# How to Maintain Forage Quality during Harvest and Storage

C. Alan Rotz

Pasture Systems and Watershed Management Research Unit, USDA/ARS, Building 3702, Curtin Road, University Park, PA 16802-3702 USA
Email: alrotz@psu.edu

## Take Home Message

- Rapid field curing is important and a good conditioner can help. Spread hay in wide swaths to further speed drying, but avoid very thin swaths to reduce raking loss.
- Bale hay at about 18% moisture in low-density bales, but use a lower moisture content for high-density large bales.
- Use good silo management (rapid filling, good packing and a tight cover) to maintain ensiled forage quality. When using silage bags or bale silage, check for punctures periodically to assure that a tight seal is maintained.
- Remember that on the dairy farm, only about one third of the forage needs to be of the highest quality when that forage is segregated by quality and fed to animal groups accordingly. Provide only the feed that they will eat in one day or less to minimize feeding loss.

## Introduction

High quality forage is recognized as an important requirement for maintaining maximum production of dairy cows. Adequate roughage is needed in diets to provide good rumen function, but as more roughage is fed, the energy density of the diet is reduced. High quality forage allows the animal to consume more forage along with a high-energy intake to maximize production.

The most important forage quality measures are the fiber and energy contents. As the fiber level increases, the energy content generally decreases, so a measure of the neutral detergent fiber (NDF) content can adequately reflect both. Thus, the goal in forage production is to obtain low NDF contents for maximum energy intake with adequate roughage. Although the NDF content may become too low in immature forages, this is normally not a concern. If it does occur, lower quality forages can be blended to compensate. Protein content and the type of protein are also important, but inadequate protein levels normally can be overcome by adding concentrate feeds in rations.

Although high quality forage is important for dairy producers, there is a tendency to overrate its importance. For animals in early lactation, the highest quality forage is needed to maximize their intake. Maximizing intake during this crucial stage will allow cows to peak their production at a high level. Thus, the value of forage quality cannot be over estimated for these animals. For other animals, including cows in the last half of their lactation, early dry cows and yearling heifers, forage quality is less critical. Thus, dairy producers must focus on producing or buying the best forage they can obtain for feeding the critical groups while reserving lower quality forage for other animals. This means that only one-fourth to one-third of the total forage needed on the farm must be of this highest quality. For the dairy producer that keeps this in mind, producing high quality forage will be a less stressful process.

Producing high quality hay and silage is a challenge, particularly in temperate climates. Major processes in conserving forage are mowing, field curing, baling or chopping, storage, and feeding. Dry matter (DM) losses and quality changes occur during each of these processes reducing the quality of the final product. Although some loss is inevitable, good management can reduce or compensate for these losses to provide the quality forage needed for each animal group.

## ▪ Mow at the Right Time

Producing high quality forage begins with mowing. Forage crops should be mown at the right maturity to optimize yield and quality. Quality in most forage crops declines rather rapidly as the crop enters a reproductive stage of development and growth begins to slow. The optimum maturity level varies among forage species, but normally this level occurs in the late vegetative to early reproductive stages. Mowing at this time provides a good yield, a relatively low fiber content, and adequate energy and protein contents.

The challenge in forage production is to obtain this quality level at a time when weather conditions are suitable for wilting or drying the crop. When heavy rain and poor drying conditions are expected, it is normally best to delay. If the forecast is light rain with adequate to good drying conditions to follow, it may be best to proceed with mowing. If your management requires that only a portion of your total forage be at the highest level of quality, this becomes an easier decision.

Another decision is the best time of day to mow. On warm, sunny days when the crop is actively growing, the plant stores readily digestible (non-fiber) carbohydrates in the plant tissue. Thus, a crop mown in late afternoon will have lower fiber and higher energy contents at mowing. This crop lays in the field for an extra night period though, where at least a portion of these carbohydrates are used in plant respiration. With good drying conditions, some of this energy can be preserved through the harvest and storage processes providing higher quality forage. In temperate climates where weather conditions are variable, these carbohydrates are often used in plant respiration or lost due to rain damage during the curing process. For hay making in dry climates, afternoon mowing may be a recommended practice, but for most areas, it is likely best to mow in the morning to obtain a full day of good drying.

