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THE DOLLARS AND SENSE OF HAY PRODUCTION

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Donald E. Pogue
Dairy Scientist and Assistant Superintendent
North Mississippi Branch Experiment Station

Roscoe L. Ivy
Agronomist
Prairie Research Unit

Richard R. Evans
Animal Scientist and Superintendent
Prairie Research Unit

C. Pat Bagley
Animal Scientist and Head
North Mississippi Research and Extension Center

Introduction

Hay is the primary feed source for cattle during the winter. The quality of hay is dependent upon harvesting a high-quality forage, and the proper management through baling, storage, and feeding. Hay losses from baling to feeding can range from 5% to 65%. A review of the economic value of this nation's cattle industry makes clear the importance of producing high quality hay and minimizing losses.

Of all agricultural commodities produced in the United States, beef cattle and calves rank number one, and dairy cattle and dairy products number two (1994) in terms of total economic value. Together, the beef and dairy industries combine to account for more than 38% of all U. S. agricultural income. The selling and marketing of hay ranks third in the United States (1994) in total sales of agronomic crops, at $11.8 billion, slightly less than the $12.0 billion generated by soybeans and less than the $23.0 billion in annual sales from corn (AFGC, 1995). Based on these figures, the combination of beef cattle and calves, dairy and dairy products, and hay account for about half of all agricultural economic activity in the United States. This total economic value does not include the value of grazed forages, which provide more nutrients to livestock on an annual basis than does hay.

On a global basis, beef and veal production was estimated in 1995 to be approximately 80 billion pounds with the United States accounting for just over 30% of this total (MLC, 1994). Animal production has been recognized as the leading economic multiplier activity in the world today (Parker, 1990). On a worldwide basis, only 8% of the human diet comes from animal products, while in countries like the United States and Canada, 30% of the caloric intake is from animal products (Bourlaug and Dowswell, 1994). Carruthers (1993) has put forth an interesting hypothesis that the developed countries, and the United States in particular, will become even more important suppliers of meat and dairy products in the future, with developing countries becoming more important as producers of manufactured goods. As countries increase their standards of living and per capita income, there is an accompanying rise in the consumption of beef and other meat products.

Based upon these trends, the future of beef, dairy products, and the forages cattle utilize as major nutrient resources appears quite positive. However, in a global market, there will be increasing pressure to maintain a low cost of production. Efficient systems of grazing and hay production will provide the basis of cost-efficient livestock production.

Estimates are that the cost of total digestible nutrients (TDN) is approximately 2.5¢ per pound for grazed forages compared to an estimated 7¢ per pound of TDN for hay or silage. Wilkins (1990) estimated that silage and haymaking are two to three times more expensive than grazing when compared on a per pound of TDN basis. In other parts of the world, such as Europe, the majority of forage is stored as silage (Wilkinson and Stark, 1987), while most forage in the United States is stored as hay. Fowler (1969) estimated that of all calories consumed by beef cattle, 75-80% are from either grazed or stored (hay) forages. While hay usually represents the least expensive method of providing nutrients to cattle when grazing is not available, hay is relatively expensive and time-consuming to produce and feed. It sometimes appears that producers spend all of the hot months growing forage and making hay, and all the cold months feeding hay.

Much of the hay sold in the United States is sold by the bale, based on color or forage type, with little concern over quality. Good-quality hay is often sold too cheap, and poor quality hay is often sold for more than it is worth. Poor-quality hay is low in both protein and energy and is usually high in fiber. Because poor-quality hay is high in fiber, cattle tend to eat less because of its slow rate of digestion in the rumen, and therefore, do not/cannot eat enough to make efficient gains. Contrast this to a good-quality hay that cows readily consume and quickly digest, resulting in more efficient production of meat and milk. Knowing hay quality is a critical factor in formulating economical supplementation programs, if necessary.

This publication focuses on all aspects of hay production, based on experience as well as research at the Mississippi Agricultural and Forestry Experiment Station, several brochures, and information from agricultural experiment stations in other states. It includes:

- Forage types as hay crops.
- Fertility requirements of forage crops.
- Weed control in forages.
- Haying equipment.
- Impact of hay quality on supplemental feeds and costs.
- Hay storage losses.
- Hay storage systems.

The purpose of this bulletin is to focus on the importance of managing forages for hay production, and to suggest how producers can reduce costs and prevent nutrient losses in hay systems by improving management in production, storage, feeding, and supplementing.

PART 1: FORAGES THAT CAN BE USED TO PRODUCE HIGH QUALITY HAY

Forages are the backbone of almost every successful livestock operation in the Southeast. Grazing of forages by livestock can reduce the amount of stored forage needed for maintenance and production. However, stored forage is needed when pasture growth is insufficient to meet livestock feed requirements. A good grazing and hay program can supply the majority of livestock nutrients needed on a year-round basis. A total forage-hay management program must be developed to meet the needs of livestock, unless the producer is only in the cattle business during seasons of the year when forages are actively growing.

When developing a forage program or improving an existing forage program, factors to be considered include: 1) objectives of the livestock producer, 2) type of livestock, 3) available capital, 4) physical location, 5) climate, (6) soil type, and (7) available labor.

Forage species fall into two broad groups: 1) legumes or 2) grasses. These forages can be further subdivided within two broad categories. The subgroups under the main groups are cool season and warm season forages. Forages within the subgroups can be further subdivided into annual and perennial forages. An **annual** is a plant that germinates, grows, reproduces, and dies in one growing season. A **perennial** is a plant that, under suitable conditions, persists for more than one growing season. **Warm-season** plants begin growth in the spring or early summer and make most of their growth during the warmer months of the year. **Cool-season** plants make most of their growth during the cool season of the year. In the South, cool-season plants are usually planted and begin growth in autumn, but sometimes they are planted in early spring. Bermudagrass is an example of a warm-season perennial grass; ryegrass is an example of a cool-season annual grass. Table 1 gives a classification and listing of forage crops commonly grown in Mississippi. Table 2 lists legumes commonly grown in Mississippi.

The selection of forage crop(s) to plant or establish for hay should be based on several factors, including: 1) forage type and variety, 2) adaptation, 3) nutritional needs of animals, 4) quality of hay, 5) hay yield, and 6) cost of establishment and maintenance. There is no perfect forage crop. Generally, some of our most long-lived forages are relatively low in quality. Some high-quality forages can be short-lived because of heavy grazing pressure imposed by livestock, or because of insect, drought or disease pressure. Examples of this includes alfalfa, fungus-free fescue, and several of the clovers.

Selection of forage species for hay is limited to those adapted to the soil types and conditions on a producer's location and his management capabilities. Hay can be produced from both annual and perennial crops, but perennial forages are generally more economical because of the lower yearly cost of establishment compared to annuals. Legumes are usually higher in quality than are grasses, and cool-season grasses are generally higher in quality than warm-season grasses. This is generally true under similar management conditions, although forage quality is impacted by time of the year, regrowth, and other factors.

TABLE 1. FORAGE GRASSES COMMONLY GROWN IN MISSISSIPPI.

Grasses			
Perennials		Annuals	
Warm-season	Cool-season	Warm-season	Cool-season
Bahiagrass	Tall fescue	Browntop millet	Oats
Bermudagrass	Orchardgrass[a]	Corn	Rye
Dallisgrass		Crabgrass	Ryegrass
Johnsongrass		Forage sorghum	Triticale
		Foxtail millet	Wheat

		Grain sorghum	
		Pearl millet	
		Signalgrass	
		Sorghum-sudan hybrids	
		Sudangrass	

[a] Limited to only the northern one-third of Mississippi counties.

TABLE 2. FORAGES LEGUMES GROWN IN MISSISSIPPI.

Legumes			
Perennials		Annuals	
Warm-season	Cool-season	Warm-season	Cool-season
Kudzu	Alfalfa	Alyceclover	Arrowleaf clover
Sericea lespedeza	Birdsfoot trefoil	Cowpea	Ball clover
	Red clover	Korean lespedeza	Berseem clover
	White clover	Soybean	Black medic
		Striate lespedeza	Burclover
			Common vetch
			Crimson clover
			Hairy vetch
			Hop clover
			Persian clover
			Rose clover
			Subterranean clover
			Winter pea

A number of forage species are used for hay production. Forage crops are in one of three stages of growth: vegetative, reproductive, or dormant. The vegetative stage of growth is when the crop is comprised of leaves and stems. The reproductive stage of growth occurs when the crop is flowering or seedhead formation occurs. Dormant is when the plant is not actively growing, such as bermudagrass during mid-winter. In general, forage to be harvested for hay should be in the vegetative stage of growth, or just beginning its reproductive stage of growth. This is the point where forage quality and quantity for hay production is usually optimized. The **ideal stage** to harvest various forage crops is provided in Table 3. Grass-legume mixtures should be harvested according to maturity of the legume.

