MINIMIZING LOSSES IN
HAY STORAGE AND FEEDING

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Each year more than 60 million acres of forage crops are harvested for hay in the United States. Annual production from this acreage is over 150 million tons of hay valued at more than 12 billion dollars. Hay is the most widely grown mechanically-harvested agronomic crop in the United States.

As a source of nutrition for livestock, hay offers numerous advantages. It can be made from many different crops; when protected from the weather it can be stored indefinitely with little nutrient loss; package sizes and shapes can vary greatly; and harvesting, storage, and feeding can vary from being done by hand to being completely mechanized. Hay often can meet, or almost meet, the nutrient needs of many classes of livestock.

Because of its many merits, hay is the most commonly used stored feed on livestock farms across the nation. Unfortunately, losses of hay during storage and feeding are often high, particularly with round bales stored outside in high rainfall areas such as the eastern United States. It is estimated that the total value of hay storage and feeding losses nationwide exceeds three billion dollars annually! On some farms, such losses account for over 10% of the cost of livestock production.

These are real, and not just potential, losses (time, labor, and monetary inputs are lost along with the hay). Unfortunately, many producers probably do not realize how large their losses really are, or that with relatively little effort or expense they could be reduced considerably. The purpose of this publication is to provide information as to how and why hay losses occur, and how they can be reduced.

TYPES OF STORAGE LOSSES

Hay storage losses vary greatly depending upon several factors, but storage technique is of utmost importance. Losses of dry hay stored inside a barn are usually of little concern. However, even for barn stored hay, losses rise sharply as moisture levels increase above 20%, and losses from round bales stored outside under adverse conditions can be much larger. During storage, hay can be subject to dry matter losses as well as losses of forage quality.

Dry Matter Losses

Dry matter losses during storage result from plant respiration (the continuation of normal plant processes), microbial activity, and weather deterioration. Even at low moisture levels (20% or less) there is some loss due to respiration and low numbers of microorganisms, but this is constant across hay types and essentially unavoidable.

At higher moisture levels (above 20%) where mold growth is likely to be visibly detectable, dry matter losses are greater, and significant levels of heating (which can also lower forage quality) occur due to microbial activity. Although numerous bacteria are present in hay, fungi account for most of the microbial growth.

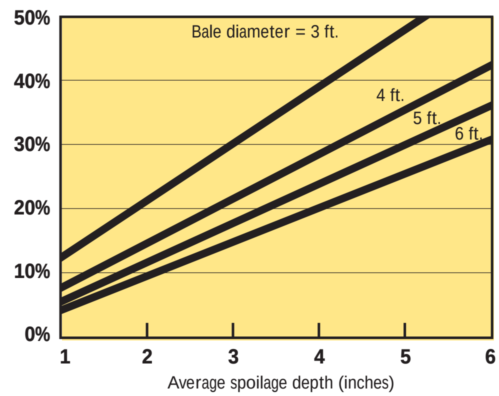
Heating of hay is related to moisture content. Peak temperature is often reached within a week after baling, but with higher moisture hay and conditions which limit heat escape, it may take as much as three weeks. At safe moisture levels (less than: 20% for rectangular bales; 18% for round bales; and 16% for large rectangular packages) inside storage losses are typically around 5% of dry matter, but losses several times higher have been reported for extremely moist hay.

“Weathering” (the term which is commonly used to refer to the effects which climatic conditions have on hay) is partially a physical process. Some of the dry matter loss which occurs during outside storage is caused by leaching, which refers to the dissolving and removal of nutrients by the passage of rain water over the surface of, and through, the bale. The more digestible nutrients are, the more soluble they are, and thus the more likely they are to be removed by leaching.

The switch from small rectangular bales to large round bales on most U.S. farms has resulted in higher storage losses (in many cases, several times higher). Round bales are not inherently subject to greater losses, but they are much more likely to be subjected to adverse storage conditions, often remaining outside with no protection between baling and feeding. Feeding losses are usually sharply higher with round bales as well, partly because big round bales are generally fed on sod while rectangular bales are often fed in bunks.

The extent of weathering damage during outside storage varies mainly with climatic factors and with forage species. Weathering primarily affects hay in the outside circumference of a large round bale rather than in the ends. Consequently, package size (mainly the diameter) affects the proportion of the bale contained in the surface layer, and thus the magnitude of losses (Figure 1).

Figure 1. Dry matter loss vs. average spoilage depth in round bales of various diameters.*



*SOURCE: Buckmaster, D.R., 1993. Evaluator for Round Hay Bale Storage. J. Prod. Agric., 6:378-385.

In the eastern United States it is not unusual for 4 to 8 or more inches of spoilage to occur on the outside of large round bales stored outside with no protection. A weathered layer 6 inches in depth on a 5.6 foot x 5.6 foot bale contains about one-third of the package volume. Other things being equal, the percentage of hay lost decreases as bale size increases because a smaller proportion of the bale volume is contained in the surface layer. This has important implications regarding baler purchase decisions.

Sampling each lot of hay for nutritive analysis is necessary if hay is to be fed in an efficient manner.

Forage Quality Losses

Storage conditions can also have a dramatic effect on hay chemical composition and feeding value. Typical effects on the interior (unweathered) and exterior (weathered) portions of bales on crude protein, acid detergent fiber (ADF), and in vitro digestible dry matter (IVDDM) are shown in Table 1. Even if there were no dry matter losses or additional feeding losses with weathered hay, changes in forage quality would be of great concern.

Total crude protein declines with weathering, but the percentage of crude protein may increase due to dry matter losses (a phenomenon which has been reported to also occur with rain damage of field-curing hay). This is because protein is less subject than other plant constituents to weathering loss. However, the proportion of digestible crude protein may decrease, especially if the hay undergoes heating due to excessive moisture.

Soluble carbohydrates, which are highly digestible, decline during weathering as shown by increases in ADF and decreases in IVDDM; thus carbohydrate levels differ greatly between the weathered and unweathered portions of round bales. Declines in hay quality from weathering are

Table 1. Forage quality of the interior and exterior portions of alfalfa round bales stored outside.*

Portions Of Bales	Crude protein	Acid detergent fiber	IVDDM
	- - - - - - - - % of dry weight - - - - - -		
Interior	18.9	38.6	61.4
Exterior	19.4	45.8	46.9

*SOURCE: Anderson, P.M., W.L. Kjelgaard, L.D. Hoffman, L.L. Wilson, and H.W. Harpster. 1981. Harvesting practices and round bale losses. Trans. ASAE.24:841-842.