There are several mower designs available for cutting forage crops with the primary types being cutterbar and rotary disk mowers. The type of mower used has little effect on mowing losses and the resulting forage quality. Rotary mowers tend to have a higher power requirement and thus require a larger tractor and more fuel to operate. With a higher mowing capacity though, less time is required offsetting some of the increased fuel use and reducing the labor required. Even though the purchase price of rotary mowers is a little higher for a given width of cut, the overall cost of mowing is similar between these major mower types.

## ■ Dry or Wilt the Crop Rapidly

The need for rapid wilting or drying of forage crops in the field is well recognized, but accomplishing this task remains a challenge. Many factors affect the field-drying rate of forage (Rotz, 1995). Drying is restricted by the structure of the plant, swath structure, and soil and weather conditions. The most restricting factor varies throughout the drying process and with crop management. When a high yield crop is laid in a narrow swath, the swath tends to be most limiting because the moisture cannot readily move out of the swath. When forage is spread in a thin swath, the movement of moisture out of the plant can become limiting. Under these circumstances, conditioning of the crop can be most beneficial to allow moisture to leave the plant more easily.

In temperate climates, weather is often the most restrictive factor in drying. Of all weather influences, solar radiation level is the most important (Rotz, 1995). This energy from the sun is required to evaporate and move moisture out of the plant. The drying of hay requires the removal of about three tonnes of moisture for every tonne of hay produced. This requires 7 billion joules of energy, which is the equivalent of 270 liters of fuel oil. In haymaking, we are fortunate that free energy from the sun can be used to carry out this process. Be skeptical when you hear of new, miraculous and inexpensive processes that can dry hay without the sun. Warm air temperature and low humidity also aids drying, but the sun is the primary driving force. Wet soil under the swath also slows drying by allowing moisture to move up into the swath.

Dry matter losses and quality changes occur while the crop is wilting or drying in the field. These include plant respiration, rain, and machine induced losses. Plant respiration is a natural process that continues after the plant is cut. Respiration converts carbohydrates stored in the plant tissue to carbon dioxide, heat, and moisture that leave the plant causing a loss. Plant respiration ceases when the crop dries to a moisture level below 40%, so rapid drying early in the field curing process can reduce this loss (Rotz and Muck, 1994). Since this loss is primarily readily digestible carbohydrates, the loss increases the fiber content and reduces the energy content of the forage (Table 1).

Rain damage, when it occurs, can have the greatest effect on loss and quality (Table 1). Rain causes loss by knocking off leaves and leaching soluble nutrients from within the plant tissue. Since leaves are normally higher in nutrient concentrations than stem parts, the loss of leaves reduces overall quality. The greater loss though is the less visible loss from leaching. Soluble carbohydrates, proteins, and minerals are washed from the plant material leaving a higher fiber concentration and lower energy concentration. Generally the greater the amount of rain and the drier the crop when rain occurs, the greater the loss of DM and nutrients.

## Condition to Speed Drying

Mechanical conditioning treatments are often used to speed drying; these can be categorized as either roll or flail conditioners. Rolls smash and/or break the plant stems, and flails abrade the waxy surface of the plant and break stems. Both processes can improve drying, but for alfalfa, roll devices are more effective with less field loss (Rotz, 1995). Some roll designs are promoted for faster drying, but field and laboratory studies consistently show little or no difference in the drying of alfalfa or grass treated with commonly used crushing roll designs. Roll conditioning is most effective on a thick stemmed crop such as an early cutting of alfalfa. Flail type conditioners are better suited to grass crops, and they provide a greater throughput capacity when harvesting high yielding or entangled crops.

Dry matter losses and the associated nutrient changes caused or promoted by conditioning increase with crop maturity and the severity of conditioning. Although more severe conditioning provides faster field curing, harvest losses are generally greater. Normally less severe conditioning is recommended to obtain adequate drying with relatively low loss (1-2% of yield). This low loss has little effect on forage quality.