If forages are fertilized properly and cut at the proper stage of growth, nutritional needs for most classes of livestock can be met without supplemental feeds, other than a complete mineral supplement. Table 4 gives a comparison of some of the forage species commonly used for hay production in Mississippi. Again, cool-season grasses tend to be higher in quality than warm-season grasses, provided they are harvested at the proper stage of growth. Legumes tend to be higher in quality than either warm- or cool-season grasses.

TABLE 3. RECOMMENDED STAGE OF GROWTH FOR HARVESTING VARIOUS FORAGE CROPS[1] AS HAY.

Plant species	Time of harvest

Alfalfa	Bud stage for first cutting, one-tenth bloom for second and later cuttings. For spring seedings, allow the first cutting to reach mid- to full bloom.
Orchardgrass or Fescue	Boot to early head stage for first cut, aftermath cuts at 4 to 6 week intervals as forage is available.
Red, Arrowleaf, or Crimson Clovers	Early bloom.
Sericea Lespedeza	Height of 15 to 18 inches.
Ryegrass, Oats, Rye, or Wheat	Boot to early head stage.
Soybean	Mid-to-full bloom and before bottom leaves begin to fall.
Annual Lespedeza	Early bloom and before bottom leaves begin to fall.
Ladino or White Clover	Cut at correct stage of growth for companion grass.
Hybrid Bermudagrass	15 to 18-inch height for first cutting, harvest every 4 to 5 weeks or when 15 inches high.
Bahiagrass	Cut every 21 to 30 days.
Sudangrass, Sorghum-Sudan Hybrids, Pearl Millet or Johnsongrass	Boot stage or a height of 30 to 40 inches.

[1]J.D. Burns, J.K. Evans and G.D. Lacefield, "Quality Hay Production," Southern Regional Beef Cow Calf Handbook, SR5004.

There are differences between forage species regarding the tonnage they are capable of producing. Most species, when cut at the proper stage of growth, will provide adequate crude protein and energy content to meet animal nutritional needs for most classes of livestock.

PART 2: SOIL FERTILITY AS IT INFLUENCES FORAGE PRODUCTION AND MAINTENANCE

Soil fertility is crucial to adequate forage production, stand persistence, and decreasing weed competition. ***Don't guess, soil test*** is the only way to know the fertility of a soil and determine what fertilizers are needed to successfully grow a forage crop. Recommendations given following a soil analysis are based on the assumption that all forages produced will be utilized for grazing, silage, or hay.

Pastures for hay or grazing should be fertilized and limed according to soil test recommendations. The pH scale is the measurement of the acidity or alkalinity of a particular soil. Soils with a pH reading of 7 are neutral, soils with a pH below 7 are termed acid, and those above pH 7 are basic or alkaline. Most forage crops perform best with a soil pH between 5.8 to 6.5, although many may grow at pH levels well outside this range. To adjust the pH of an acid soil to a more neutral level, lime should be applied according to soil test recommendations. Correcting soil pH improves the availability of several essential elements in the soil needed for plant growth, while it blocks or reduces the uptake of certain elements that can be toxic to plants. Lime comes in two different forms, dolomitic or calcitic, with calcitic the more common, and usually less expensive per ton in this area. Calcitic lime is a good source of calcium. Dolomitic limes supply both calcium and magnesium. When soil tests indicate that soils are low in magnesium, dolomitic lime should be used since it is a good source of magnesium and will also raise the soil pH. With either source of lime, the finer the grind or the particle size, the more quickly the lime will increase soil pH.

Major nutrients that are routinely measured in soil analyses are phosphorous and potassium. Tests for many secondary and micronutrients must be specifically requested. Secondary nutrients are calcium, magnesium, sulphur, and manganese. Micronutrients include manganese, iron, boron, copper, molybdenum, chloride, and zinc. Soil test results will show producers the status of each element requested in a soil analyses and allows them to formulate a fertilizer plan specific to individual fields. On permanent pastures, soil tests should be conducted every 2-3 years at a depth of about 2 to 6 inches. On hay fields and where annual forage crops are planted, soil tests should be taken annually at a 6-inch depth. Reliable soil test results enable a producer to purchase only what fertilizer is needed. Removal of the major nutrients by plants and from nutrient movement in the soil occurs at a ratio of approximately 4-1-4 (N, P, K, respectively) for hay land and 4-1-2 for permanent pastures. Legumes remove soil nutrients at a rate of approximately 0-1-3 from the soil, and N fertilizer is not required by legumes. Hay harvesting removes large amounts of nutrients, and removal rates increase with higher hay yields. These above figures are averages and should be used only when a soil analysis of the specific site is not available. Average nutrients removed by forage crops are presented in Table 5.

TABLE 4. AVERAGE HAY YIELD, CRUDE PROTEIN, AND TOTAL DIGESTIBLE NUTRIENT (TDN) CONTENT OF VARIOUS HAY CROPS[1].

			Approximate nutrient level[3]	
Type of hay	Annual (A) or perennial (P)	Average hay yield (tons/ac)[2]	Crude protein, %	TDN,%
Cool-season forages				
Alfalfa (early bloom)	P	3-6	17-22	57-62
Arrowleaf clover	A	2-3	14-17	56-61
Oats	A	1-4	8-10	55-60
Orchardgrass	P	2-5	12-15	55-60
Red clover	P	2-4	14-16	57-62
Rye	A	1-4	8-10	50-55
Ryegrass	A	1-4	10-16	56-62
Tall fescue	P	2-4	10-15	55-60
Warm-season forages				
Annual lespedeza	A	1-2	14-17	52-58
Bahiagrass	P	3-5	9-11	50-56
Coastal bermudagrass (4 wks)	P	5-8	10-14	52-58
Common bermudagrass	P	2-6	9-11	50-56
Dallisgrass	P	2-5	9-12	50-56
Johnsongrass	P	2-5	10-14	50-60
Pearl millet	A	2-6	8-12	50-58
Soybean	A	2-3	15-18	54-58
Sericea lespedeza	P	1-3	14-17	50-55
Sudangrass	A	2-6	9-12	55-60

[1]D. M. Ball, C. S. Hoveland and C. D. Lacefield. 1991 Southern Forages. PPI Press. Atlanta, GA.

[2]Assuming the crop is grown in an area to which it is adapted using recommended production and harvesting practices.

[3]Dry matter basis, assuming recommended production and harvesting practices and no excessive weather damage. Forage quality is affected by many factors.

TABLE 5. NUTRIENT REMOVAL BY HAY CROPS[1].

Crop	Yield (tons) Per Acre	Approximate nutrients removed N	P_2O_5	K_2O
Alfalfa[2]	5	225[2]	65	225
Coastal bermudagrass	6	240	60	240
Red clover[2] - orchardgrass	4	170[2]	50	160
Tall fescue	3	120	45	120

[1]Data compiled by J.K. Evans and Garry Lacefield, University of Kentucky.

[2]The legumes alfalfa and red clover do not require a source of fertilizer N.

In summary, lime makes required nutrients more available for the plant by correcting soil acidity. Phosphorous is needed in small amounts for growth, root growth, and winter survival. Potassium is needed in larger amounts for winter hardiness, plant persistence, and plant growth. Nitrogen is the basic component in increasing yields. Nitrogen fertilizer increases crude protein content and growth rate of the plant. On some sandy soils, sulphur may be needed. Each nutrient must be present in adequate amounts for forage production and stand persistence.

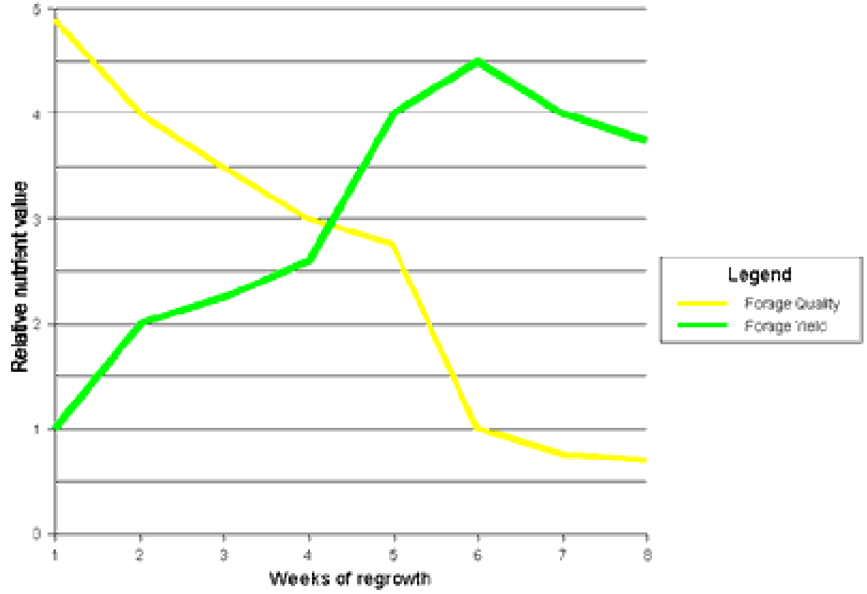
PART 3: FACTORS AFFECTING HAY QUALITY

Producers many times become overly concerned with yield of hay (bales or tons per acre) and neglect hay quality. While even poor quality hay can be utilized by cattle, protein and\or energy supplements will be needed to overcome nutrient deficiencies in the diet. Feeding poor quality hay significantly increases supplemental feed costs needed to meet animal nutritional needs. The difference in quality from poor, fair, and good hay may be only a matter of when the hay is harvested. A fair-quality hay could have been a good-quality hay had it been harvested 10 days earlier. Cutting 10 days earlier would improve forage quality with little appreciable reduction in total yield harvested. A seed head is important if you are selling seed, but not if you are making high-quality hay. **Any time a plant goes from vegetative production to the reproductive stage of growth in its life cycle, forage quality decreases.** This principle applies to all forages commonly grown in Mississippi. For optimum quality and quantity, grass should be harvested when it is in the boot stage and legumes (clovers and alfalfa) should be harvested in the early flowering (10% flower) stage. As plants reach the reproductive state of maturity and seed heads or flowers appear, growth rate slows, digestible protein declines, and fiber levels increase.