HAY QUALITY- THE KEY TO ANIMAL PERFORMANCE

Hay quality is critically important, especially for animals having high nutritional requirements, and the ultimate test of hay quality is animal performance. Hay quality is considered satisfactory when animals consuming it perform as desired. For anyone who is producing, feeding, buying, or selling hay, forage quality should be a major consideration.

Factors which affect hay quality include: growing conditions, fertility, species, varieties, pests, presence of weeds, harvesting, curing, handling, and storage. However, the stage of maturity when harvested is the most important factor, and the one where management can have the greatest impact.

As plants advance from the vegetative to the reproductive stages, fiber and lignin increase, while protein, digestibility, metabolizable energy, and acceptability to livestock decrease. Early cut hay makes a more desirable feed because it contains more nutrients. Hay cut at an early stage of maturity is also more palatable and is more readily consumed by livestock.

Evaluating Hay Quality

Several methods exist for evaluating hay quality: visual, chemical, near infrared reflectance spectroscopy (NIRS), and animal performance. Visual estimates can help, but vary considerably. Descriptions based on these estimates show high quality hay to be early cut, leafy, soft, free of mold and foreign material, and having a pleasant odor. Color can be misleading, because hay having a bright green color may be mature and fibrous, while faded hay may often have excellent nutritional value.

The most precise way to determine the nutrient content of hay is through laboratory analysis. If a representative sample is taken and analyzed for nutritive content, the results can help determine how much and what type of supplementation, if any, is needed in order to meet the nutrient requirements of the animals being fed, and to obtain the level of performance desired. This leads to efficient and economical feeding programs.

Sampling For Forage Quality Analyses

When hay is tested, a random, representative sample must be obtained because laboratory results will be only as accurate as the sample submitted. A sample should be taken for each lot of hay. A "lot" represents a group of bales of hay which were grown in the same field, harvested under the same conditions and at the same time, and stored in the same way.

When collecting samples, a hay probe should be used which has a minimum cutting diameter of 1/2 inch and a minimum length of 12 inches. Samples should be taken from the ends of conventional rectangular bales or from the radial sides of large round bales, with 15 to 20 probe samples being composited and then submitted for analysis from each lot of hay. Samples should be stored in an airtight bag for shipment to the laboratory. Sampling of weathered hay for nutritive value is more complex than sampling unweathered hay. Ideally, weathered and unweathered portions of bales should be sampled separately and the analysis results from the two fractions weighted according to their relative contributions to entire bales.

Table 2. Losses of forage quality during storage of round-baled grass and grass-legume hay.*

Hay type	Fraction	Crude protein	in vitro digestible dry matter	Relative feed value	$ value loss
		- - - % of dry wt. - - -		index	$/T
Grass	unweathered	13.5	58.8	72	—
	weathered	16.4	42.5	75	9.72
Alfalfa	unweathered	14.2	56.5	86	—
	weathered	16.9	34.2	79	22.68

*SOURCE: Lechtenberg, V.L., K.S. Hendrix, D.C. Petritz, and S.D. Parsons. 1979. Compositional changes and losses in large hay bales during outside storage. pp. 11-14 In Proc. Purdue Cow-Calf Res. Day. West Lafayette, IN, 5 Apr. 1979. Purdue Univ. Agric. Exp. Stn. West Lafayette, IN.

1 Hay value determined: Y = (0.81 x RFV index) - 14.8 where Y = $/ton of hay. Minnesota Quality-Tested Hay Auction Data. SOURCE: Martin, N.R., & Duane Schriever. 1996. Minnesota forage update Vol. XXI, No. 2, p. 5.

usually greater for legumes than for grasses (Table 2).

Some heating of hay is normal, but extreme heating (above 120°F) lowers forage quality along with dry matter. Microbial activity associated with heating uses soluble carbohydrates, which reduces digestibility and increases fiber levels. A reduction in voluntary intake accompanies excessive increases in NDF.

In addition to causing huge dry matter losses, weathering lowers forage quality, reduces palatability and intake, and increases feeding losses due to animal refusal. Cattle ate only the center portion of this highly weathered bale.

UNDERSTANDING THE WEATHERING PROCESS

From the preceding discussion, it should be obvious that most of the hay storage losses which occur are associated with hay being stored outside in a situation in which it is exposed to the elements, resulting in weathering. The longer hay is exposed to unfavorable weather conditions, the greater losses will be.

How Weathering Occurs

Bales stored outside on the ground without covers increase sharply in moisture content during storage. This is especially true for the outer 2 to 3 inches of the bale in which moisture may increase by as much as 120%. Weathering begins slowly, but then accelerates because weathered hay is more easily penetrated by rain, and doesn't dry as rapidly thereafter.

In areas of high and/or frequent rainfall, or with hay which does not shed water readily, the method of storage can make the difference between less than 5%, or more than 50%, dry matter loss from weathering! Furthermore, losses of more than 14% of the total crude protein and more than 25% of the total digestible nutrients can occur in the most highly weathered portions of a bale. An important associated factor is that the palatability of weathered portions of bales is decreased, which lowers intake and increases refusal.

Thatch Formation

In theory, a round bale should form a thatch that will, at least initially, shed almost all of the rain which falls on the top of the bale, but any of several factors may prevent this from occurring. Examples of forage crops which have the potential to thatch well when packaged in a uniform, dense bale are fine-stemmed, leafy, weed-free bermudagrass or tall fescue.

Hay made from coarse-stemmed forage crops will not thatch well. This is due to large stems, hollow stems, or other physical factors which do not allow thatch formation. For example, water can easily penetrate the tops of bales of many summer annual grasses, thus quickly beginning the weathering process. Coarse-stemmed weeds within hay can also provide an avenue for water to penetrate bales.

Once a wet layer forms, a bale does not shed water well and moisture levels inside the bale are likely to continue to increase during the storage period. As the wet, moldy area on the top of the bale deepens, less and less drying occurs between rains. Hence, once weathering gets underway, it usually proceeds much faster than with newly baled hay.

Understanding the importance of thatch formation is made easier by considering the amount of water which must be shed during storage. A 6 foot long by 6 foot diameter bale will receive about 22 gallons of water for each inch of rain. Therefore, if there

In the eastern United States, storing bales outside unprotected for several months will typically result in at least 5 or 6 inches of hay around the top and sides which has essentially no feeding value. Losses on the bottoms of bales are usually even greater due to contact with wet soil.

are 30 inches of rainfall during the storage period, a bale will receive 660 gallons of water.

Location Of Weathering

For hay harvested at a low moisture level, weathering usually occurs in three layers. The outside is typically wet, dark, and rotten and has no feeding value. Underneath is a thinner layer of moist and heavily molded hay which is of relatively low quality. A third transition layer, which may exhibit light mold and have a higher moisture content than the outer surface layers, usually surrounds the unweathered interior.