Considerable research and development has been devoted to “intensive conditioning”. Many machine designs have been evaluated, which shred the plant material to allow more rapid field curing (Savoie, 2001). Drying rate is increased by 25 to 150% with the fastest drying in thin wide swaths under good drying weather. Power requirement is at least twice that of a mower-conditioner, and field losses can be very high. To reduce losses, various methods have been used to press the shredded material into a mat. When rain occurs, losses can still be up to four times greater than that when traditional conditioning is used. Due to a complex and expensive machine design, commercial application of intensive conditioning has not occurred.

A chemical treatment, referred to as a conditioner or drying agent, can be sprayed on the crop at mowing to help speed drying (Rotz, 1995). The chemical affects the waxy surface of the plant to allow easier moisture removal. The most effective treatment is a potassium and sodium carbonate based solution. This treatment has only been effective on alfalfa, and it is most effective on cuttings harvested in the summer months. This treatment can double the drying rate of the crop when used under good drying weather with the crop dried in a relatively thin swath. On the average, this increase reduces field-curing time about half a day. Faster drying reduces respiration loss and occasionally avoids rain damage. The major deterrent to this process has been the need to handle large quantities of the liquid treatment.

## Swath Manipulation to Speed Drying

As forage dries in the field, the top of the swath dries more rapidly than the bottom. Manipulation of the swath can speed the drying process by moving the wetter material to the upper surface (Rotz, 1995). Swath manipulation can also improve drying by spreading the hay over more of the field surface, increasing exposure to the radiant solar energy and drying air. There are three operations used in haymaking to manipulate the swath: tedding, swath inversion, and raking. These treatments can help speed drying, but each machine pass creates additional loss by dislodging leaves and other plant material.

Tedding can be used anytime during field curing, but it is best to do so before the crop is too dry (above 40% moisture content). The stirring or fluffing of forage typically reduces field-curing time up to half a day. Tedders are sometimes used to spread a narrow swath formed by the mower-conditioner over the entire field surface. When done soon after mowing, the average field curing time can be reduced up to 2 days compared to drying in a narrow swath. In addition to speeding drying, tedding may allow more uniform drying, so wet spots in the swath are reduced.

Disadvantages of tedding include increased losses and increased fuel, labor, and machinery costs. When tedding is done on a relatively wet crop (above 50% moisture), the resulting loss is less than 3%; however, applied late in the drying process, the loss can be more than 10%. Tedding will also increase raking loss. When a light crop (less than 3.5 t/ha) is spread over the field surface, raking loss can be more than double that when raking narrow swaths. Spreading the hay may promote bleaching of hay color. Bleaching does not necessarily affect the nutritive value of hay, but it often affects the market value.

Swath inversion machines have been used that gently lift and invert the swath. Exposing the wetter bottom of the swath speeds drying, reducing the average field-curing time a few hours. Swath inversion is not as effective for improving drying as tedding, but shatter loss is very low. With less drying benefit, there is less potential for reducing rain and respiration losses. The added labor, fuel, and machinery costs of the operation are generally greater than the benefit received.

Raking is another form of swath manipulation. Raking tends to roll the wetter hay from the bottom of the swath to the outer surface of the windrow, which improves drying. Following the initial improvement, the increase in swath density can reduce drying rate, so the crop moisture content at raking is important. Raking also causes loss, and this loss is related to crop moisture (2% when wet to 15% in very dry crop). The best moisture content to rake hay for low loss and good drying is between 30 and 40%. In dry climates, hay can be raked at night or early morning when leaves are moist and less prone to shatter. Raking at the proper time can reduce field-curing time a few hours to allow an earlier start at baling.

In haymaking, the best recommendation is to dry hay rapidly. Mechanical conditioning should be used, and high yielding crops should be spread in wide swaths. Tedding may be useful in drying grass crops, but it should be avoided with alfalfa, particularly after the crop has partially dried. In silage making, drying is a little less critical. Wilting in narrow swaths can reduce raking loss, particularly for low yielding harvests. Mechanical conditioning should be used, but it will not be as effective under these conditions. Raking can be used to improve harvest capacity. A substantial economic benefit can often be obtained by rolling swaths together to allow large balers or forage harvesters to operate more efficiently.