The new growth or regrowth of any forage following harvest is relatively high in quality as evidenced by the grazing patterns of cattle. Cattle tend to continually regraze the shortest grass in a pasture and leave the taller, stemmy, less palatable, and more mature grass. The early grass regrowth is short and lush, and cattle tend to graze it over and over again. Cows will usually eat the coarse stemmy grass when it is the only forage source available. When cattle are forced to graze poor-quality forage, they generally lose weight and experience nutritional stress. Keeping the grazing patterns of cattle in mind, we can plot the general relationship between forage quality and quantity (Fig. 1).

It is known from the observed grazing pattern of cattle that new growth is high in quality and palatability, but it is also obvious that there is less total forage available to be grazed. Having this relatively short, high-quality forage is ideal for grazing, but not practical for hay harvest. As time passes and plants mature, the total forage yield increases, with an accompanying decrease in quality. The two lines in Figure 1 cross at about 4 weeks of regrowth for most forages. This generally corresponds to the boot or early flowering stage of the warm-season grass forage plants. This point, where amount and quality intersect, will usually yield the greatest harvestable amount of TDN. Before this intersection, there is high-quality forage, but relatively low yield; and after this point, the forage is lower in quality and higher in yield.

Figure 1. The Relationship Between Forage Quality and Forage Yield Based upon Weeks of Plant Regrowth.



It is approximately at this intersection of forage quality and forage yield that the plant enters the reproductive stage of growth. The sole purpose of the plant at this point is to produce a seed and to protect the seed from being grazed as best it can. Studies with tall fescue have shown that the hemicellulose content is highest when the plant is in the reproductive stage of growth. While quality is relatively high, voluntary intake of the forage by grazing livestock is low with tall fescue in a reproductive stage of growth (Bagley et al., 1983). It seems that the plant, by increasing hemicellulose levels, is attempting to protect itself from grazing of the seed heads by livestock to increase its chance of producing seed to propagate itself. Hemicellulose has been identified as a plant characteristic most closely related (negatively) to voluntary intake (Van Soest et al., 1968).

Table 6 shows how alfalfa (often called the queen of all forage crops) decreases in energy and protein content as it increases in plant maturity. According to the table, alfalfa loses approximately 16% of its energy value and 33% of its protein value in only a 2-week period. A decrease in quality characteristics occurs in grasses and clovers as well, but not always as excessive in such a short period as in alfalfa. As the plant matures, lignin, an indigestible plant component, also increases (Van Soest et al., 1965) causing a decrease in palatability and digestibility. The combination of lower quality and lower palatability can result in dramatic decreases in animal performance. Blaxter et al. (1961) found that for each one percentage unit decrease in forage digestibility, animal gains decreased by 5%.

TABLE 6. THE EFFECTS OF ALFALFA STAGE OF GROWTH ON VARIOUS NUTRIENT CHARACTERISTICS.

Stage of maturity at harvest of alfalfa	TDN %	Crude protein %	Acid detergent fiber[1]%
Mid-bud	64	21	<40
First bloom	61	18	44
Mid-bloom	57	16	51
Full-bloom	54	<14	56

[1]Acid detergent fiber (ADF) is a measurement of some of the lesser digestible fiber portions of a plant, including lignin.

Hay Testing

"Don't Guess - Hay Test." Smell and color of hay reflect the conditions under which hay was harvested and stored, but tells you essentially **nothing** about quality. Bright green, clean-smelling 8-week-old mature Coastal bermudagrass hay will be readily consumed by cattle, but the TDN content will not produce the desired animal performance. Nelson et al. (1980) reported that daily gains of steers were .59, .28 and -.09 lb/day for bermudagrass hay that was harvested at 4, 6, or 8 weeks of regrowth. The only way to know the quality of hay is by having it tested for nutrient characteristics. Once the quality of hay is determined, proper supplementation can be determined. Efficient producers feed only supplements needed by the animal. The cost of overfeeding protein and energy, particularly protein, which is the most expensive ingredient on a per-pound basis, is one few producers can afford. Animals **fatten** on grass they harvest themselves, but producers generally attempt to **maintain** this body condition during winter with harvested forages and supplemental feeds.

Your county agent can show you how to take a hay sample, where to send them, and provide other needed information. Most counties have a hay probe to help ensure the collection of a good, representative hay sample. Along with your hay sample, send information to the forage testing lab about what class of livestock you intend to feed the hay and available supplemental feeds. You will receive recommendations showing which and how much of various supplements are needed to be fed in order to achieve a balanced diet for livestock. Collect hay samples from 8 to 10 bales in each cutting to ensure having a representative sample. If you test the hay in June and feed it in December, the quality may be lower if the hay is stored outside because of nutrient losses.

Table 7 gives the nutrient requirements for a 1,000-pound cow, either dry or lactating. Remember, a cow produces and maintains her weight based on how well her nutrient requirements are met. Feeding less than animal requirements will result in weight loss, decreased milk production, and may result in a longer interval between calving and rebreeding and a lower conception rate.

TABLE 7. DAILY NUTRIENT REQUIREMENTS OF A 1000-POUND COW

	Dry matter intake	TDN	Crude protein
	-------lb-------		
Dry (6-9 mo. pregnant) cow	19.6	10.5	1.6
Lactating cow (Avg. milking)	22.0	13.8	2.5

TABLE 8. THE AMOUNT OF VARIOUS SUPPLEMENTS REQUIRED WITH DIFFERENT QUALITY HAY TO MEET COW PRODUCTION REQUIREMENTS.

Hay quality		1,000-lb dry cows		1,000-lb lactating cows	
		Corn	CSM	Corn	CSM
		-------lb------			
Excellent	(58% TDN, 12% CP)[1]	None	None	None	None

Good	(55% TDN, 10% CP)	None	None	1.0	.5
Fair	(52% TDN, 8% CP)	.5	None	2.0	1.5
Poor	(48% TDN, 6% CP)	1.5	1.0	3.0	2.5

[1]TDN = total digestible nutrients. CP = crude protein.
CSM += cottonseed meal (41%CP).

Table 8 shows the supplemental feeds required with different quality hays. The higher the quality, the less supplemental feed needed to balance the diet.

Table 9 shows the cost difference for a 150-day wintering period for cows fed different quality hays. The cost for wintering a cow with either fair or good-quality hay is less than when a poor-quality hay is fed. Only a laboratory analysis reveals the true nutrient content, enabling producers to make good business decisions regarding feeding the cow herd. Since hay is seldom harvested under ideal conditions, testing the hay allows producers to feed lower- quality hay early in the winter when nutrient requirements are lower for the cow herd, and save the better-quality hay for later in the winter when the cows have calved and their nutrient requirements have increased. **Always feed the lowest-quality hay to the animals with the lowest production requirements.** Also, balance hay with animal needs - generally, the youngest animals need the highest quality forage, followed by lactating cows and finally dry mature cows.

TABLE 9. SUPPLEMENT COST FOR DIFFERENT QUALITY HAYS FED BEEF CATTLE DURING A 150-DAY WINTERING PERIOD.

Item	Hay quality		
	Good	Fair	Poor
Amount of supplement required			
Corn, lb	60	165	315
Cottonseed meal, lb	30	90	240
Annual cost of supplements	5.10	14.63	33.38

All hay is not the same. Table 10 shows the yearly results for hay samples analyzed through the forage testing laboratory in Mississippi for four different hay types. Alfalfa hay samples submitted had an average crude protein content of 17.99% and a TDN of 59.50%. These nutrient analyses data for alfalfa are high averages. Careful examination also shows some low crude protein (7.84%) and TDN (47.8%) values for alfalfa hay that were submitted. The crude protein and TDN in poor-quality alfalfa is no better than that in poor-quality ryegrass or bermudagrass hay. **Forage type does not assure high quality**, and neither does color or smell. From Table 10, one can see that all forages analyzed can have poor to excellent-quality hays. As shown in these hay sample data, there are occasions when bermudagrass hay can be of higher quality than alfalfa hay. People will pay a premium for alfalfa hay, but there are occasions when it is not worth this higher price. A good business decision would be to request a copy of the hay analyses prior to the purchase.