The sides of round bales shed water better than the tops because less surface is directly exposed to rain. Therefore, an isolated uncovered bale should have less weathering on the sides than on the top. However, moisture can be trapped where bales touch on the rounded sides, and this trapped moisture delays drying and thus results in greater weathering during storage.

Data suggest that often 50% or more of the storage losses associated with outside storage occur in the vicinity of the bale/soil interface (that is, at the bottom of the bale). Dry hay touching damp soil draws moisture into the bale. Hence, if hay and soil are in contact, large weathering losses occur on the bottoms of bales even when they are stored on a well-drained site. As a bale begins to weather on the bottom, it will flatten and allow even more hay/soil contact, and more top area will be horizontally exposed to rainfall, each of which increases the amount and rate of weathering.

FACTORS AFFECTING OUTSIDE STORAGE LOSSES

In research trials in the eastern United States in which large round bales have been stored outside without protection for six months or more, dry matter losses of 30% or greater have been common. Some of the most important factors relating to the extent and dollar value of outside storage losses are as follows:

Bale Density

In general, the denser or more tightly hay is baled, the lower the amount of spoilage that will occur, assuming hay moisture at baling is 18 to 20% or lower. Bale density is affected greatly by the type of baler being used, with some large round balers providing a density up to twice as great as other balers. The average density of a bale is less critical than the density on the outer surface.

Other factors may also affect bale density. By making proper baler adjustments and taking time to do a good job, an experienced baler operator can often produce bales which are much tighter than those someone else might produce using the same equipment. Some fine-stemmed hays such as bermudagrass naturally tend to produce a tight bale which sheds water much better than coarse-stemmed hays such as johnsongrass, pearl millet, or sorghum-sudangrass.

Having well-formed, tight bales is an important factor in reducing storage losses. Most haying equipment companies can provide information that discusses the steps (or tricks) required to produce dense, uniform bales when using their products. The density of round bales (at least in the outer few inches) should be a minimum of 10 pounds of hay/cubic foot.

While increased bale density reduces spoilage by reducing moisture penetration, it also reduces the rate at which moisture and heat can escape from a bale.

Thus, as density increases, it becomes increasingly important to make certain that hay is in a safe moisture range for baling. Unfortunately, leaf shatter from legume hays also increases with decreasing hay moisture levels.

A low moisture content, use of a forage crop with stems fine enough to form a thatch, and a bale density of at least 10 pounds/cubic foot in the outer portions of bales are important factors affecting resistance to weathering during outside storage.

Other Field Operations Or Techniques

Reduction of storage losses can begin with the formation of the hay swath prior to baling. A uniform swath of proper size for the baler being used will help to produce a dense, uniform bale. Other things being equal, smaller windrows facilitate dense bales because they result in more layers per roll; however, leaf shatter of legumes, as well as baling time, may be increased. Operating rakes, tedders, and balers in the same direction as hay was cut may also help make a tighter bale.

DEFINITION OF SELECTED FORAGE QUALITY TERMS

CRUDE PROTEIN (CP)
The total quantity of true protein and nonprotein nitrogen present in plant tissue. This can be calculated by multiplying the nitrogen fraction by 6.25.

DRY MATTER (DM)
The percentage of a plant sample which remains after all water has been removed.

NEUTRAL DETERGENT FIBER (NDF)
The percentage of cell walls or other plant structural material present. This constituent is only partially digestible by animals. Lower NDF levels are generally associated with higher animal intake.

ACID DETERGENT FIBER (ADF)
The percentage of highly indigestible plant material. Higher ADF levels are generally associated with lower digestibility.

DIGESTIBLE DRY MATTER (DDM)
The percentage of a sample which is digestible. DDM is a calculated estimate based on feeding trials and from the measured ADF concentration.

IN VITRO DIGESTIBLE DRY MATTER (IVDDM)
is a similar term which indicates that the digestibility level was determined via a laboratory test as opposed to one which utilized live animals fitted with a port open to the rumen which allows digestion of small samples inside the animal.

DRY MATTER INTAKE (DMI)
This is the amount of forage an animal will eat in a given period of time. Estimates of DMI are based on results from animal feeding trials and the measured NDF concentration of a forage or feed.

DIGESTIBLE DRY MATTER INTAKE (DDMI)
An estimate of how much DDM an animal will consume in a given period of time. It is calculated as follows:
DDM X DMI/100.

RELATIVE FEED VALUE (RFV)
A measure of a forage's intake and energy value. It compares one forage to another according to the relationship DDM X DMI/100 divided by a constant. RFV is expressed as percent compared to full bloom alfalfa which has an RFV of 100. In most cases, as RFV increases forage quality also increases.

Moisture content at baling can be an important consideration, and this is especially true in the case of large hay packages. Some studies have shown that hay baled at only 2 to 3% higher moisture than other hay from the same field will maintain a higher moisture content for several months thereafter, thus favoring microorganism growth. Because large hay packages have restricted ability to lose moisture, even relatively small differences in moisture level can have a measurable negative impact (lower total and digestible dry matter and higher fiber).

Bale wrapping has some influence on storage losses of large round bales stored outside. A Missouri study showed weathering losses increased as the spacing between the twine on bales increased from 2 to 8 inches. However, wrapping bales with twine spaced closely together increases costs because more twine is used and more time is required for wrapping.

Most studies have shown net wrap to be slightly better than twine in preventing storage losses. Producers who use net wrap have also indicated that they can wrap a bale with only two to three revolutions and produce more bales per hour than with twine. Net wrap has the additional advantage of stabilizing bales better than twine, thus making bale handling and storage easier, but it also increases cost.

Though not a storage procedure per se, a preservative is sometimes applied to the swath or to forage as it enters the baler. The preservative is often a buffered acid which decreases mold and mildew growth. This allows hay to be baled at a higher moisture level which may increase leaf retention of legume hays, thus slightly improving harvest yield and forage quality, as well as hastening baling by one-half to one day, thus reducing the risk of rain damage.

Acid-treated hay which is protected from rain during storage may have slightly lower storage losses than untreated hay if stored for only a few months, but after storage for as long as six months, there may be no difference between treated and untreated hay. Acid treatment does not appear to retard the weathering process with hay stored outside, however. Furthermore, acids can result in corrosion of hay equipment.

Injecting hay with anhydrous ammonia increases crude protein by adding nonprotein nitrogen. It has also been shown to increase digestibility of grass hay, and can be quite effective in reducing or eliminating mold growth and heating. In addition, because injected bales must be sealed airtight to avoid ammonia loss, weathering loss is avoided. However, the caustic nature of this product creates danger to humans, and has occasionally caused hay to be toxic to animals (particularly with high moisture, high quality hays).