## Bale or Chop at the Appropriate Moisture Content

Balers are available that produce bales of a wide variety of shapes and sizes. The traditional small rectangular bale is a viable option, but handling bales of this size tends to require considerable manual labor. Large, high-density bales are becoming more popular, particularly for hay transported long distances. Balers producing these large packages also offer greater baling capacity, harvesting up to twice the hay per hour as the small package balers. A popular option on livestock farms is the large round bale system.

Typical DM losses during hay baling vary between 2 and 6% of the yield (Table 1) with the loss equally divided between pickup and chamber losses. Chamber loss is influenced by baler design and crop moisture content. These losses are about 1 to 3% in small rectangular balers and 0.5 to 2% in large rectangular balers. For large round balers, losses vary among baler designs. With a variable chamber design, chamber loss is similar to a small rectangular baler, but the loss can be three times as much with a fixed chamber baler. Chamber loss is mostly high quality leaf material, so chamber loss has more affect on the quality of the remaining forage than most other machine losses. By maintaining the chamber loss below 3%, the effect on forage quality is relatively small (Table 1).

**Table 1. Typical DM losses and quality changes during forage harvest and storage (Rotz and Muck, 1994).**

| Type of forage, Type of loss | Dry matter loss (% DM) | | Change in nutrient concentration (% DM) | | |
|---|---|---|---|---|---|
| | Range | Normal | CP | NDF | TDN |
| *Legume crops* | | | | | |
| Respiration[a] | 1 - 7 | 4 | .9 | 1.7 | -1.7 |
| Rain damage[a], 5 mm | 3 - 7 | 5 | - .4 | 1.4 | -1.5 |
| 25 mm | 7 - 27 | 17 | -1.7 | 6.0 | -7.0 |
| 50 mm | 12 - 50 | 30 | -3.5 | 14.0 | -14.0 |
| Mowing/conditioning | 1 - 4 | 2 | - .7 | 1.2 | -1.4 |
| Tedding | 2 - 8 | 3 | - .5 | .9 | -1.2 |
| Swath inversion | 1 - 3 | 1 | 0 | 0 | 0 |
| Raking | 1 - 20 | 5 | - .5 | 1.0 | -1.2 |
| Baling, small bale | 2 - 6 | 4 | - .9 | 1.5 | -2.0 |
| round bale | 3 - 9 | 6 | -1.7 | 3.0 | -4.0 |
| Chopping | 1 - 8 | 3 | 0 | 0 | 0 |
| Hay storage, inside | 3 - 9 | 5 | - .7 | 2.0 | -2.0 |
| outside | 6 - 30 | 15 | 0 | 5.0 | -7.0 |
| Silo storage, sealed | 6 - 14 | 8 | 1.4 | .7 | -3.7 |
| stave | 7 - 17 | 10 | 1.8 | 1.7 | -4.7 |
| bunker | 10 - 16 | 12 | 2.3 | 2.7 | -5.6 |
| *Grass crops* | | | | | |
| Respiration[a] | 2 - 8 | 5 | .8 | 3.2 | -1.8 |
| Rain damage[a], 5 mm | 1 - 3 | 2 | - .2 | .9 | - .5 |
| 25 mm | 4 - 14 | 8 | -1.3 | 5.3 | -3.0 |
| 50 mm | 8 - 27 | 15 | -2.7 | 11.0 | -6.0 |
| Mowing/conditioning | 1 - 2 | 1 | 0 | 0 | 0 |
| Tedding | 1 - 3 | 1 | - .2 | .4 | - .4 |
| Swath inversion | 1 - 3 | 1 | 0 | 0 | 0 |
| Raking | 1 - 20 | 5 | - .3 | .5 | - .6 |
| Baling, small bale | 2 - 6 | 4 | - .5 | .9 | -1.0 |
| round bale | 3 - 9 | 6 | -1.0 | 1.8 | -2.0 |
| Chopping | 1 - 8 | 3 | 0 | 0 | 0 |
| Hay storage, inside | 3 - 9 | 5 | -1.3 | 3.2 | -1.8 |
| outside | 5 - 22 | 12 | 0 | 8.0 | -4.8 |
| Silo storage, sealed | 6 - 14 | 8 | .8 | .9 | -3.7 |
| stave | 7 - 17 | 10 | 1.2 | 2.2 | -4.7 |
| bunker | 10 - 16 | 12 | 1.5 | 3.6 | -5.6 |

[a] Respiration loss includes plant and microbial respiration for crop cured without rain damage. Rain damage includes leaf loss, nutrient leaching, and respiration resulting from rewetting.

