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Managing for High-quality Hay

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Hay is the most common source of stored feed used in livestock operations. Because surveys show that 86 percent of the harvested hay is used on the producer's own farm, producers should be concerned with producing high-quality hay to maximize animal performance.

Hay harvested at the proper stage of plant growth and undamaged by weather provides nutrients at a lower cost than other high-quality supplemental feeds. The range of hay quality varies greatly, depending on climate, fertility, weed control, stage of maturity at harvest, harvest conditions and storage. Most forage species, whether legumes or grasses, can produce high- or low-quality forage.

Although many types of forages are preserved as hay for livestock feed, much of it is of poor quality and fails to provide the nutrition needed. Low-quality hay requires extra supplementation to meet animal requirements. High-quality hay is dry, palatable, highly digestible forage that has enough nutrients to meet the livestock's nutritional needs.

The quality of hay depends on a combination of both physical factors and its nutritional status. High-quality hay:

- Requires little or no additional supplementation;
- Is bailed at a moisture level low enough to prevent spoilage, yet moist enough to prevent losses from shattering; and
- Is free of foreign matter, weeds and molds.

Legumes such as alfalfa and clovers generally contain a higher percentage of protein, minerals and vitamins than grasses. However, grasses usually produce more hay and more total digestible nutrients per acre than legumes. Grasses also have fewer insect, disease and harvest problems and require fewer production inputs than alfalfa.

Regardless of the type of forage, good hay production requires special attention to details and constant management.

Factors determining hay quality

Hay quality is affected by such factors as maturity at harvest, soil fertility, nutritional status of the plant, available moisture during the growing season, season of the year, ratio of leaves to stems, stem size, weed control, foreign matter, harvesting, weather at harvest and storage. Of all factors, the most important is stage of maturity or age of the plant at harvest.

About 70 percent of hay quality is determined by the plant's stage of maturity at harvest. As a plant matures toward heading, flowering and seed formation, its growth pattern changes from producing digestible leaves to producing indigestible hard stems, and its ratio of digestible leaves to indigestible stems changes. This ratio determines the forage's nutritive content and digestibility. At each growth stage, the digestible part of the plant tissue decreases rapidly.

Digestibility affects animal performance: A 1 percent increase in digestibility of a warm-season forage increases animal performance by 5 percent.

When immature, plant cells have a thin primary cell wall and are succulent, with soft, flexible tissue that is high in water and water-soluble nutrients. Immature leafy forage plants contain easily

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digestible nutrients; old, mature stems and leaves contain complex nutrients and mature indigestible fiber. As plants begin to form seed, cells mature and a secondary wall composed of cellulose and lignin begins to develop, making the plant more rigid. Like wood, lignin is indigestible.

For example, Coastal bermudagrass, which is 12 inches tall, can be 58 percent digestible in the top third of the plant, 54 percent digestible in the middle third, and only 50 percent digestible in the bottom third. Coastal bermudagrass harvested at 6 weeks old has only 50 percent of the crude protein content and 80 percent of the energy of hay harvested at 4 weeks old.

Because leaves are more digestible and contain most of the nutrients, the higher the leaf content, the higher the quality. Stems are typically lower in digestibility and nutrients. Also, seed heads are usually produced on the ends of stems with no leaves, decreasing the leaf-to-stem ratios. To determine the maturity, look for seed heads. As a guide, grass hay with only a few immature seed heads is high quality; the more mature seed in the heads, the lower the quality.

The proper stage of growth for harvesting forages is when the most total digestible nutrients per acre are available. This usually represents the best compromise between quality and yield. Generally, the younger the crop at harvest time, the higher the quality, but lower the yield. A more mature crop at time of harvest has a higher yield but lower quality. With maturity, crude protein content drops in all crops, and crude fiber increases (see tables 1 and 2).

Research also indicates that forages are higher in quality during spring and fall and lower during mid-summer. Therefore, hay harvested during the spring tends to be higher in forage quality than hay harvested in July and August.

Fertility and water interaction

A forage's protein content is figured by multiplying its nitrogen content by 6.25. It is reported as percent crude protein. Thus, a forage containing 2 percent nitrogen contains 12.50 percent crude protein. The amount of nitrogen fertilizer applied per acre for grasses then greatly influences the crude protein levels in forages harvested at the right stage of maturity. Table 3 lists the pounds of nitrogen contained in dried forages at different production levels.

Because most nutrients are absorbed by roots when dissolved in water, the uptake of nitrogen and other nutrients depends on how much moisture is in the soil. When nitrogen is absorbed with adequate water, new plant proteins and cell formation create growth. If nitrogen levels are too low, grasses continue to pick up water, which evaporates through the leaves, but produce no new growth.

Table 1. Percent of crude protein and crude fiber at different stages of growth for various forages.

