POSTHARVEST CHANGES IN ALFALFA QUALITY

C. Alan Rotz[1]

ABSTRACT

Alfalfa losses and quality changes begin as soon as the mower contacts the standing crop and these losses continue until the preserved feed is consumed. Harvest losses are caused by plant respiration, rain, and mechanical damage by equipment. Loss from plant respiration is relatively small when the crop is dried quickly under good drying conditions, but under slow drying conditions it can be up to 7% of the crop dry matter (DM). When rain damage occurs, the resulting losses can be as much as 30% of the crop dry matter, and of course, at times the whole crop is lost. Mechanical losses increase as more machinery operations are used. For example, a raking operation can reduce the crop yield 5% with some of this loss being the more nutritious leaves. All of these losses, but especially respiration and rain damage, reduce the concentrations of digestible nutrients and increase the fiber content in the remaining forage. Losses and quality changes are small when dry hay is stored in a shed, but when stored outside, DM losses can be 15% or more. Lost DM is protein and other highly digestible nutrients. Silage DM losses generally range from 5 to 15% depending on the type of silo used and other management practices. This loss again comes from the most nutritious portions of the forage, and much of the crop protein is converted to non protein nitrogen, which has less value to the animal. These quality changes can reduce the intake and production of animals consuming the forage.

Key words: Alfalfa, forage quality, losses, harvest, storage, hay, silage

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.

Important forage quality measures are 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 along with adequate roughage. Although the NDF content may become too low in immature forage, this is normally not a concern. If it occurs, 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 using concentrate feeds in rations.

---

[1] C. Alan Rotz, Agricultural Engineer, USDA / Agricultural Research Service, Building 3702, Curtin Road, University Park, PA 16802-3702; Email: al.rotz@ars.usda.gov. **In**: Proceedings, California Alfalfa and Forage Symposium, 12-14 December, 2005, Visalia, CA, UC Cooperative Extension, Agronomy Research and Extension Center, Plant Sciences Department, University of California, Davis 95616. (See http://alfalfa.ucdavis.edu for this and other proceedings.)

Although high quality forage is important for dairy producers, there is a tendency to overrate its importance from a whole-farm perspective. For animals in early lactation, the highest quality forage is needed to maximize their intake. Maximizing forage and energy intakes during this crucial stage allows cows to peak at a high production level, which will tend to set them on a higher course for the rest of their lactation cycle. Thus, the value of forage quality cannot be overestimated 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 should focus on producing or buying the best forage they can obtain for feeding the critical groups while reserving lower quality forage for other animals. If this strategy is followed, less than half 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. Each of the major processes in hay and silage making will be discussed including their effect on forage quality and possible management options for reducing these losses.

HARVEST PROCESSES

Mowing. Producing high quality forage begins when the crop is mown. 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 for alfalfa harvest 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. To preserve this yield and quality, the crop must be dried rapidly with as few machine operations as possible.

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 drying, loss, 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 higher for a given width of cut, the total cost of mowing is similar between these major mower types.

Field Curing. The need for rapid field wilting or drying of forage crops is well recognized, but accomplishing this task remains a challenge. Many factors affect the field drying rate (Rotz, 1995). Drying is restricted by plant structure, 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 is most beneficial by allowing 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

Table 1. Typical DM losses and quality changes during the major processes used in alfalfa harvest and storage (Rotz and Muck, 1994).

Type of forage, Type of loss	Dry matter loss (% DM) Range	Average	Change in nutrient concentration (% DM) CP	NDF	DDM[a]
Respiration[b]	1 - 7	4	.9	1.7	-1.7
Rain damage[b], 0.2 inch	3 - 7	5	- .4	1.4	-1.5
1 inch	7 - 27	17	-1.7	6.0	-7.0
2 inch	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
large rectangular bale	1 - 4	3	- .7	1.0	-1.5
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

[a] Decrease in digestible dry matter or total digestible nutrients (TDN). This also reflects the loss of energy available to the animal.
[b] Respiration loss includes plant and microbial respiration for crops cured without rain damage. Rain damage includes leaf loss, nutrient leaching, and respiration resulting from rewetting.

of about three tons of moisture for every ton of hay produced. This requires 7 million BTUs of energy, which is the equivalent of 70 gallons 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 temperatures and low humidities also aid 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. Since this loss is primarily readily digestible carbohydrates, the loss increases protein and fiber contents and reduces the digestibility and energy content of the forage (Table 1).

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

Conditioning. Common conditioning treatments used to speed alfalfa drying include roll and impeller devices. Rolls smash and/or break the plant stems, and impellers 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. Impeller conditioners are better suited to grass crops, and they provide a greater throughput capacity when harvesting high yielding or entangled crops. Different impeller designs have been found to provide similar improvements in drying.

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 drying, 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 a relatively small effect on forage quality. With the loss of leaves and less mature portions of the stem, small decreases in crude protein content and forage digestibility can be expected with an increase in fiber content (Table 1).

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). Field drying rates are increased by 25 to 150% with the fastest drying in thin wide swaths under good drying weather. The 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 been slow.

A chemical treatment, referred to as a conditioner or drying agent, can be sprayed on alfalfa during 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 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 reduces field-curing time about half a day. Faster drying reduces respiration loss and occasionally avoids rain damage. Over the long run, the value of the nutrients saved has been shown to return the cost of the treatment. The major deterrent to using this process has been the need to handle large quantities of the liquid treatment.