Baling at the appropriate moisture content is important for minimizing harvest loss and maintaining quality following harvest. For low-density (small rectangular and most large round) bales, the recommended baling moisture content is about 18%. For high-density bales (large rectangular), drier hay in the range of 12 to 14% is recommended to improve preservation. Losses increase when hay is baled at lower moisture contents. In dry climates, baling at night when leaf moisture is higher relative to stems can cut harvest losses in half.

Losses in forage chopping vary from 1 to 8% with similar amounts lost from the pickup and by drift. Drift loss occurs as the chopped material exits the spout of the harvester and travels toward the trailing wagon or truck. Drift loss is influenced by crop moisture content, wind conditions, machine adjustment, and operator skill. The quality of the lost material is similar to that harvested, so the loss has little effect on the quality of the remaining forage. By chopping forage at a moisture content of 60% or more, harvest losses are kept low.

## ▪ Store Forage Using Most Appropriate Procedures

### Hay Storage

Respiration of microorganisms (bacteria, fungi, and yeasts) on hay causes heating and further DM and nutrient loss during storage. Similar loss occurs in all sizes and types of bales stored in a shed (Rotz and Muck, 1994). Greater heating occurs as hay density increases, particularly in large bales. Dry matter loss during the first month of storage varies from 1 to 8% increasing with hay moisture content. For hay with more than 25% moisture, excessive loss and even spontaneous combustion can occur. Although most loss occurs in the first month, a small loss of about 0.5% DM per month continues in hay stored in a shed. Unprotected hay stored outside experiences this same loss plus an additional loss from weathering on the exposed bale surface (outer 10 to 20 cm). Loss in large round bales stored outside varies widely, ranging from 3 to 40%. This loss is primarily affected by weather, length of storage, and storage method.

Dry matter loss and heating of hay affect the concentration of most nutrients. Much of the lost DM is nonstructural carbohydrate respired to carbon dioxide and water. Some crude protein is also lost. The lost protein is the more soluble nitrogen components, which causes small increases in the water insoluble nitrogen and acid detergent insoluble nitrogen (ADIN) concentrations. In addition, the heating in high-moisture hay causes the formation of further ADIN (unavailable protein) through Maillard reactions. Fiber concentrations increase during storage due to the loss of non-fiber constituents. Because the loss is primarily highly digestible nutrients, the digestibility of forage DM decreases during storage (Table 1).

The best way to preserve hay quality is to bale the hay at the appropriate moisture content and store it in a shed. Shed storage may not always be the most economical approach though. When dry hay makes up a relatively small portion of animal diets, hay quality is not that important and outside storage can be a viable option.

## Hay Preservation Treatments

In haymaking, field losses can be reduced by baling at a moisture content between 20 and 25%. Baling moist hay may reduce raking and baling losses providing an increase in harvested yield (up to 7%) and harvested quality. Moist hay deteriorates rapidly in storage however, offsetting the benefit of reduced field loss unless the hay is treated to enhance preservation. Additives used for the preservation of high-moisture hay include propionic acid, organic acid mixtures, buffered acid mixtures, anhydrous ammonia, and microbial inoculants.

Propionic acid (or an effective organic acid mixture) when applied at rates of 1 to 2% of hay weight, normally reduces mold growth and heating. To reduce corrosion of equipment, buffered acid products have largely replaced the straight acids. Acid treatment reduces storage loss during the first few months of storage, but the loss remains higher than that in dry hay. Acid-treated hay remains more moist throughout storage, which maintains a little higher level of microbial activity. Over a 6-month storage period, the loss in acid-treated hay catches up, providing little difference in DM and nutrient losses between treated and untreated high-moisture hays. When compared to dry hay, acid-treated damp hay is often higher in fiber content and less green in color.