TABLE 10. AVERAGES AND RANGES OF ALL HAY SAMPLES SUBMITTED TO THE MISSISSIPPI CHEMICAL LAB, 1990-1994.

		Nutrient characteristics		
Forage	Item	Crude protein	Acid detergent fiber	TDN

		------%------		
Alfalfa	Average Range	17.99 7.84-24.20	36.56 26.15-47.52	59.58 47.87-70.7
Common bermudagrass hay	Average Range	9.89 4.57-21.48	41.21 29.90-56.15	56.44 39.80-69.0
Tifton-44 bermudagrass hay	Average Range	11.12 6.35-18.72	40.33 30.89-59.18	57.42 36.43-67.9
Ryegrass hay	Average Range	10.25 4.60-25.35	41.39 21.67-56.50	56.24 39.42-78.2

PART 4: TYPES OF HAYING EQUIPMENT

The cost of purchasing, maintaining, and operating hay equipment is high. Basic equipment needed for any hay operation includes a forage cutter, rake, and a baler. In addition, a tractor with a minimum of 50 hp is needed. The larger round balers and mowers require larger tractors, often in the range 85 to 90-hp. Sizes and types of hay equipment should be appropriate to the acreage involved with hay production. The following sections discuss the advantages and disadvantages of the different types of haying equipment to help producers make a more informed decision about these expensive purchases involved with producing hay.

A. Hay Mowers

Sickle Bar and Sickle Bar Mowers with Conditioners

The traditional piece of hay cutting equipment in most non-fire ant infested parts of the United States is the sickle bar mower. The sickle bar mower is relatively inexpensive and cuts hay cleanly by using a scissoring motion of the blades. The sickle bar uses a movable blade with replaceable cutting teeth that pushes the green forage against a stationary rasp bar that shears off the plants. When these blades are new and sharp, cutting is very efficient. The sickle bar can be combined with a pair of rubber rollers to form a mower-conditioner, which cuts, squeezes and crimps the forage that passes through after being cut. The sickle bar mower with conditioner became the premier machine used in hay cutting for many years and allowed the forage to cure faster.

There are disadvantages to using the sickle bar mower. These include problems with cutting hay that has been blown down and with teeth breakage. By carefully cutting blown-down forage against the direction the hay is down, a relatively good job can be done in harvesting. Rocks and sticks sometimes found in a hay field can cause breakage of blades, teeth, or both when they come in contact with the sickle bar cutter. Broken blades and teeth result in streaks of uncut hay in the hay field. Repair time of broken pieces is decreased by having the proper tools and replacements parts with the tractor, or an extra cutter bar in the hay field.

The most important cause for the demise of the sickle bar mower in lower parts of the South has been the infestation of hay meadows by the imported fire ant. If fire ants are heavily populated in a field, cutting efficiency with a sickle bar is usually low due to clogging of the bar or breakage of teeth. Tonnage harvested in these infested fields is reduced due to poor cutting efficiency, and the operator is irritated after removal of several of these mounds from his cutter. Because of the presence of fire ants in Mississippi and most of the humid

Southeast, sickle bar cutters have almost become obsolete.

A 7-foot sickle bar costs approximately $2,500, while a 9-foot cutter with a conditioner costs approximately $11,000.

Disk Mowers and Disk Mowers with Conditioners

The disk mowers are the best mowing machines available for cutting hay in areas where fire ants are a problem. These mowers are fast, cut the forage evenly, and are relatively easy to maintain. One of the best features of the disk mower is that it can operate on uneven ground. The fast spinning rotary motion of the heads of the disk mower cuts through mounds with little problem. However, wet mounds may cause some accumulation of soil on the cutter bar. The blade sets of a disk mower are easily accessible and should be replaced and/or sharpened on a routine basis. If blades are broken or excessively worn, they can cause an imbalance in the cutter head, which may result in costly and unnecessary wear and repair on the cutter bar. Always keep shields and guards in place with disk mowers because blades rotate at high speeds and can occasionally sling objects that could cause injury. Disk mowers will cut anything that a sickle bar cutter can, only faster.

Disk mowers are more expensive to buy and maintain than sickle bar cutters. A 9-ft disk mower costs about $6,000; the addition of a conditioner increases the cost to about $16,000.

B. Rakes

The hay rake is the least expensive piece of haying equipment that will be purchased. There are several types of rakes, including side delivery models, wheel rakes, tedders, and rake tedders.

Side-Delivery Rake

The oldest type and a popular rake is the side-delivery hay rake. Both pull-type and three-point hitch side delivery rake models are available and both are effective. Most producers use the pull-type model. The rakes generally have four or five bars, each with tines that rotate either to the right or left. These bars are attached to a pair of rotating wheels, which spin as the rake wheels turn in ground-driven models. There are also three-point hitch models which are powered by the PTO. Pickup teeth are attached at approximately 8- to 10-inch intervals on each bar. The turning action of teeth, while skimming the ground, collects the cut hay and discharges it on the right or left side of the rake. Side-delivery rakes are heavy duty and last many years if properly maintained. These rakes handle long, short and intermediate length hays, forming a peaked, narrow windrow, which is more of an advantage for square than round balers. The cost of a single side-delivery rake is approximately $3,600.

Wheel Rakes

Wheel rakes are a relatively new innovation and can be bought as either single- or double-wheel models with three, four or five wheels to a side. Rotation of the wheel and hay collection into the windrow is a result of the ground to wheel-tooth friction. Rotation of the wheels (and teeth) results in the forage being picked up and windrowed on either the left or right side or a single windrow in double-wheel models. Rough terrain in pastures can result in poor ground-to-wheel tooth contact, which results in the loss of the turning or spinning action of the teeth and leads to poor pickup and windrowing. Making hay in rough terrain also increases maintenance costs of tines and other parts of haying equipment.

Wheel rakes may be the best rake for use with round balers. One can adjust the width of the double-wheel rake windrow to approximately match the width of the pickup reel on the round baler. This helps the driver of the round baler make a more dense and uniform bale with less effort and weaving action.

The wheel rake will probably require more maintenance and may not last as long in the hayfield as a side-delivery rake. However, the cost of the wheel rake is much less than that of a side-delivery model. Wheel rakes cost about $900 for a single, $1,700 for a double (3-wheel models). A wheel rake does not handle long-stemmed hays as well as does a side delivery rake and windy conditions can cause hay to accumulate on the wheels. Wheel rakes come in three-point hitch and pull-type models and, when operating properly, one rake will windrow about as much hay as a round hay baler can keep up with.

Tedders and Rake Tedders

Hay tedders fluff-up hay, allowing more air movement through the windrow so the forage dries more quickly. This quicker drying time allows hay to be baled sooner, giving hay a greener appearance and making the hay more marketable, although not necessarily higher in quality.

Most cattle producers do not always use a hay tedder since it is viewed by some as an unnecessary cost. However, hay sold to horse owners is generally tedded since appearance and color are often as important as quality characteristics in a hay sale. The tedder is especially helpful when windrowed grass hay has been rained on and must be spread to dry before it can be baled. A hay tedder is a must when spring hay crops, such as ryegrass or oats, are being cured because of their high moisture content and relatively poor drying conditions. The tedder can be used to windrow hay by reversing the rotation of the teeth and the resulting windrow is much like that of a side-delivery rake. Tedders typically cost $4,500 or more.

C. Balers

Hay balers make either square or round bales. Square baler models make either small (50 to 80 pounds) or large size (2,000 pounds) bales. Small square bales have been the standard in the hay industry for many years. The newest innovation is the large, square hay balers (800 to 2,000 pounds per bale) that is most often used for hay to be transported long distances. Most of the large, square balers are found in the western United States. These bales average 1,500 pounds or more and are most commonly comprised of alfalfa hay being fed in confinement livestock operations, particularly dairies.

Square Baler

The 50- to 80-pound square hay bale is the standard for most hay that is sold. While price of hay should be determined by quality and exact weight, square hay bales are often marketed based upon color and smell of the hay with little regard to the weight of each bale. Square balers compress hay in rectangular bales tied with wire or string. Square bales stack and store easily, but must be stored in a dry place as soon as possible after baling. Hay that has been rained on after being square baled will generally mold, lose quality, and heat up and can cause a barn fire. Square bales are labor-intensive and costly to handle, store, and feed. Small square bales primarily use human labor for hauling to the barn after baling and for feeding. Mechanical pickup and stacking units are available, but cost-effective only for large hay operations. If producers sell hay, square bales are usually the most profitable method to use because the price per pound of hay is maximized. Square bales can be handled without equipment and easily transported in relatively small quantities. The baler that makes the small square bales is relatively expensive, costing approximately $12,000.