Swath Manipulation. 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 two 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%, and the reduction in quality is relatively low (Table 1). If applied late in the drying process, the loss can be more than 10%, and this loss of leaves can greatly reduce alfalfa quality. Tedding will also increase raking loss. When a light crop (less than 1 ton DM/acre) 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, which may reduce the average field-curing time by a few hours. Swath inversion is not as effective for improving drying as tedding, but shatter loss is very low and thus forage quality is not affected (Table 1). 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 this initial improvement, the increase in swath density can reduce drying rate, so the crop moisture content at raking is important. Raking at the proper time can reduce field-curing time a few hours to allow an earlier start at baling or chopping.

Raking also causes loss, and this loss is related to crop moisture (about 2% when wet to over 15% in very dry crop). The best moisture content to rake hay for low loss and good drying is between 30 and 40%. When the crop is spread over much of the field surface, it is more difficult to gather and loss increases. Wheel and parallel-bar rake designs provide similar losses. With the sweeping action of a rotary rake though, more forage particles may lodge in the stubble causing greater loss. Raking loss normally consists of similar amounts of leaf and stem material, so the effect on forage quality should be relatively small (Table 1). Leaf loss and the resulting effect on quality may be high though when alfalfa is raked at less than 30% moisture. In dry climates, hay can be raked at night or in the early morning when leaves are moist and less prone to shatter.

An alternative to raking is the use of a merger. Windrow mergers typically use a pick-up and belt cross-conveyor to move the crop without sweeping it along the ground. With this movement, the crop is less susceptible to loss and rocks are less likely to be carried into the windrow. Although alfalfa losses and quality changes have not been measured when merging windrows, they should be minimal and similar to those documented for swath inversion (Table 1).

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 should be avoided with alfalfa, particularly after the crop has partially dried. In silage making, drying is a little less critical, and wilting in narrow swaths can reduce raking loss. Mechanical conditioning should still be used, but it will not be as effective under these conditions. Raking or merging may be used to improve harvest capacity. A substantial economic benefit can be obtained by rolling swaths together to allow large balers or forage harvesters to operate more efficiently at their full capacity.

Baling and Chopping. 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 compared to the small package balers. The most popular option on eastern livestock farms is the large round bale system.

Typical DM losses during hay baling vary between 2 and 6% of the yield with this 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, loss with a variable chamber design is similar to that of a small rectangular baler, but this loss can be three times as much with a fixed chamber design. 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 acceptable (Table 1).

Baling at the appropriate moisture content is important for minimizing harvest loss and maintaining quality following harvest. For low-density bales (small rectangular and most large round), the recommended baling moisture content is 16 to 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 drier 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 this loss has little effect on the quality of the remaining forage (Table 1). By chopping forage at a moisture content of 60% or more, harvest losses are kept low.

STORAGE PROCESSES

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 4 to 8 inches). Loss in large round bales stored outside varies widely, ranging from 3 to 30%. 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 (very digestible cell contents). Because the loss is primarily highly digestible nutrients, the digestible forage DM and energy contents decrease 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 before the hay is fully dried. Baling moist hay reduces 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 treatments reduce the heating and drying that normally occurs during the first month of storage. This reduces the initial loss, but this loss remains higher than that in dry hay. Acid-treated hay remains more moist throughout storage, which apparently 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.

Microbial inoculants are sometimes used to preserve moist hay. Inoculation with a few forms of *Lactobacillus* in combination with other bacteria and enzymes has shown no effect on mold, color, heating, DM loss, or nutritive change in high-moisture hay. Applications of *Pediococcus pentosaceus* and bacillus-based products have improved the visual appraisal of moist hay following storage with minor and inconsistent effects on heating, forage nutritive value, and animal performance compared with untreated hay at similar moisture contents. To obtain a response from this treatment, the added bacterial population apparently must be much greater than the natural occurring bacterial populations. This implies that a poor response can be expected when the crop is field-cured under poor drying conditions where natural populations will be high.

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, loss, and degradation of hay quality.

An alternative to preservation treatments is the use of a low-cost drying system during storage. This approach has been used for many years in some regions of the eastern US. 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 and quality changes similar to that in hay baled dry. 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 and microbial 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 oxygen occurs through the silo walls or cover. This oxygen again is used in microbial 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. High-moisture silage can create effluent. Effluent contains many soluble compounds (sugars, fermentation products, soluble protein, non protein nitrogen, 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 or crude protein occurs in the silo unless there is effluent loss or nitrate in the incoming crop. Consequently, a 1 to 2% of DM increase in crude protein content should occur, but this is dependent upon 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 that occurs during storage. The change in NDF levels during silo storage may range from a 1% DM decline to a 4% DM increase, dependent upon the respiration loss relative to the amount of cell wall hydrolysis. Carbohydrates lost are highly digestible, so DM digestibility declines by 2 to 7%.

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 DM and quality 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 non protein nitrogen. 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, or 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% of 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 crude protein 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.

FEEDING

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 the resulting 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 if they are 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, when animals are given free access to hay, feeding loss is similar to the loss that occurred during the storage period 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. Feeding loss can actually improve the quality of the hay consumed though, since it is normally low quality stem material that is sorted and rejected by cattle.

Silage is normally fed in a total mixed ration where loss is relatively low, usually less than 3% of the DM fed. 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. As ensiled feeds are again exposed to oxygen during the feeding process, respiration of microorganisms on the feed convert DM to heat and gaseous emissions that leave the feed causing loss of highly digestible DM (primarily carbohydrates) reducing energy and increasing fiber contents. Rapid and efficient feeding helps minimize this loss of quality. Loss due to sorting and rejection of mixed feeds may provide a small increase in the quality of the feed consumed since that rejected is normally lower quality forage particles.

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.