Anhydrous ammonia is perhaps the most effective hay preservative. Mold development, heating and DM loss are reduced or eliminated in hay of up to 35% moisture when wrapped in plastic and treated with ammonia. Although anhydrous ammonia is very effective, animal and human safety concerns deter its use. Ammonia treatment of forage has caused toxicity to animals when applied at high application rates (greater than 3% of hay weight) on alfalfa hay. Direct exposure to anhydrous ammonia can cause severe burns, blindness, and death.

Bacterial inoculants are sometimes applied to hay. Inoculation with a few strains of *Lactobacillus* have shown little effect on mold, color, heating, DM loss, and quality change in high-moisture hay. Products containing *Bacillus* bacteria are better suited to the aerobic hay environment, but there is still little scientific evidence that they can provide substantial improvement in preserving moist hay.

Based upon the scientific information available on chemical and biological treatments, my recommendation is to bale dry hay whenever possible. When moist hay is baled, organic acid treatments can provide a relatively safe method for insuring against excessive heating and browning of hay.

An alternative to preservation treatments is the use of a low-cost drying system during storage. Hay is stacked on pallets with a plenum under the center of the stack. A fan forces ambient air through the stack during the first month of storage. The air movement dries the hay, prevents heating and mold development, and allows loss similar to dry hay. The economic value of this low-cost drying system is better than that of chemical preservatives as long as additional labor for hay handling is not required.

## Silage Storage

Wet forage is best preserved by ensiling in an anaerobic environment. Creating an environment without oxygen is essential for stopping plant respiration, preventing aerobic microbial growth, and stimulating the growth of lactic acid bacteria. The lactic acid bacteria ferment sugars producing lactic and acetic acids, which lower silage pH. A low pH inhibits plant enzyme activity and prevents the growth of undesirable anaerobic microorganisms.

During silo filling, the dominant process affecting forage quality is plant respiration. This respiration causes a small DM loss, and it may increase silage temperature, which influences the rates of many other ensiling processes. Once the silo is filled, remaining oxygen is rapidly transformed allowing anaerobic fermentation to decrease silage pH. After anaerobic microbial activity has ceased due to low pH or lack of substrate, the stable phase begins. Even if silos are well sealed, slow diffusion of air occurs through the silo walls or cover. This oxygen again is used in respiration contributing to further loss. When the silo is opened, much more oxygen is present at the open face, and this oxygen penetrates into the silage mass. With greater oxygen availability, aerobic microbial growth and respiration increase substantially, causing heating as well as DM and nutrient loss. Silage with high moisture can create effluent. Effluent contains many soluble compounds (sugars, fermentation products, soluble protein, NPN, ash, and minerals) which cause further DM and nutrient loss. Total silo losses range from 6% in sealed structures to over 15% in bunkers (Table 1).

Digestible carbohydrates are largely lost through respiration, increasing the concentration of other forage components. For example, little loss of nitrogen (CP) occurs in the silo unless there is effluent loss and/or nitrate in the incoming crop. Consequently, a 1 to 2% of DM increase in CP should occur, but this is dependent upon the CP of the crop entering the silo and the DM lost during silo storage. Changes in NDF content are also dependent upon the amount of enzymatic and acid hydrolysis of structural carbohydrates during storage. The change in NDF levels during silo storage may range from a 1% DM decline to a 4% DM increase, dependent on the respiration loss relative to the amount of cell wall hydrolysis. Carbohydrates lost are highly digestible, so DM digestibility or total digestible nutrient (TDN) concentration declines by 2 to 7% DM.

Good silo management can reduce loss and maintain quality. Recommendations include rapid filling, good packing (for bunker silos), and rapid and complete covering as soon as filling is complete. With the high capacity harvest systems used today, bunkers are often filled with inadequate packing. Covering bunker silos can return up to $8 through reduced loss and improved quality for every dollar spent on plastic and labor used in covering the silo. Silage bags and bale silage can also maintain high quality forage when a tight seal is maintained throughout the storage period. Small leaks such as that caused by bird and rodent damage can lead to large amounts of spoilage and excessive loss.