As fields are cut, baled, and stored, some system for identifying hay as to field and cutting date should be implemented. This information is useful in determining the effect of management practices on forage quality and/or animal performance, and in testing the nutritive quality of hay to allow the formulation of rations which efficiently meet animal nutritional requirements.

Climatic Influences

Climatic conditions obviously play an important role in determining the extent of spoilage loss of hay stored outside. In general, the higher the rainfall during outside storage, the greater the amount of storage loss which will occur. However, rainfall distribution also has an influence (in fact, results from some studies have implied that rainfall distribution can be considerably more important than rainfall amount). To illustrate, a rainstorm which results in 2 inches of rain falling very quickly is likely to have much less impact than the same rainfall coming in small amounts every other day over a period of two weeks.

Other climatic factors such as high humidity, which slows drying of wet hay, likewise enhance storage losses. Temperature also has an effect, because microbial activity within the bale is favored when warm, humid, overcast conditions prevail. Hay which is stored in a sunny area which receives the benefit of unobstructed breezes dries more quickly and tends to have lower spoilage losses than hay stored in shady and/or less well-ventilated areas.

Outside storage of hay normally presents little or no problem in the arid western United States, so in this area large stacks of hay are often stored outside totally unprotected from the elements. However, in high rainfall/ high humidity areas, outside storage losses can be extensive and quite costly.

Site Selection

If hay is to be stored outside, it is desirable to locate the storage site close to the feeding area because bales become more difficult to handle as they weather. It is easier to move them a greater distance when they are new and tightly wrapped.

Well-drained upland storage sites are best. Bottom areas should generally be avoided as they tend to be heavier soils. Also, many bottom areas are prone to flooding, which is detrimental to hay and may limit vehicle access during rainy periods. Hay/soil contact should be avoided if at all possible, but if hay must touch the soil, a sandy, well-drained area is greatly preferable to a heavy soil and/or a poorly drained site.

It is also advisable to select a storage site where the danger of fire is minimized. Several steps which can be taken to reduce the likelihood of fire are discussed in a later section titled "Reducing Fire Risk."

Bale Orientation/Placement

Once the storage site has been located, attention should be given to bale placement and orientation. Except when multiple-bale covers are used, large round bales should be stored in rows with sides not touching so as to avoid creating a moisture-holding area between sides. However, the flat ends of bales should be firmly butted against one another. This conserves space and may help protect the bottoms of bales (other than the one on the upper side of the slope) from water flowing down the slope. Properly done, this protects the ends almost as well as if they were part of one continuous bale.

If possible, rows should run north and south so as to allow maximum exposure of the rounded sides to the sun. This increases drying of the rounded surface of bales during the day. At least 3 feet should be left between bale rows to ensure sunlight penetration and allow good air circulation.

If direct hay/soil contact cannot be avoided, taking steps to minimize the amount of water reaching the bales, and the length of time they stay wet, will at least help. A gently sloping site (preferably with a southern exposure to maximize solar drying) will allow water to quickly drain away from the hay. Bales should be oriented up and down the slope so that they will not create a dam for surface water, and placed near the top of the slope to minimize the amount of water flowing around the hay.

Protecting The Tops Of Bales

There are numerous types of commercially available coverings for large round hay bales, and they vary in both effectiveness and cost. These include small "caps" which are staked or pinned to the bale and which cover the top third to half of the bale. If handled carefully, such products often can be used more than one season, which makes them less expensive and therefore more feasible to use. Some individual bale covers may be difficult to keep securely in place for an extended period of time.

One can also buy a large roll of plastic sheeting and cut individual bale covers, although experience has proven this method to be time consuming and the pieces somewhat awkward to handle. If plastic sheeting is used, it should be at least 6 mil thick. Individual bale covers are most suitable for producers who use relatively small quantities of hay in a given feeding season.

The expense of a tarp, plastic sheeting, or other fabric covering, as well as the labor involved to cover hay, can be reduced by placing a group of bales under one cover. Often bale rows are stacked in a triangular fashion with two or three rows forming the base. This gives either three or five rows of hay per stack, with the total number of bales varying with the length of the stack.

A cover must be secured firmly to prevent wind from blowing it off during storage. It is desirable to leave the flat ends of the outside bales uncovered and to leave a few inches uncovered along the sides of the rows to allow moisture to escape and air to circulate under the bales. However, winds of only 15 to 20 mph can exert a considerable lifting force as it blows across the top of a plastic or tarp, and even a slight breeze may lift a loose edge of a poorly secured cover.

Another disadvantage of using plastic sheets is that condensation may occur under the bales if hay was moist when stored or if water gets under, and into, the bales. The result is that a significant amount of spoilage may occur next to the plastic even though rain cannot reach the hay. (This makes a strong case for making certain any hay stored using this technique is quite dry, preferably 18% moisture or less, before being covered and is not in contact with the soil.) In addition, disposal of plastic after use may be a problem.

At least one commercially available hay cover is made from a slightly porous fabric. It is marketed in large tarp-sized sheets, and can be used to cover several bales at a time, usually with one row of bales stacked on top of two other rows in triangular fashion. This reusable product offers the advantage of shedding a high percentage of rain water while still allowing moisture to escape during sunny, drying days. However, bottom spoilage may occur on bales which touch the ground unless steps are taken to prevent it.

If a cover is used (particularly a plastic cover), it may be desirable to relate the size of individual stacks to the rate at which hay is to be fed. Once a row end is uncovered and bales are removed for feeding, covers are seldom placed back as securely as they were initially. The result is that wind may blow a cover off, or partially off, resulting in some weathering of the remaining hay. Therefore, minimizing the amount of hay stored under one cover may help reduce weathering losses in some situations.

Use of a rock pad is one effective yet inexpensive way to eliminate hay/soil contact.

Other companies market equipment which places either individual bales or several bales inside plastic "sleeves." This approach effectively protects the tops and sides of bales, but it is quite important to make certain that the hay is dry when baled and to make certain there is no way for moisture to enter the bales or for condensation to "pool" at the bottom of the plastic during storage. Otherwise, there may be high spoilage losses on the bottoms of bales. When each sleeve covers only one bale, the sleeve should be tight. Despite the plastic on the bale bottoms, individually sleeved bales should not be stored directly on the ground.

Some companies produce equipment which completely wraps or seals individual bales in stretch plastic. Done correctly, this may be the most effective way to eliminate weathering losses with outside storage. However, depending on the equipment design, this may be expensive in terms of labor, equipment, and plastic, plus disposal of plastic after feeding is required.