Forage	Stage of growth	Percent crude protein	Percent crude fiber
Alfalfa	Early bloom	19.3	27.3
	Full bloom	16.9	31.7
Coastal bermudagrass	3 week growth	18.3	24.2
	7-8 weeks growth	6.7	25.5
Oats	Pre-boot	27.6	19.8
	Early bloom	15.3	28.0
Sudan grass	Early boot	16.8	30.9
	Early bloom	8.1	36.4
Johnson grass	Early boot	15.0	31.2
	Half bloom	8.6	36.0
	Mature seed	5.6	37.9

Table 2. Effect of harvest frequency on yield and digestibility of hay.

Harvest frequency weeks	acre Yield/ (tons)	Percent crude protein	Percent leaf	Percent stem	Percent fiber	Dry matter digestibility
3	7.9	18.5	83	17	27.0	65.2
4	8.4	16.4	79	21	29.1	61.9
5	9.2	15.4	70	30	30.6	59.3
6	10.3	13.3	62	38	31.6	58.0
8	10.2	10.7	56	44	32.9	54.1
12	10.4	9.0	51	49	33.4	51.0

For the best combination of yield and quality without contributing to excess nitrogen in runoff or groundwater, adjust nitrogen to the yield potential. Figure 1, developed from research near Crystal City, Texas, shows the relationship between nitrogen, quality and water use.

Also critical to maintaining stands and producing quality hay are phosphorus, potassium and other nutrients. Take a soil test once a year to determine the amount of plant nutrients remaining after the previous year's production so that those elements removed by harvest can be replaced.

One ton of forage has about 50 pounds of nitrogen, 15 pounds of phosphorus and 40 pounds of potassium. Removing 3 tons of forage annually in the form of hay removes about 150 pounds of nitrogen, 45 pounds of phosphorus and 120 pounds of pottassium. For more fertility information, see Extension publication B-6035, "Crop Nutrient Needs for South and Southwest Texas."

High-yielding production removes other nutrients also. Periodically sample soils in hay fields to determine the levels of pH (Table 4), sulfur, calcium, zinc, iron, etc. If the nutrient levels in the soil are dropping, replace as needed. Generally, nutrients other than nitrogen can be applied once a year.

Harvesting

The goal of harvesting should be to maintain the highest possible nutritive quality, by cutting at the proper stage of maturity, promoting rapid drydown, maintaining high leaf content and timely baling at the right moisture content. Because living cells continue to respire and use energy, manage hay to allow the forage to dry to below 40 percent as quickly as possible. Most forage plants are almost 80 percent water and continue to metabolize cellular carbohydrates and sugars until the moisture levels reach 40 percent. Tight windrows, moist soil and cloudy, humid conditions all delay drying and promote valuable energy losses.

Recent experiments by the U.S. Department of Agriculture indicate that cattle prefer afternoon-cut hay over morning-cut hay. Because cells make sugars and carbohydrates in the presence of sunlight, afternoon-cut hay may contain a higher percentage of highly digestible sugars and carbohydrates. Plants cut in the morning have partially depleted the supply while respiring or using energy through the night.

Harvesting practices that improve hay quality include:

- Cutting in the afternoon;
- Laying hay down on dry ground or stubble to prevent soil moisture from rising into the windrow;
- Raking operations that do not cause leaf loss; and
- Baling at the right moisture level.

Bacteria and fungi that cause hay to deteriorate need moisture to grow. If hay is baled at too high a moisture level, its temperature rises to the point that its quality is lowered, and it may even catch fire. Microbes cannot reproduce if moisture levels are below about 14 percent. Small bales are often referred to as needing to go through a "sweat" in the field before stacking. The "sweat" is an additional moisture loss if the hay was baled too "green." Small 60- to 70-pound bales can be baled at 16 to 18 percent moisture. Hay stored in large round bales need to be dryer (14 to 16 percent) at baling, because moisture cannot escape from the center of a large bale.

Table 3. Pounds of nitrogen in forages at different production levels.

Percent nitrogen	Percent crude protein	1 ton/ acre	2 tons/ acre	3 tons/ acre	4 tons/ acre	6 tons /acre
1.0	6.3	20	40	60	80	120
1.3	8.1	26	52	78	104	156
1.6	10	32	64	96	128	192
2.0	12.5	40	80	120	160	240
3.0	18.8	60	120	180	240	360
4.0	25	80	160	240	320	480

Figure 1. Effects of nitrogen on percent protein, yield and water efficiency.