## Silage Treatments

Additives used in silage making include bacterial inoculants, enzymes, acids, anhydrous ammonia and urea. The most common additives are bacterial inoculants, which augment the natural lactic acid producing bacteria on the crop. When the added bacteria dominate fermentation, the resulting silage has less acetic acid and ethanol, more lactic acid, and a lower pH than expected from the unaided natural fermentation (Muck, 1996). This shift in fermentation often reduces DM loss by 1 to 3%. An additional benefit is a small reduction in proteolysis and the resulting breakdown of true protein to NPN. These changes should have a relatively minor effect on animal performance, but average improvements of 2 to 4% are reported. An inoculant is most beneficial when the natural lactic acid bacterial population is low, which is more likely under cool drying conditions, rapid drying, and low rainfall.

Cell-wall degrading enzyme additives are used to reduce the fiber content of silage and provide extra sugar for fermentation. These additives, often combined with bacterial inoculants, are more effective on grass silage than alfalfa. Typical reductions in fiber content range from 1 to 5% DM. Fiber broken down by the enzymes is that readily broken down in the rumen of the animal. Thus, fiber digestibility is reduced giving a net result of little impact on animal performance.

Acids such as formic acid have long been used to obtain a more rapid drop in silage pH. This treatment has been used primarily on non-wilted silage to prevent clostridial fermentation. A rapid drop in pH also reduces proteolysis improving the nitrogen use efficiency of animals. Corrosion of equipment and health and safety issues deter the use of acid treatments.

Both ammonia and urea are common additives to corn silage. These additives boost the CP content and make silages more stable by killing aerobic microorganisms. These additives increase crop pH at ensiling and thereby cause more fermentation and fermentation products, particularly acetic acid. Both compounds, but especially ammonia, improve DM and fiber digestibilities and reduce proteolysis. In spite of these benefits, animal performance is normally not improved. In addition, DM loss is often increased, presumably due to increased fermentation losses by either lactic acid bacteria or clostridia.

## ■ Feed What They Need

After you have done a good job of preserving forage nutrients through harvest and storage, good feeding procedures must be followed to avoid further loss. This is especially true for dry hay. Normally the most effective way to feed hay is to grind and mix it in a total mixed ration. This however has a substantial added cost in labor, fuel, and equipment. The added costs must be weighed against the benefits, but this procedure is effective in reducing sorting, rejection, and loss of hay. When hay provides a relatively small portion of the total ration, this procedure can be used to feed hay of moderate quality without detrimental effect on the animals, even high producing lactating cows.

When hay is fed alone, avoid free access to large amounts of hay. Feeders should be used to limit trampling and excessive loss. As a general rule, feeding loss of hay is similar to the loss that occurs in storage prior to feeding. Thus, if good storage procedures are used with about a 5% loss, the rejection and loss during feeding will be 5% or less. If hay is stored outside with a storage loss of 15% or more, the animals will reject about that much more during feeding. Thus, doing a good job in storing hay can provide a double benefit.

Most often, silage is fed in a total mixed ration with relatively low loss. A consideration though is to remove silage from the silo (particularly a bunker) in a manner that minimizes the exposed surface. In addition, feeding should be done no less often then once per day to minimize respiration loss and deterioration in the feed bunk. Avoid providing too much feed, but a little extra is normally recommended to assure maximum intake.

## ■ References

Muck, R.E. 1996. Inoculation of silage and its effects on silage quality. Proc. Informational Conference with Dairy and Forage Industries. US Dairy Forage Research Center, Madison WI. pp. 43-51. http://www.dfrc.ars.usda.gov.

Rotz, C.A. and R.E. Muck. 1994. Changes in Forage Quality during Harvest and Storage. *In:* Forage Quality, Evaluation, and Utilization, Eds. G.C. Fahey, Jr. et al. Am. Soc. Agron., Madison, WI. pp. 828-868.

Rotz, C.A. 1995. Field Curing of Forages. *In:* Post-Harvest Physiology and Preservation of Forages. CSSA Special Publication no. 22. Crop Sci. Soc. Agron. and Am. Soc. Agron., Madison, WI. pp. 39-65.

Savoie, P. 2001. Intensive mechanical conditioning of forages: a review. Canadian Biosystems Engineering 43:2.1-2.12.