Large square bales are most common in the western United States. These large bales may weigh 800-2,000 pounds and are most commonly alfalfa hay. The large, square bales store and transport more easily than large, round bales because they can be stacked tightly and more easily on a truck, rail car, or boat. They are subject to the same spoilage potential in humid conditions as the small square bale. Much of the hay put up in these large square bales is sold to large livestock farms, usually dairies, or shipped overseas. This baler costs approximately $20,000.

Large Round Baler

The large round baler, also a relatively recent innovation, has become the most popular method of baling hay. Small round balers were available about 30 years ago, but are not as popular as the large, round baler. There are many misconceptions associated with large, round hay bales, particularly their storage. Round bales shed water similarly to a thatched roof, but they **cannot** be stored outside and exposed to rain without **losing quality and quantity**. The amount of these losses depends on the amount of water penetrating from the top and the bottom of the bale. Most round bale sizes range from 800 to 2,000 pounds, but there are smaller-size balers available. Bale size may be dictated by feeding requirements, number of animals, as well as tractor size. The bigger the bale, the greater the horsepower requirement for baling and transportation. Large round hay bales differ by making either a hard or a soft center core. Research shows little difference in storage losses or in moisture loss after baling with either core-type system. However, greater leaf loss has been reported in the soft-core baling system when packaging alfalfa.

Most round balers use multiple wraps of twine to keep the bale together, with hemp and plastic twine the most common. Since the number of twine wraps around a bale is greater with round bales, twine diameter requirements are less than for twine used for square bales. Plastic twine will remain intact longer than will hemp twine during outside storage, but hemp twines biodegrade better in the pasture. Used plastic twine must be picked up after hay feeding in pastures to keep it out of pasture clippers and other machinery.

Round hay balers with a net wrap attachment were introduced in the mid-1980's. The net wrap may be the best material for round bales, particularly where outside hay storage must be used. Round bales with the net wrap are tight and dense and will shed some water when stored outside. If net wrap bales are elevated to avoid ground contact, little quality is lost with outside storage. The plastic netting must be removed from each bale before feeding to prevent problems with this material being in pastures and potentially getting tangled in machinery. This net wrap attachment adds approximately $2,000 to the cost of the baler.

D. Equipment Tips

Operation of any haying equipment should be preceded by a thorough evaluation of all pieces of machinery and tractors, including lubrication of all moving parts based on the maintenance schedule recommended by the manufacturer. **Preventive** maintenance should be the main objective of any hay operation. Breakdowns of hay equipment are inevitable because of the number of moving parts involved, but many breakdowns are due to lost bolts, loose parts, etc., and are preventable.

Having a minimum number of equipment operators will usually lead to less down time for equipment maintenance. An operator who regularly operates a particular piece of equipment knows when the sound of a machine changes, and unusual sounds may indicate an impending problem. Increased familiarity with a piece of machinery usually results in a better lubrication and maintenance schedule. Many equipment malfunctions start out being minor, but not recognizing/correcting the problem leads to greater problems.

Moisture meters are handy for those producers who wish to bale hay at a certain moisture percentage. For example, hay offered for sale to horse owners needs to be 15% moisture or less to reduce the potential for mold. Cattle are less sensitive to mold than horses, but excessive mold lowers palatability, if not quality, regardless of which class of livestock consumes the hay.

Leafy hays, such as alfalfa, will shed their leaves if raked while they are too dry. On the morning before baling, leafy forages (dry or nearly dry clovers, alfalfa and soybeans, etc.) can be windrowed early while the dew is still on the hay to minimize leaf loss. These hays will dry very quickly in the windrow. Mower-conditioners allow producers to windrow the hay when it is cut, permitting the hay to be baled without raking to reduce leaf loss. However, baling time may be longer because of less airflow through some parts of the windrow.

The density of bales can be varied with the ground speed of the tractor and baler. Generally, the slower the ground speed of a tractor, the denser the bale. If hay is slightly damp and the possibility of rain is increasing, you might increase the ground speed of the baler and put up a looser bale, which will allow moisture to escape more easily because of greater airflow through the bale. These loosely formed bales tend to "squat" more than bales with a higher density and should be stored inside if possible to reduce storage losses. Because the outside of the bale is not wrapped as tightly, water can get into the bale more easily than in a more tightly wrapped bale.

Bales packed too tightly in the middle often have an egg-shaped configuration. These bales tend to suffer greater deterioration because of a greater surface area exposure than a more square-cornered bale would have. Round balers pack hay from the outside inward.

The first round baler pickup patterns suggested a weaving pattern across the windrow. Most manufacturers may still suggest the weaving pattern to start the bale, but then suggest operators to travel approximately equal distances on each side of the windrow to create a uniform, sharp-edged bale edges.

PART 5: THE IMPORTANCE OF WEED CONTROL

A weed is defined as "a plant growing in a setting in which it is considered undesirable." In other words, a weed is any plant growing where it is not wanted. It is important to keep hayfields free of weeds that are nonnutritious, nonpalatable, and/or toxic to livestock. There are various types of weed problems. The most common weed problems are: 1) established perennial grass with broadleaf and/or grassy weeds, 2) established grass-clover with broadleaf and/or grassy weeds, and 3) newly planted grass, clover, or grass-clover with broadleaf and/or grassy weeds.

Weeds need to be controlled because they reduce the yield of desirable forage, lower forage quality, and compete with desirable forages for moisture, nutrients, sunlight, and space. Some weeds are toxic to livestock while others are simply unpalatable or can cause physical injury to livestock (i.e. thorns). In a grazing system, there are many weeds that cattle will avoid while grazing as long as there is ample desirable forage. However, when the weed is baled up as hay, cattle will consume it because they cannot easily select them out of the hay. Thus, weed control in hay meadows is even more critical than in a grazing system.

Weeds growing in association with a forage crop can aggressively compete with desirable forages for soil nutrients. Many types of weeds initiate growth earlier in the spring than do common pasture grasses, such as bermudagrass. Woody-type weeds can grow taller and shade out the desirable grasses if they are not controlled. It takes as much soil nutrients to grow a pound of weeds as a similar amount of desirable forage. A nutrient analysis of pigweed shows it will contain twice the amount of nitrogen as does the companion grass, with similar amounts of phosphorous and potash (Watson and Cole, 1978). Smartweed contains 1.6 times more phosphorous and ragweed 3.5 times more potash than the typical companion forages. Weed control is particularly critical in situations when soil fertility is below optimum levels.

There are various methods of controlling weeds, including mechanical, chemical, fire, crop competition, crop rotation, and biological control. The weed control methods most often used are mechanical and chemical, or a combination of the two. Some producers will use fire at certain times, but burning is becoming more unacceptable because of smoke, difficulty in controlling the spread of the fire, the associated liability, and air quality concerns.

In many situations, weeds in forages can be controlled with herbicides. The Weed Control Guidelines for Mississippi (anonymous, 1997) gives a complete glossary of approved and recommended herbicides, herbicide combinations, weeds controlled by specific chemicals, rates, timing, and restrictions as to replanting, haying, grazing, and withholding time for animals to be slaughtered.

General guidelines that need to be followed in applying herbicides include: 1) match the herbicide and rate of application to the type of forage crop and weed to be controlled, 2) apply herbicide at the correct time, 3) apply to weeds that are actively growing, 4) apply when temperature is above 60^{o} F for maximum effectiveness, 5) apply to assure good coverage of herbicides on the weed to be controlled, 6) always use herbicides in a safe manner, and 7) read and follow label directions **exactly.**

Recommendations for weed control are very difficult to make because of the number of variables involved. All pastures will have weeds, but that does not mean weed control is required. There is a threshold for the amount of weeds in a pasture that needs to be reached before weed control is recommended. The threshold for controlling weeds depends on the end-use of the forage. If the weed in a pasture is perilla mint, herbicide control is required when only small amounts of this toxic weed are present. If the weed is curly dock, very little is tolerated by lactating dairy cows, but more can be tolerated by grazing beef cows. For a horse hay market, very little of any weed can be tolerated if hay is to be sold at a premium. Therefore, any recommendations for weed control must be based upon the exact weed and the intended use of the hay.

PART 6: ROUND BALE STORAGE SYSTEMS

In a hay storage system, organization and identification are key components to success. It is important to know where each cutting of hay is stored in a barn, have it properly analyzed for quality, and have the hay accessible when a group of animals needs a particular type and grade of hay. If each hay cutting cannot be stored for accessibility, then similar grades of hay should be grouped so each grade can be accessed when needed. A hay identification system such as tagging, signs, or diagrams should be used to keep track of field origin, type, stage of growth, harvest date, and other factors that would help indicate hay quality. It is recommended that all hay groups be sampled and the results of the forage analyses be available and part of these records. This information allows the producer to match hay quality with animal nutrient needs for improved animal performance, greater efficiency in the use of supplemental feeds, and a more balanced diet. Most hays will need some type of supplemental feed when fed to higher producing animals, and balancing the diet based on hay quality allows for the most efficient use of both hay and supplements.

