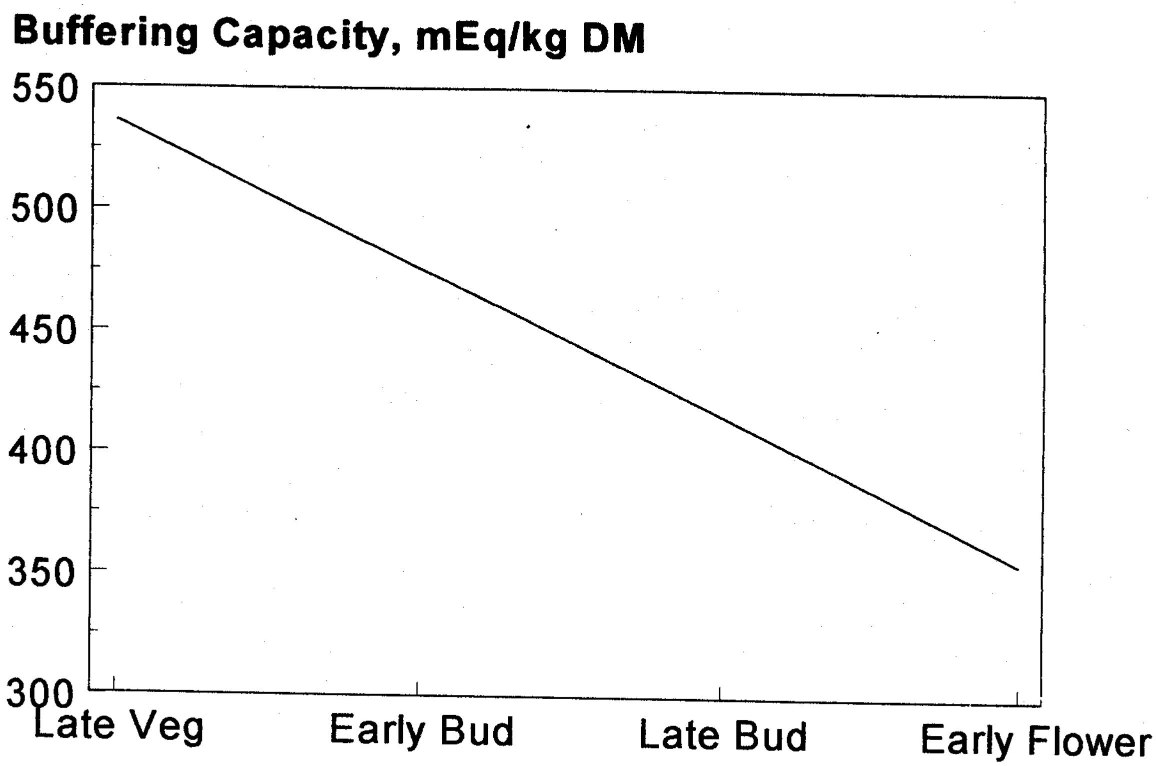


FIGURE 4. Average total nonstructural carbohydrates (sugar plus starch) in alfalfa at mowing and ensiling and the resultant silage pH from three harvests (Owens, 1996).

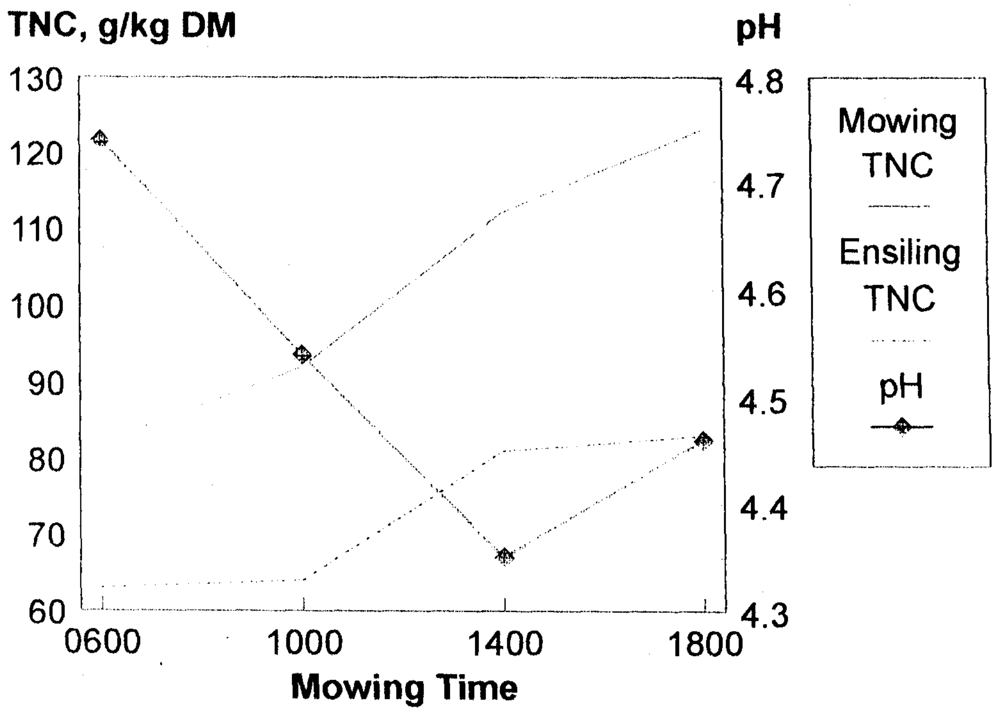
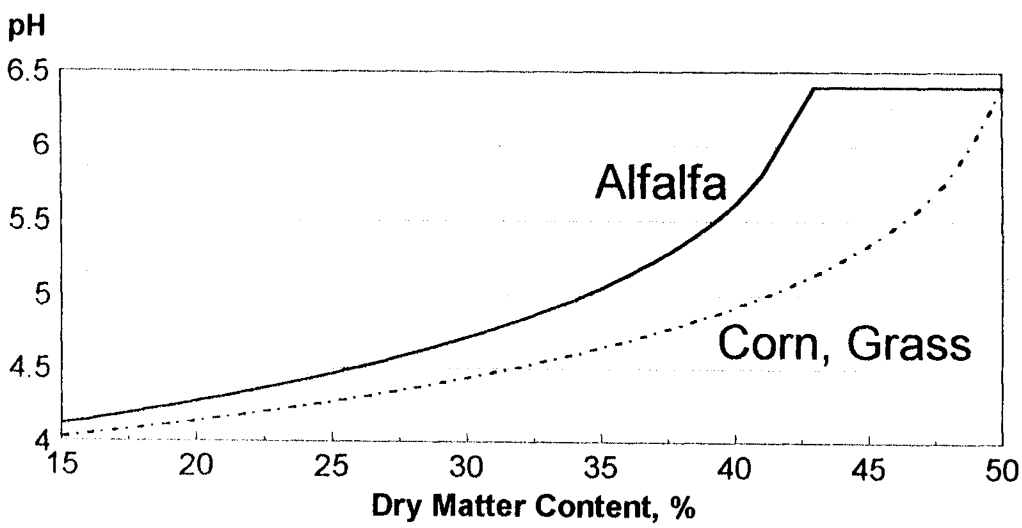



FIGURE 5. The critical pH below which clostridial growth will be inhibited (based on Leibensperger and Pitt, 1987).



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