Several research studies have involved spraying bales with water repellent substances. Hydrogenated animal fats and plant oils have been used most frequently, and offer the attributes of being natural, environmentally friendly, and biodegradable. With most such products, animal refusal of treated hay does not appear to be a problem, but the fat or oil may attract insects, which can include fire ants in areas where they are present. Additional research is needed to determine the feasibility of this approach.

Protecting The Bottoms Of Bales

Several studies have shown that it can be more important to protect the bottoms, as opposed to the tops, of bales. The bottoms of bales can be protected in countless ways, limited only by imagination and ingenuity. The bale bottom is protected when it is held off the ground by something that does not trap and hold water. For example, wooden pallets, telephone posts, scrap pipe, and cross ties have all been successfully used in hay storage. The most important point is to prevent hay/soil contact, but providing some air flow under the hay is also desirable.

Wooden pallets offer an inexpensive method of eliminating hay/soil contact, but are labor intensive as they need to be moved as hay is used. They make it easy to change storage location(s) from year to year because they have to be moved anyway. However, pallets contain nails which can puncture tires or cause other damage.

Another relatively inexpensive and effective storage technique is to place hay on rock pads. A good rock pad keeps bales off the soil, and also provides all weather support for equipment. Rocks 1 to 3 inches in diameter should be piled 4 to 8 inches deep, depending on the soil type and the weight of the equipment to be used. This size rock traps no water and effectively channels water away.

Rock pads last for many seasons and can easily be repaired if damaged. An erosion cloth can be placed below the rock pad to help slow the rate at which heavy equipment may push rocks down into the soil and therefore increase the life of the pad (which can be ten years or more).

COSTS VERSUS BENEFITS OF HAY STORAGE

Many producers probably do not fully realize the economic importance of storage losses because the amount of loss is difficult to determine on a farm, and total hay costs are considerably higher than out-of-pocket expenses.

Before making decisions regarding hay storage, a producer should obtain and study hay budgets to determine the actual cost of hay production and the dollar value of hay storage losses. Budgets are usually available from County Agricultural Extension Agents.

Cost Of Hay Losses

Proper hay storage has a cost in terms of both time and effort, and this must be considered by producers seeking to reduce losses. Material and labor costs expended to store hay, as well as the nutritional value of hay, dictate which storage techniques are most cost effective. The higher the quality of the hay, the greater the economic cost of storage and feeding losses (Table 3).

Storage losses increase the quantity of hay needed, plus they may lower forage quality of the remaining hay enough that additional supplementation of animal diets is required. The cost of storage losses can readily be calculated based on the selling price of hay of various qualities. The economic values of dry matter losses provided in Table 4 were calculated using Minnesota quality-tested hay auction prices. This information can be used to calculate how much one can afford to spend in constructing overhead storage or in improving site drainage.

Table 4 illustrates that as hay value increases, a greater investment in time, energy, and money can be justified to reduce losses. Furthermore, in addition to the value which is lost due to weathering, the lost hay must then be replaced. For example, dry matter losses of 15 to 20% require a livestock producer to harvest 15 to 20% more hay, which further adds to the costs of production, harvesting, and storage.

Table 3. Cost of hay consumed as affected by storage and feeding losses.

	Beginning hay value, $/ton[1]		
% Loss	50	70	80
5	52.69	73.68	94.74
10	55.55	77.78	100.00
15	58.87	82.35	105.88
20	62.50	87.50	112.50
25	66.68	93.33	120.00

[1] Numbers listed under a given beginning hay value represent the cost of unweathered hay fed (that is, losses due to storage and feeding, in essence, increase the cost of hay).

Table 4. Economic value of loss (storage and feeding) of hay by quality test.

Test standard	Average quality RFV[1]	Price	5%	10%	20%	40%
			Value of loss[2]			
	index	$/T				
Prime	168	121	6.05	12.10	24.20	48.40
1	138	97	4.85	9.70	19.40	38.80
2	115	78	3.90	7.80	15.60	31.20
3	97	64	3.20	6.40	12.80	25.60
4	81	51	2.55	5.10	10.20	20.40
5	60	34	1.70	3.40	6.80	13.60

[1] Represents the mean test values from 11 years of quality test auction data in Minnesota.

[2] Y = (0.81 x RFV index) - 14.8, where Y = $/ton of hay. This calculated loss value assumes a 4 inch weathering loss and 5 foot diameter bales (25% of the hay volume).

Barn Storage

Barn storage is usually considered to be a consistently highly effective method of storing hay, so it is often used as the standard against which other techniques are compared. When the typical dry matter storage loss of dry hay during inside storage (usually around 5%) is compared to the 30% or more common with hay stored outside in the humid portions of the United States, it isn't difficult to see that reduced losses can often provide payback on barn construction within a few years. The more valuable or porous the hay, the higher and/or more frequent the rainfall, and/or the longer the period of storage, the more easily barn construction can be justified.

For commercial hay producers there may also be considerable benefit from the improved appearance which results from barn storage. Outside storage hurts the appearance of hay even when actual losses are minimal. Appearance is not closely linked to nutrient content or feeding value, but it is often important in marketing, and may justify barn storage even in relatively low rainfall climates.

Storage buildings may provide benefits in addition to those which result from storing hay. For example, part of a hay barn might be used for other purposes during a portion of the year. Furthermore, the overall value of a farm should increase with the addition of a hay barn.

Bale density is another important consideration affecting the cost effectiveness of barn storage. The density of small rectangular bales is usually around 9 pounds per cubic foot, while the density of large round bales can vary from less than 5 to more than 10. Even when high density round bales are used, at least a third less round bale hay than rectangular bale hay can be stored in a given storage structure due to the wasted space between bales.

When a storage facility is constructed for round bale storage, dimensions should be based on the diameter and length of the bales that will be stored. For such structures, a design which does not require interior roof-supporting poles is desirable so that equipment operation will not be impeded.

On many farms, particularly in the eastern United States, reduced hay storage losses can provide payback on barn construction within a few years.

Costs And Risks Of Barn Storage

The cost of building a hay storage structure can vary greatly. Comparisons of structures of various types and sizes should be made on a cost-per-square-foot basis. Material costs are higher in some areas than others, and climate largely determines siding costs. Even in high rainfall areas at least one side may be left open without significant adverse results.

Labor costs typically account for around 35% of the cost of erecting a hay storage structure. Thus, a producer who can provide most or all of the labor for building a storage structure can substantially reduce out-of-pocket construction expenses.

Costs other than construction which are associated with barn storage are greater than might be expected. Before making decisions regarding erecting storage facilities or pricing hay which has been stored inside, the following items should be taken into consideration.