In situations where hay storage is limited, the highest-quality hays should always receive the producer's best storage system. High-quality forages have more water-soluble nutrients that can be removed more quickly out of the bale by the action of water, and the nutritive deterioration from moisture is rapid. Poorer-quality hays have less digestible nutrients initially, so there is less nutritive value to lose during storage.

A well-designed hay storage system provides for protection from moisture to all sides of a hay bale, provides ventilation around the bale for moisture removal during the curing phase after baling, and facilitates the removal of moisture condensation caused by the daily heating and cooling of hay. Properly stored and ventilated hay should be drier after the storage period than when it was initially baled and placed in the storage facility.

Results from hay storage trials (Pogue et al., 1992; Pogue and Tomlinson, 1993) conducted at the North Mississippi Branch Experiment Station in Holly Springs indicate that most plastic hay covers work well for maintaining hay quality when bales are elevated away from ground moisture (Table 11). However, these covers do not correct the problem of water being absorbed into the bale from ground contact when these bales are stored touching the ground (Table 12). These data indicate that nutrient losses caused by water moving through stored hay bales occurs with both falling water (precipitation) and from rising water (absorbed from ground contact).

The major problem caused by water is loss of hay nutrients. Nutrients present in hay can be divided into two broad categories: water-soluble nutrients and fiber components. These water-soluble nutrients include both sugars and proteins in the plant, the most important nutrients in terms of quality and digestibility. Because the sugars and proteins are water soluble, water moving through the bale results in these nutrients being "washed away," resulting in a reduction in hay quality. The higher initial quality (high in protein and sugars) of hay, the greater the potential losses from moisture action.

Plastic Net Wrap

Plastic net wrap on large round hay bales helps prevent water from penetrating the hay bale by uniformly compressing the outer surface providing a dense outer layer that tends to shed rainfall. However, when the dense surface produced by a net wrap is placed in direct contact with the soil during storage, soil moisture is readily absorbed by the bale. Moisture content can increase up to 30% in the bottom of the bale compared to approximately 10% in a similarly outside stored, but elevated bale (Tables 12 and 13). Likewise, twine or net-wrapped bales covered with a bale slip or sleeve and elevated above the soil produce hay comparable to shed-stored hay (Table 11). Again, when these same bales are ground-stored, moisture collected from rain and condensation within the bale tends to pool between the bottom of the bale and plastic sleeve or slip, with moisture levels increasing to about 40% in the bale bottoms compared to 10% or less when elevated or shed-stored (Table 12). Elevated bales do collect some moisture during rain events, but elevation off the ground allows for air circulation around and under the bale to remove the excess moisture and help reduce deterioration of hay quality.

Twine Wrapped

Twine-wrapped bales without additional protection from the effects of moisture will spoil at a rate of about 1 inch per month of storage, or approximately 30% of the bale's total dry matter during a 6-month storage period. This spoilage can be reduced to less than 5% by storing hay under a shed or covering it with plastic and elevating it above ground moisture. A hay storage system, even when using plastic coverings, should provide as much air movement around the bale as possible. A round hay bale at the time of baling will contain approximately 15% moisture. After baling and during proper storage, hay will dry down during inside storage to about 9% moisture, meaning that 6% of the bale weight will typically be lost if there is good air circulation. In a 1,500-bale, this potential moisture loss is approximately 90 pounds, or 12-13 gallons of water per bale. Therefore, bale weight losses during inside storage are primarily moisture losses, and do not indicate excessive dry matter losses. Plastic sheeting used for protecting hay bales stored outside should be secured above ground level to allow the soil under the bale to dry and to allow air currents to evaporate any condensation between the bale and plastic coverings. This also allows condensation that occurs to drain away from the bale during the expelling of the 12-13 gallons of water mentioned above.

Bales stacked in a pyramid should be covered with each end of the stack left open to provide the necessary air movement to remove plant cell moisture and condensation under the covering. Air circulation is critical in the proper storage of hay because of the natural loss in moisture of hay after baling. If this water accumulates in certain areas of the bale storage mass, the results can be mold and loss of nutrients and quality.

Bale Caps

Commercial bale caps have three disadvantages in bale storage systems. These bale caps: 1) cover less than half of the total bale surface; 2) are relatively expensive compared to other type coverings, and even compared to prorated barn storage costs; and 3) are difficult to secure and keep covering the bales during an extended storage period. Again, elevating a bale stored outside greatly improves storage and reduces hay quality losses, particularly when a bale cap is used. The bottom of a bale stored on the ground with its top covered by a cap has bottom spoilage similar to a bale not covered since much of the nutrient loss in round hay bale storage occurs from the bottom up, rather than from the top down.

Plastic Stretch Wrap

Plastic stretch wrap is best used for storing high-moisture forages as haylage in situations where adequate drying time is not available to produce dry hay. High-moisture forage can often be baled as haylage and wrapped 12-24 hours after cutting at moisture levels of 40-55% under most weather conditions. Fermentation of the haylage, similar to silage, is complete after a 3-week storage period at which time feeding may begin. In most cases, the sooner these bales are fed, the less chance there is for them to have spoilage losses caused by a loss of their anaerobic condition (i.e. tears or breaks in the plastic sheeting). Allowing proper fermentation of high-moisture haylages and storage is dependent upon air being excluded from the haylage. Typically, only our highest-quality forages (such as ryegrass and alfalfa) are put up as haylage. Most haylage is put up in early spring when forage quality is high, but these are less than ideal climatic conditions for dry hay production.

Plastic Wrap on Dry Hay

If plastic wrap is used on dry hay, hay should be as dry as possible at the time of wrapping to prevent excessive bale heat and moisture collection during curing. Remember, a 1,500-pound bale will attempt to shed about 12-13 gallons of water as it cures from its 15% moisture content at baling to its stable 9% moisture level after adequate storage time. Also, plastic should not be allowed to curl over the ends of the bales because this allows the wrap to catch and trap moisture against the hay. Plastic-wrapped bales should not be stored end to end before the bale is fully cured to allow for improved air circulation. End-to-end storage of plastic-wrapped bales blocks the only exit for excess moisture from these bales and cuts off most air from circulating around the bale.

Storage on Tires

In most cases, storing round bales on tires results in excessively high moisture content, particularly in bale bottoms, and creates generally poor storage conditions. Tires trap moisture in two locations. First, any moisture draining from the bale either in the form of rain or condensation during bale curing is trapped between the tire's rim and the bale. Second, all moisture escaping between the tire's rim and the bale flows into the tire's air chamber and provides a constant supply of moisture to the bottom of the bale. Also, tires totally block air flow under bales, which severely retards the evaporation of moisture from the tire, soil, and the bale. Storage of hay bales on tires has consistently been shown to be one of the poorest storage methods of all those that have been evaluated and should be avoided. Elevating round bales away from ground moisture and providing airflow under bales significantly improves storage conditions of round bales stored outside (Table 13).

Bale Bags

Individual hay bale bags that can be made air tight are best used for high-moisture bales and are commonly referred to as baleage or haylage (i.e. ryegrass and alfalfa). Early spring forages can be stored using this method when climatic conditions would prevent making dry hay. Two disadvantages to bale bags are their relatively high cost ($7.50-$14.50) and the need to feed baleage or haylage as quickly after fermentation as possible. Similar to the plastic stretch wrap in method of preservation, any damage to the bags that allows air inside the bale destroys the anaerobic condition and allows spoilage to occur and decreased feeding value.

PART 7: FEEDING AND STORAGE LOSSES

Hay feeding losses are much greater than many producers realize. Even with high-quality hay and excellent storage, poor feeding practices can result in hay nutrient losses of 20-30%. To prevent feeding losses, managers should start by producing hay that is highly acceptable and palatable to the animal. When hay is fed free-choice, always use panels or rings which allow only the head of the animal to reach the bale. In a study comparing the feeding of conventional square bales and round bales on a sod without restrictions and round bales with panel restrictions (Smith et al., 1975), animal gains were higher on restricted round bales. Further, it required only 58% as much hay (presumably that much less hay loss) to produce those higher gains compared to nonrestricted round bales. Livestock gains were significantly higher when fed restricted round bales compared to limit-fed square bales, with the same amount of hay required per pound of gain (Table 15).

In a study (Lechtenberg, et al., 1974) where three different bale types were fed either with or without racks, an average of 32% more hay was required by cows when no racks or rings were used (Table 14), indicating a substantial loss (approximately 32%) during hay feeding. Hay feeding location is important because placement of bales on a dry, well-drained area can help further keep the bottoms of bales from becoming damp and spoiling before all the hay can be consumed. Some producers feed hay on concrete slabs or gravel beds, which will help reduce feeding losses caused by ground moisture. There is now a fabric that, when installed under gravel, prevents gravel from sinking into the soil under conditions of excessive moisture. This should also help reduce moisture spoilage losses from water absorption by the bale during feeding.