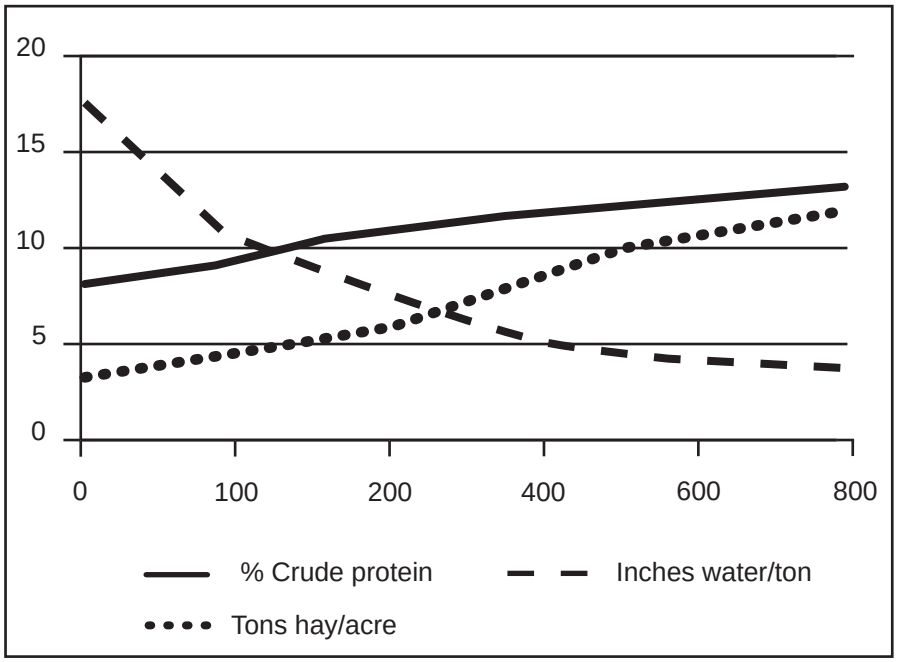

Table 4. Effect of soil pH on relative efficiency of nutrient uptake.

Soil pH	Nitrogen	Phosphorus	Potassium
4.5	21	8	21
5.0	38	10	30
5.5	52	15	45
6.0	63	15	60
7.0	70	30	60

Quality losses

High-quality forages are only a part of high-quality hay production. Poor harvesting can cause as much as a 50 percent loss on digestible nutrients. Other losses can be caused by:

- Cutting forages past the optimum stage of maturity;

- Rain leaching soluble nutrients (highly digestible nutrients) out of the cutting forages and before baling;
- Plant tissues respiring; and
- Leaf shattering from overdry forages.

The biggest losses to quality are caused by delaying harvest from the optimum developmental stage. Alfalfa digestibility declines 0.5 percent per day after flowering; Coastal bermudagrass digestibility declines 0.2 percent per day from 4 to 8 weeks old.

The most digestible nutrients in plants are the water-soluble contents of cells. The younger (immature, succulent) the plants, the more water-soluble nutrients they contain. The older (more mature) the plants, the less water-soluble nutrients they contain.

Rain on cut forages leaches nutrients out of the plant cells and increases dry matter losses. The longer the forage is wet and the more rain that washes through the hay after cutting, the greater the nutrient losses. In a Purdue University study, 1 inch of rain reduced the total digestible nutrients (TDN) content of field-cured hay by 5 percent; dry matter losses from wind-dried hay were 3.5 percent per inch of rain. In general, leaching losses are lower for a fast, short, 1-inch rain than a slow, soaking rain of the same amount. Losses are higher for dry than fresh-cut forage.

Plant cells are living tissue that continue to respire (burn energy) even after cutting. Cutting a plant does not stop the tissue from continuing to live for a while. Drying kills the cells: When moisture drops below 40 percent, cell activity stops. Poor drying conditions allow readily digestible carbohydrates (energy) to continue to respire, which can cause a 10 to 15 percent loss of the original dry matter. Coastal bermudagrass at the Overton Experiment Station changed from 11.1 percent crude protein and 51.6 percent TDN at cutting to 8.9 percent crude protein and 42 percent TDN at baling after two days of drying.

As hay dries, the leaves become brittle and may break apart or fall off the plant. Alfalfa leaves are attached very delicately to the stems and are particularly prone to leaf loss when raked too often or when too dry. Raking losses can amount to 5 to 15 percent and poor baling practices can result in an additional 1 to 15 percent loss.

St orage losses

The amount of storage losses are directly related to the moisture to which the hay is subjected. Hay baled at too high a moisture level develops mold and bacterial degradation or even, in extreme cases, catches fire. Moldy hay can cause digestion problems in livestock. As the hay is "digested" by microbes, dry matter is lost. Keep hay dry. Round bales stacked outside on wet soil lose as much as 25 percent of their original weight in 1 year.

Summar y

Close attention to all aspects of hay production will result in production of high quality and quantities of livestock feed.

ABCs of F orage T esting

ADF	Acid Detergent Fiber is a measure of cellulose, lignin, silica, insoluble crude protein and ash, the least digestible parts of the plant.
CF	Crude Fiber is a measure of total plant fiber.
CP	Crude Protein is an estimate of the amino acids/proteins in a hay/feed based on the total N in the material.
DDM	Digestible Dry Matter is the percentage of digestible dry matter.
DM	Dry Matter is an oven-dried weight, or 0 percent moisture.
DP	Digestible Protein is an estimate of the animal-available crude protein.
NDF	Neutral Detergent Fiber is a test using water to dissolve highly soluble components such as sugars, carbohydrates and proteins from forage. NDF measures the structural fiber in the plant. It is an excellent predictor of consumption.
TDN	Total Digestible Nutrients is an estimate of the percent of total digestible nutrients. It is based on the ADF (acid detergent fiber) of the quantity of available nutrients in the forage.

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