Shrinkage- Hay which has been stored inside for several months will typically lose 5 to 10% of its weight as compared to freshly baled hay due to a combination of dry matter loss and moisture loss.

Depreciation- The economic value of a building declines steadily over time. Generally, depreciation is considered to be around 5% of the initial value per year.

Interest on investment- This is “opportunity cost” or the amount of return which could have been made with the money used to build a storage structure if it had been invested elsewhere.

Repairs- A good figure to use is that approximately 1 to 2% of the value of a building must annually be spent on repairs. Most of this will occur during the latter part of its useful life.

Taxes and insurance- Taxes vary greatly with location, so to determine tax costs a producer should check with local officials. Having insurance on a storage facility is generally advisable, but each producer must decide whether he needs it and, if so, how much. Some farm policies may cover such additional buildings at little extra cost. Often the combined costs of taxes and insurance amount to about 1% of the average value of the building over its useful life.

Other- If a barn has an earth floor, water from outside should not be allowed to run under the hay. Otherwise, spoilage will occur on the bottom bales even though the hay is under shelter.

Bale dimensions, how high bales will be stacked, and the anticipated length of usefulness of the storage facility will also affect the economics of barn storage. For example, if a building costs a certain amount per square foot to build, but bales will be stacked three high and the facility is expected to last for 20 years, the cost per square foot for bale storage per year (construction cost only) can be determined by dividing the construction cost by 3 and then by 20. The cost/bale/year can then be obtained by multiplying the cost per square foot by the square footage of the size of bales to be stored (for example, a 5 foot x 6 foot bale will occupy about 30 square feet of storage space).

In the final analysis, in order to determine whether it is economically feasible to build a hay storage structure a producer must calculate anticipated construction costs, then compare this figure with an estimate of the value of hay being lost without it. Figure 2 provides the break even costs for barn construction at various loss levels, costs/square foot, and hay values.

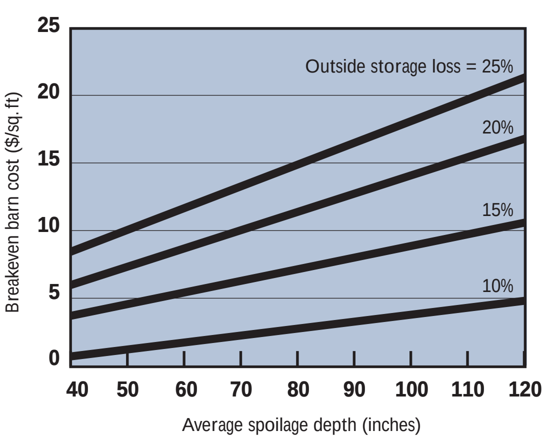


Figure 2. Break even barn cost for various levels of storage loss and varying hay value at harvest.
(This analysis includes the following assumptions: in-barn average stacking height of three bales, ten-year barn amortization, and construction cost of $7.50/square foot. Inputs other than storage loss and hay value are not included.)

SOURCE: Buckmaster, D.R. 1993. Evaluator for Round Hay Bale Storage. J. Prod. Agric., 6:378-385.

Table 5. Average and range of increase of percentages of dry matter and digestible dry matter with barn storage as compared to various protection techniques used for hay stored outside. (Medium rainfall areas.)*

	Increase With Barn Storage, % Units	
Treatment Compared To Barn Storage	Dry Matter	Digestible Dry Matter
On Ground Without Cover	8.7	12.7
	(3.6 - 14.5)[1]	(3.3 - 17.2)
Drained Surface (Rock, Pallets, etc.)	2.4	6.8
	(-1.3 - 6.7)	(-0.4 - 13.4)
Plastic Cover On Bale Tops	3.2	3.6
	(0.6 - 4.6)	(2.9 - 4.3)
Drained Surface + Plastic Cover	0.3	-1.4
On Bale Tops	(0.9 - 2.9)	(-2.1 - 1.8)
Net Wrap	1.5	—
	(0.6 - 1.5)	—
Plastic Sleeve	0.6	—
	(-1.4 - 2.7)	
Pyramid Stack + Cover On Top	3.7	—

*SOURCE: Russell, Jim, and Ray Huhnke. 1997. Winter Feed Management To Minimize Cow-Calf Production Costs: Hay Storage And Feeding. The Forage Leader (a periodical published by the American Forage and Grassland Council, Georgetown, TX). [1]Parentheses denote the range of values in tests included in this summary.

The costs versus the benefits of using other techniques to protect hay should be compared to: (1) hay stored outside with no protection, and (2) building a hay storage facility. Experiments have generally shown that more than half (and sometimes nearly all) the difference in storage losses between outside storage on the ground with no protection and barn stored hay can be eliminated through the use of various strategies. A summary of 12 experiments comparing storage losses of barn stored hay to various other storage techniques is provided in Table 5.

Barn Safety Considerations

Safety considerations should be a high priority when planning barn storage of hay. These include making certain that equipment available on the farm is capable of safely placing bales in stable stacks, having a shield on stacking equipment to prevent injury to the operator if a bale falls, and making certain that excessive pressure will not be exerted on the walls or supports of the storage facility (stacking bales on end reduces the latter hazard).

REDUCING FIRE RISK

Each year there are many reports of hay barns burning, as well as of fires occurring in hay stored outside. Fire is always a concern with hay, but it takes on even greater importance when an expensive barn can be lost in addition to the hay.

Fire in stored hay may occur from either external or internal causes. Internally started fires are a result of hay going through an extreme heat. As discussed earlier, heating is a direct result of microorganism activity in hay stored at excessively high moisture levels. Even if excessive heating does not result in a fire, it will reduce forage quality.

Combustion Due To Extreme Heating

The principal way to avoid fire resulting from internal heating (sometimes referred to as “spontaneous combustion,” though this term is misleading) is to bale hay at proper moisture levels. Hay in round bales should contain no more than 18% moisture when placed inside a barn, while hay in small rectangular bales should contain no more than 20% moisture. Hay that is suspected of being too wet should be stored outside for about three weeks until the danger of combustion due to heating is past. New crop hay should never be placed against dry hay.

The danger of fire from heating of hay of higher-than-optimum moisture can be decreased somewhat by "loose stacking" the bales so good air movement and ventilation can occur. Hay preservatives, which reduce fungal and bacterial growth, sprayed on hay during the baling process help reduce (though do not always prevent) excessive heating in higher moisture hay. Bales known to contain, or suspected of containing, excessive moisture can be temporarily loosely stacked outside, then moved inside after the danger of fire is past.