The practice of leaving round bales in the pasture where they were baled without moving them can increase spoilage and feeding losses. Hay feeding losses in this situation can be reduced by using temporary electric fences to restrict animals to only certain bales of hay left in pastures so they will consume the hay in a shorter period. This procedure forces animals to clean up all hay bales before they are allowed access to new or more desirable bales. Once a bale has been partially consumed, more of the hay is exposed to the deleterious effects of rains. Once the size of the bale has been reduced by consumption, cattle will also tend to walk over the hay, bed down on the hay, and make it unfit for consumption. Substantial hay feeding losses are possible from both trampling and the longer exposure to ambient weather conditions and their adverse affects on hay nutrients.

All animals tend to select the highest-quality forage to consume first, whether in the form of pasture or hay. For mature, nonlactating cows, nutrient requirements are such that they should be forced to consume all of a low-quality hay bale before additional hay is fed.

Hay left in the feeding ring when additional hay is placed on top of it will usually go uneaten. Higher-producing animals should have more of a choice so they can select higher- quality hay, which allows them to maintain high levels of performance through increased dry matter consumption. High-producing animals should not be forced to clean up lower-quality or unpalatable hay.

Hay feeding losses, in many instances, are related to the quality of hay stored and storage losses. High-quality hay coming out of storage in a well-preserved condition will be more readily consumed than environmentally damaged hay. For this reason, it is often hard for the producers to separate feeding losses from storage losses.

Without protective storage of hay bales, it is not uncommon to lose substantial amounts of quality and dry matter in the outer 6 inches of a hay bale, which represents approximately 35% of the total volume of a round hay bale. Combine this loss of 35% of hay nutrient content during storage with any possible feeding losses caused by improper feeding conditions and practices, and these total losses can be excessive. Nelson et al. (1983) estimated that total losses for good-quality ryegrass hay can be as high as 65% when both storage and feeding losses are combined. The hay used in that study was a good-quality ryegrass hay, the type of hay that should be fed to cattle with high production requirements.

Dollar value losses of poorly stored and improperly fed hay can best be calculated by the amount of nutrients that must be replaced in the form of additional hay or protein/energy supplements. Research from Mississippi and other states indicates a 25 to 30% total loss for round bales of high quality is a conservative estimate with bales stored outside on the ground. If these bales are fed without using rings or panel feeders, hay losses can reach 50% (Table 16).

Considering the variety of bale sizes and storage periods, a 400-pound loss per 1,200- pound bale is a realistic loss. If the hay originally contained 8% protein and 55% TDN, this loss can amount to 32 pounds of protein and 220 pounds of TDN. When the TDN loss is replaced with corn at a cost of $5.50 per cwt, replacement cost is $15.12 per bale for TDN only. Replacement cost for protein losses during storage is $8.32 when using soybean meal at $11.00 per cwt, but can be as high as $20 if self-feeding protein blocks are used as the supplemental protein source. If additional hay is purchased to replace the dry matter losses from storage and feeding, cost will be approximately $10 per bale. Regardless if loss is figured on replacing protein, TDN, or hay, the minimum losses will be approximately $8 - $10 per bale when hay is ground stored.

Most hay storage systems will be economical compared to outside ground storage when all losses are considered. Hay barns or sheds are the most reliable storage method, and in long-term operations (10-20 years), represent the most economical storage method. High-quality, open-sided, steel buildings can be erected for approximately $4.50 per square foot of covered floor space (quote from Griffin Steel Building, Inc., Ripley, MS, June 1995). Prices for sheds and pole barns vary depending on the availability of labor and materials for each operation. In many instances, used materials can be purchased and the building erected by the producer for much less than a manufactured building commercially erected will cost. The square footage needed per bale depends on the dimensions of the bales and the height to which the bales are stacked. As an example, a standard 5- foot wide x 6-foot diameter bale will require approximately 28 square feet of storage space when stacked on end, and 30 square feet when stacked on sides. The floor area needed per bale is directly related to how high bales are stacked. Stacking three bales high is a safe and workable system that can be handled with a fork lift or tractor equipped with a front-end loader. Using a three-bale high stack reduces the square footage of storage needed per bale to approximately 10 square feet of floor space per bale. Using a top-of-the-line steel building price of $4.50/square feet and a 20-year building life, storage cost per bale would be $2.22 per bale each year. Using a 10-year building life would double the storage cost per bale to $4.44, but would still be a very economical choice considering the value and quality of the saved hay losses and other uses for the building when its not being used for hay storage. Again, the nutrient and storage losses are greatest for high- quality hay, so better-quality hay will give you the greatest payback when using barn storage. When producing poor- or fair-quality hay, losses may not be as substantial.

TABLE 11. MOISTURE IN UPPER HALF OF ROUND BALES ELEVATED AND GROUND STORED AT THE NORTH MISSISSIPPI EXPERIMENT STATION, HOLLY SPRINGS, MS.

	Moisture[1]	
Treatment	Pre-storage	Post-storage
	%	%
Elevated 12 inches		
Net Wrap	9.0	9.9

Net Wrap/Sleeve	9.9	8.8
String Wrap	8.7	18.8
String Wrap/Sleeve	9.1	9.2
String Wrap/Cover	7.5	8.4
String Wrap/Cap	7.4	9.5
Average	8.6	10.7
Ground Storage		
Net Wrap	8.8	12.3
String Wrap	11.4	19.7
String Wrap/Sleeve	11.2	14.4
String Wrap/Cover	11.8	13.0
Plastic Wrap	12.6	11.1
Average	11.2	14.1
Elevated on Truck Tires		
String Wrap/Cap	13.6	21.6
Net Wrap	19.1	24.1
String Wrap/Sleeve	13.3	22.1
Average	15.3	22.6
Shed Storage on Pallets		
Net Wrap	11.2	7.8
String Wrap	14.2	8.5
Average	12.7	8.1

[1] Two bales per treatment, 6 cores taken per bale.
[2] + = gain; - = loss in moisture content.
SOURCE: Baling and Storage Systems for Large Round Hay Bales. D. E. Pogue, J. R. Johnson, J. E. Tomlinson, North MS Research and Extension Center Annual Report, p.173, 1992.

TABLE 12. MOISTURE CONTENT IN THE BOTTOM 16-INCHES OF ROUND HAY BALES STORED ON GROUND.

Treatment	Pre-storage moisture (%)	7 mo post-storage (%)	Change (%)
Net Wrap	8.8	26.2	+17.4
Net wrap w/sleeve	11.2	39.6	+28.4
Twine wrap	11.4	30.9	+19.5
Average	10.5	32.2	+21.7

Source: Adapted from: Moisture Retention in the Bottom of Round Bales Elevated and Ground Stored. D. E.

Pogue and J. E. Tomlinson. Information Bulletin 256, p. 299, North MS Research and Extension Center. 1993.

TABLE 13. MOISTURE IN BOTTOM 16 INCHES OF ROUND HAY BALES ELEVATED 12 INCHES ON RAILS.

Treatment	Pre-storage moisture (%)	7 mo post-storage (%)	Change (%)
Net wrap	9.0	9.5	+0.5
Net wrap w/sleeve	9.9	8.2	-1.7
Twine wrap	8.7	9.3	+0.6
Average	9.2	9.0	-0.2

Source: Adapted from: Moisture Retention in the Bottom of Round Bales Elevated and Ground Stored. D. E. Pogue and J. E. Tomlinson. Information Bulletin 256, p. 299, North MS Research and Extension Center. 1993

TABLE 14. HAY LOSSES WITH AND WITHOUT RACKS WHEN FEEDING LARGE HAY BALES.

Package type without racks	No Rack -- lb--	Rack --lb--	Additional hay needed ---%---
Heston 10 stack	28.38	21.01	35.1
Vermeer 605 bale	24.00	19.58	22.6
Hawk-bilt 480 bale	27.45	19.80	38.7

Source: V. L. Lechtenberg, W. H. Smith, S. D. Parsons and D. C. Petriz. Journal of Animal Science, 39:1011-1015, 1974.

TABLE 15. STEER PERFORMANCE AND HAY CONSUMPTION USING THREE HAY FEEDING SYSTEMS.

Item	Conventional bales on sod	Round bales on sod	Round bales with panels
Hay (dry matter basis) (lb/day)	9.11	19.13	12.29
Corn lb\day	2.00	2.00	2.00
CSM 41% lb/day	1.50	1.50	1.50
Animal, no.	17	17	17
Days on test, no.	79	79	79
Initial average wt., lb	535	538	538

Final average wt., lb	615	635	646
Gain, lb	80	97	108
Average daily gain, lb	1.01	1.23	1.37
Hay required/lb of gain	9.00	15.58	8.99

Source: Hay in Round and Conventional Bale Systems. L. A. Smith, W. B. Anthony, E. S. Renoll and J. L. Stallings. Circular 216, Auburn Univ. June 1975.