External Causes

External fires have many causes ranging from lightning to the mindless tossing of a cigarette. Common sense and an alert eye can eliminate most causes of external fires. For example, it is best to avoid stacking hay close to anything that can attract lightning such as power lines, metal fence posts, trees, or towers such as antennas.

It is also advisable to avoid storing hay adjacent to vegetation that might support a fire, and to maintain a no-vegetation buffer area around stacked hay to prevent wildfire from moving into the stored hay. This is especially true if the grass or other plants in the storage area are warm season species that go dormant in winter. Risk of hay loss from fire can further be reduced by storing hay in two or more sites rather than just one.

It is a good idea to post "No Smoking" signs in conspicuous places around a hay barn and to strictly enforce this policy. A herbicide or tillage can be used to create a bare ground buffer zone at least 3 feet wide around the edge of the barn to reduce risk from wildfire.

If there is a need to check the temperature of hay, it can be done by fitting a sharpened end on a 10-foot section of 1/2 inch pipe, then driving it into the hay, followed by lowering a thermometer into the pipe. Temperatures below 120^{o}F are normal, and 120^{o} to 140^{o} are in the caution range. Hay heating to 160^{o} or higher is in serious danger of catching fire. Temperature can build in hay, particularly within the first week or two after baling, and therefore periodic monitoring of temperature until it is clear there is no danger of fire is advisable.

HAY FEEDING

On many farms, hay feeding losses are as high as storage losses, particularly if hay is fed outside (This is logical because as the amount of weathered hay increases, animal refusal also increases). Some hay losses during feeding can be expected with any feeding system, but the amount of loss varies with the system used. The major objective for any feeding system should be to keep losses to a practical minimum level, thus permitting animals to consume the majority of hay offered at feeding.

Feeding losses include trampling, leaf shatter, chemical and physical deterioration, fecal contamination, and refusal. The levels and costs of these losses will be determined by feeding method, intervals between feedings, amounts fed at a time, weather conditions, the number of animals being fed, and forage quality or hay value.

In research trials, feeding losses have ranged from less than 2% when great care was exercised, to more than 60% where no attempts were made to reduce loss. Feeding losses of 3 to 6% are quite acceptable for most feeding programs, although such low levels of loss are usually associated with systems which require high labor inputs and daily feeding.

Use Of Hay Quality Information

Hay can be most efficiently fed when separated into lots according to quality, and when classes of animals are separated and fed according to needs. This allows hay quality to be matched to livestock needs. For example, on a cattle farm the best quality hay might be fed to animals having high nutritional requirements such as young calves, yearlings, bred heifers, and lactating cows. Lower quality hay could be saved for mature, dry pregnant cows and bulls when not in breeding season.

High quality hay is early cut, leafy, pleasant smelling, and free of foreign material and toxic factors. When chemically analyzed, such hay will usually be high in protein and digestible energy, and low in fiber. The best quality hay will also be the most valuable hay and thus should be fed with the greatest care.

Feeding Methods

If not ground for use in formulating a total mixed ration, small rectangular bales are normally stored under shelter, then are usually either moved from the shelter and placed in some type of structure (bunk, manger, rack, wagon, trough, etc.) or taken to an outside area where cattle are located. Either system requires a considerable amount of labor. Most large hay packages are fed on sod whether stored inside or outside.

Feeding hay on sod offers the advantage of distributing hay on pasture land rather than concentrating it along a feed bunk or in a barn. When hay is fed on sod, livestock usually waste and refuse less hay in situations in which they have a solid footing. Dry, well-drained, or frozen sites should therefore be chosen for feeding hay outside.

Feeding in only one area permits selection of a convenient feeding location which is easily accessible and which minimizes the size of the area in which sod is killed. However, it causes excessive sod destruction, usually creates muddy conditions, often results in heavy spring weed pressure, and can result in soil compaction and/or ruts in the field.

Some livestock producers who feed in only one area prefer to feed on concrete or to haul in large gravel so the hay can be placed on a solid foundation. Also, some producers feed the lowest quality hay first, thus initially causing excessive hay wastage but providing a foundation for further feeding.

Frequently moving the feeding area allows manure to be spread more uniformly over the field(s) and therefore improves the soil fertility in bare or thin spots, while reducing the severity of (though not necessarily the total area which sustains) sod damage. It can also facilitate the "trampling in" of legume seed (usually white clover or red clover) which was broadcast over a field during early winter. Regardless of the approach used when feeding hay on sod, any areas where sod kill is encountered should be reseeded as soon after the feeding season as possible.

When hay is fed on sod, the amount of hay wasted will be much less when only a one-day hay supply is given, and when hay is fed in such a manner that all animals have access. However, unrestricted animal access to large round bales or stacks will result in grossly excessive feeding waste.

If substantial quantities of hay must be put out at one time, erecting a barrier between the hay and the feeding animals will reduce waste. The barrier can be an electric wire, feeding racks or rings, panels, wagons, or gates. Feeding racks and rings are available in a variety of shapes and sizes (racks which prevent hay from contacting the ground are particularly effective). In addition, blueprints for home construction of bale protectors are available through many universities, including from County Agricultural Extension Agents.

When racks or panels are not used, enough animals are needed to eat the amount of hay offered in a relatively short period of time. Waste can be reduced by having at least one cow for each foot of outside dimension (circumference) of the hay package. Forcing animals which have low nutritional requirements to clean up hay in feeding areas before more hay is put out can also help reduce waste.

A few producers use balers which package hay in relatively small round bale packages which are left in the field and later fed at the spot where they were dropped from the baler. This system lends itself to large hay storage losses if hay is stored in this manner for very long because the hay is unprotected from the elements and there is high bale surface area exposure. When this system is used, an electric wire should be used to limit access and thus at least reduce feeding losses.

Placing a barrier between the hay and the animals will reduce feeding losses.

Feeding Priority Of Various Hays

Obviously, the longer hay is exposed to the elements, the greater storage losses will be. Therefore, hay stored outside should generally be fed before hay stored inside. Porous hay which is highly susceptible to damage should be fed before hay which is tightly baled. Other things being equal, the best quality hay stored outside should be fed before lower quality hay, though animal nutritional requirements may also affect feeding priority.

Altering Hay Bales Before Feeding

Several types of equipment are available for grinding, shredding, unrolling, or cutting and windrowing large hay packages. These methods usually require additional equipment, but can work well under proper management. Grinding or shredding hay facilitates limit feeding (limiting the amount fed at a time) and also tends to lower feeding losses by reducing the ability of animals to selectively consume unweathered hay and refuse weathered material.

The least expensive method is to simply unroll the bale to enable livestock to line up much like at a feed bunk. Again, feeding only enough for one day reduces waste but increases labor.