TABLE 16. HAY LOSSES FOR TWINE-WRAPPED ROUND BALES AFTER 7 MONTHS OF STORAGE.

Treatment:	Ground	Gravel	Tires	Rack	Rack cover	Barn
Percent loss:	65.2	49.8	43.0	37.9	13.8	3.5

Adapted from: Forage and Grasslands Progress, Vol. XXIII and XXIV, 1985. Lalit R. Verma, Billy D. Nelson, Louisiana State University.

PART 8: CONCLUSIONS

Hay is typically the most inexpensive and widely used stored feed for the winter feeding of cattle when grazeable forages are not available. Numerous factors impact the quality of hay actually consumed by cattle, including:

ï Initial quality of the forage crop.
ï Quality forage losses during cutting.
ï Quality forage losses during curing.
ï Quality losses during raking.
ï Quality losses during baling.
ï Quality losses during transporting hay from field to the storage area.
ï Quality losses during storage.
ï Quality losses during transporting from storage area to the feeding area.
ï Quality losses during feeding.

Of these sources of hay nutrient losses, storage losses can be the greatest potential losses, but can be the most controllable. While we cannot control the unexpected rain that occurs just hours before hay is dry enough to bale, we do have control over the storage method. Barn storage is the cheapest long-term hay storage method when prorated over the entire life expectancy of the barn, if all hay storage losses and nutrient replacement costs are taken into account. For hay bales stored outside on the ground, total hay and feeding losses have been reported as high as 65% (Nelson et. al., 1981) and can routinely run 25%. Dry matter losses in a barn with complete protection from rainfall will run about 3 to 4% annually, slightly to substantially better than other hay storage systems. Using a storage system of rails to keep hay off the ground during outside storage, plus some kind of plastic sheeting or net wrap on the hay, greatly reduces hay losses compared to the uncovered ground storage, but will generally be greater in cost than the annualized cost of barn storage. Hay losses during storage are considerably greater when their impact on lowering animal performance is considered and are more pronounced when used to feed high-producing animals.

Several key points to remember in considering the production, storage, feeding, and supplementing of hay includes:

1. Fertility. It is recommended that producers should soil test annually in hayfields, and supply the amounts of

P, K, lime and other nutrients called for in the soil analyses. Maintaining these soil nutrients in the "medium" level will make forages productive and cost effective. Apply N according to how much forage you need to produce for your livestock. Recommendations are to apply at least 50 pounds of actual N (150 lb of ammonium nitrate) per acre, but usually not over 75 pounds of N per acre at any one application to promote rapid forage growth. If you are growing a hybrid bermudagrass, such as Coastal or Tifton 44, for hay production, N application rates can go up to 100 pounds per acre because of the ability of these hybrids to be very efficient with utilizing N at higher application rates.

2. Weed Control. Weeds compete with the desirable grasses and clovers in pastures for sunlight, water, and nutrients. Also, many weeds are toxic to cattle. Cattle will not graze most weeds, such as yellow buttercup, but if some weeds are baled in hay, the cattle will consume them because they are not able to select weeds out of the hay. Hay produced to sell will never command a premium price if it contains weeds - at least not by the same buyer more than once.

Chemicals are available to control weeds in pastures and hay fields. Some of these chemicals are relatively cheap, others are expensive. Young, tender annual weeds can be sprayed with lower rates of herbicides to kill the weeds and allow the more desirable forages to be more productive over the entire growing season.

3. During hay storage, water is the enemy. The nutrient components of forages can be broadly divided into two major categories: fiber components and water soluble components. The water-soluble portions of the plant are comprised of proteins and sugars - the highest-quality portion of a plant. Quality estimates (TDN) are high in hays that have relatively high portions of the water-soluble components. However, because these components are water soluble, they are the forage components most easily lost during storage because of the actions of water. Water-soluble components are lost by water penetrating the hay and carrying them away. Obviously, losing the sugars and proteins in a plant will result in a loss of the TDN value of hay.

The basis of any hay storage system must be to keep water away from the hay bale, or at best to prevent water from penetrating the outer layer of the bale. If hay is not going to be stored in a barn, and if hay that is stored outside is not elevated off the ground, consideration should be given to one of the new hay mesh wraps to keep water from penetrating very far into the bale. Over a several-year period, a hay barn is still the cheapest method of storing hay when all hay losses are considered along with reduced animal performance and increased supplemental feed costs.

High-quality hay contains a relatively high level of water-soluble nutrients. If barn space is limited, or if there is limited space to elevate hay off the ground that is stored outside, protect the highest-quality hay first by using one of these two storage methods. Do not allow high-quality hay to be turned into low-quality hay because of poor storage methods. If you start out with poor-quality hay, it cannot be harmed as severely as good-quality hay, so store the lowest-quality hay outside, or in the poorest storage area.

4. Harvest hay before it reaches advanced maturity. One signal that a forage is ready to be cut for hay is when it starts to change from a vegetative state to a mature (reproductive) stage of growth. Flowers or blooms in clovers and legumes indicate when forages become reproductive. In grasses, seed heads are a sign of reproductive maturity. When a plant goes to maturity (reproductive stage of growth), it fully intends to protect itself from grazing so that it can reproduce itself. In tall fescue, the seed head emerges, and the hemicellulose content of the plant goes up dramatically (Bagley et. al, 1983). Hemicellulose is the forage component most closely related to reduced forage intake. As hemicellulose level increases, forage intake usually decreases. The relationship between forage quality and animal intake is important in determining animal performance. Feeding a poor quality hay has two major disadvantages: 1) the hay is low in energy, so cows need to eat large quantities to gain weight, and 2) since high roughage hays are usually high in hemicellulose, cattle will not eat the hay as well as they would a hay of higher quality with lower hemicellulose. Also, fiber takes longer to digest in the rumen of cattle, so a high-fiber hay stays in the rumen longer, further reducing hay intake.

Cattle performance is based on how much energy an animal takes in, assuming it consumes a balanced diet. With high-quality, high-palatability hays, cattle eat well and gain weight readily. With low-quality hay, consumption is low and the hay consumed is low in quality, with the amount of energy consumed too low to produce adequate gains.

5. Don't guess - hay test. There is no one capable of looking at a hay sample and telling its TDN and crude protein values. Much of the hay sold in the United States is based on color, with buyers associating green color with higher quality. Hay color tells you the conditions under which hay was made. Hay cut in July and August when temperatures are hot will dry quickly to a pretty, green color. That does not mean the hay is high in quality, just that it was cut and baled under optimum conditions.

A hay producer in east Texas who routinely baled about 20,000 square bales of hay once gave a talk on marketing hay. He said he routinely made five cuttings of hay in a normal year, putting each of the five cuttings in individual areas of a barn. The producer always had a hay analysis conducted on each cutting, and placed the results of the quality analysis in a conspicuous place close to each cutting of hay in the storage area. The prettiest, greenest hay was usually his third (July) and fourth (August) cuttings. However, these third and fourth cuttings routinely produced the lowest TDN hays, based on nutrient analysis. Longer day lengths and higher temperatures are associated with increased levels of fiber in plants. Even though these hays were relatively low in quality, they were always the first bales of hay to be purchased, primarily because of their attractive appearance. The highest-quality hay was from the first cutting, but since the day lengths were shorter, and temperatures not as hot, the hay usually stayed on the ground longer during the curing process and lost its green color. Also, the first hay cutting tended to have more spring weeds present in the hay. While this first cutting was usually the highest nutritive value hay, the hay producer very seldom had anybody wanting to purchase this hay.

The east Texas hay producer described in this situation has the best of situations. He sold his poorest quality hay at a premium price, and nobody bought his best quality hay, so he fed that to his cow herd. His neighbors could never understand how they had bought what they thought was his "best" (brightest green color) hay, but their cows were never as fat as were the hay producer's own cows who were fed the assumed "worst" hay.

Strong consideration should be given as to whether a producer owns his own hay equipment, or if he purchases hay from other sources. This decision should be based on the size of the cow herd, existing equipment, abilities of the manager, and if you purchase from other sources, the quality and availability of hay.

Don't guess - hay test: know what you are feeding, and supplement with protein or energy accordingly. Each citizen of Mississippi has $100 worth of forage testing credit, with each hay sample costing about $22. When you submit a hay sample through your county Extension agent, clearly state on the hay analysis form the class of animal to which the hay will be fed. By providing this additional information, you will not only get back the hay quality analysis, but you will also get a form indicating what supplements, if any, and in what amounts they need to be fed to provide a properly balanced diet for the cattle.

Hay production can be a complicated process. Starting with the proper quality forage and storing and feeding the hay correctly can result in an inexpensive, yet cost-effective winter feed that will produce increased performance in your herd. Taking a hay sample and having it analyzed will allow you to feed a balanced diet that should meet predetermined performance levels for your cattle.

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