Minimizing Hay Requirements

The objective of any hay feeding program is to provide adequate quantities of high quality hay to meet livestock needs not being met by pasture. However, stored feed, including hay, is normally much more expensive than pasture forage, so it is economically advantageous to minimize stored feed requirements to the extent possible. Examples of ways this might be done include stockpiling forage, grazing crop residues, and lengthening the grazing season by growing various pasture crops which have differing periods of production.

KEY CONCEPTS REGARDING OUTSIDE HAY STORAGE

1. Weathering of hay results in losses of dry matter, lowered forage quality, and (perhaps even less well recognized) reduced hay intake and greater refusal.
2. The more valuable the hay, the easier it is to justify spending time and money to reduce storage losses.
3. Hay/soil contact is usually the most important source of spoilage of hay stored outside and should be eliminated if possible. This can be accomplished by placing bales on crushed rock, a concrete pad, or some object such as wooden pallets. If placing bales on the ground cannot be avoided, selection of a well-drained area (preferably with sandy soil) should be selected.
4. Water should quickly drain away from any bales stored on the ground. Storing bales near the top of a sloping area reduces the amount of water flowing around them. Bale rows should run up and down a sloping area to avoid trapping surface water.
5. Hay should be stored in a sunny location, preferably in an area where frequent breezes occur. Hay should never be stored under trees or other areas where drying is slow.
6. It is preferable for bale rows to run north and south rather than east and west. Also, a southern, rather than a northern, exposure is best.
7. The flat ends of bales should be butted together, but the rounded sides should not touch. Unless rows are put together to facilitate covering with sheets of plastic or similar material, at least 3 feet of space should be left between rows to allow air circulation.
8. The larger the bale, the lower the total percentage of weathering of hay stored outside. However, there are some disadvantages associated with handling larger bales.
9. As hay density is increased (particularly in the outer portion of the bale), outside storage losses decline. A minimum of 10 pounds of hay/cubic foot is recommended for round bales stored outside. Course-stemmed forages are more vulnerable to weathering than fine-stemmed forages which form a thatch.
10. The efficiency and cost of various methods of storing hay outside vary greatly. Whether a particular technique or combination of techniques can be justified depends on the cost of the technique(s) versus the value of hay which will otherwise be lost.

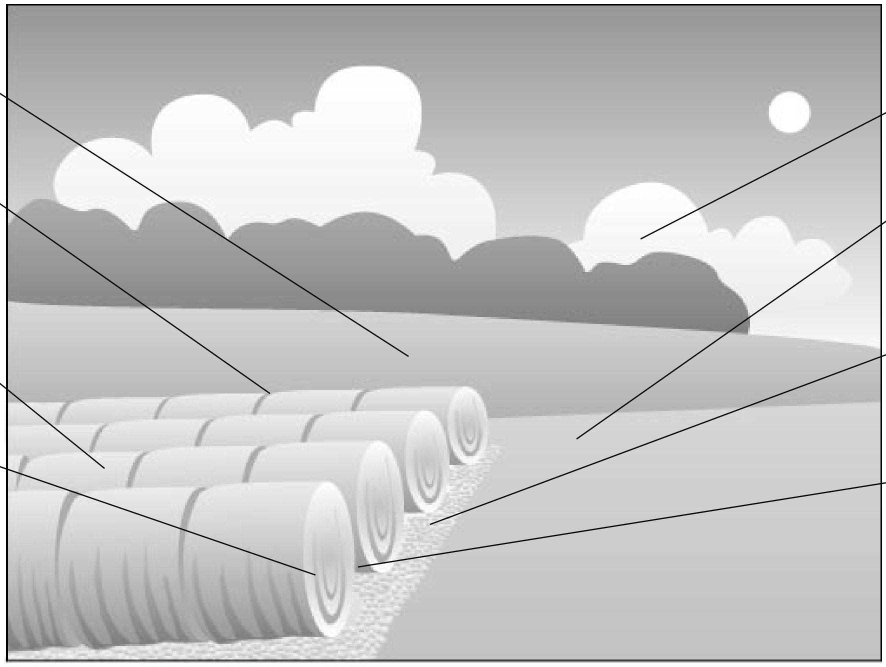
EXAMPLES OF THINGS YOU SHOULD NOT DO

Bales should not be allowed to be in standing water, even on a temporary basis.

The rounded sides of bales should not touch.

Hay should not be placed under trees.

OUTSIDE HAY STORAGE RECOMMENDATIONS



KEY CONCEPTS REGARDING HAY FEEDING

1. Hay quality should be matched to animal needs.
2. When animals are fed outside, a well-drained site should be selected to reduce feeding losses.
3. Hay stored outside should be fed before hay stored inside; coarse, porous hay stored outside should be fed before fine-stemmed, densely baled hay stored outside; other things being equal, high value hay stored outside should be fed before low value hay stored outside.
4. Putting a barrier between animals and hay will help reduce feeding losses. Hay racks can be particularly effective.
5. Minimizing the amount of hay to which animals have access at one time will reduce feeding losses.
6. Forcing clean up of hay by animals which have low nutrient requirements before feeding more hay can help reduce hay waste.

PREPARED BY:

Dr. Don Ball
Extension Agronomist/Alumni Professor
Auburn University

Dr. David Bade
Extension Forage Specialist
Texas A&M University

Dr. Garry Lacefield
Extension Agronomist/Professor
University of Kentucky

Dr. Neal Martin
Extension Agronomist-Forages and Professor
University of Minnesota

Dr. Bruce Pinkerton
Associate Professor/Extension Agronomist
Clemson University

The authors gratefully acknowledge reviews of this publication provided by:

Dr. Dennis Buckmaster
Associate Professor of Agricultural Engineering
Penn State University

Dr. Mike Collins
Professor of Agronomy, University of Kentucky

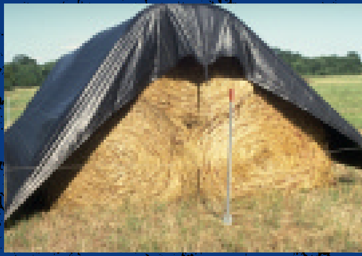
Dr. Bill Kunkle
Professor and Extension Animal Scientist
University of Florida

Dr. David Petritz
Professor and Extension Agricultural Economist
Purdue University

Dr. Alan Rotz
Research Agricultural Engineer, USDA/ARS,
East Lansing, MI

Dr. Jim Russell
Professor of Animal Science, Iowa State University and Issue Team Leader, The Leopold Center, Ames, IA.

Many Different Approaches Can Be Used To Reduce Hay Storage Losses.



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