FORAGE CONSERVATION TECHNIQUES:
HAY PRODUCTION


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INTRODUCTION

Forages can be conserved to feed livestock during periods of shortage caused by limited pasture growth or inadequate pasture conditions or when fed as a supplement (for example, when supplementing with a legume). Conserved forages can take the form of hay, haylage or baleage, and silage. While several techniques have been proven as efficient ways to store forages, it is important to keep in mind that, at best, conserved forages can rarely match the nutritive value of fresh forage, and some losses of highly digestible nutrients (sugar, protein, and fat) are unavoidable. The goal in forage conservation should focus on minimizing losses, which start immediately after cutting.

The process of selecting a conservation technique should take into account the suitability of the forage for a given technique, storage capability, weather conditions, and the intended use of the conserved forage. The selected conservation technique should maximize nutrient conservation efficiency and minimize production costs.

HAY PRODUCTION

Hay is defined as forage conserved under aerobic dry or limited moisture conditions. Fresh forage typically has between about 75% and 85% moisture concentration (Collins and Coblentz 2013). Thus, the goal in hay production is to remove moisture as quickly as possible to achieve a target moisture concentration equal to or less than 20% (or a target dry matter concentration greater than 80%). The process of reducing moisture is called curing and is normally accomplished with energy provided by the sun (field curing) or by artificial barn drying using forced heated or unheated air. Moisture concentration less than 20% (preferably less than or equal to 15%) prevents plant respiration and allows for an almost complete conservation of plant nutrients for extended periods (month). Factors that influence the process of moisture loss for hay production can be classified into three types: (1) forage-related, (2) weather-related, and (3) management-related (Rotz 1995; Collins and Owens 2003):

1. Forage-related factors:

Stem thickness and waxy cuticle

Physical characteristics of plants can affect the drying process. As stem thickness increases (solid stems), the drying process slows because of increased radial distance from the stem core to the epidermis, where water must travel to move out of the plant. It is more difficult to dry thick-stemmed, erect plants—such as corn and sorghum-type plants—as fast as plants with thinner stems, such as tall fescue, orchardgrass, or bermudagrass (Brink et al. 2014). In addition, the epidermis of leaves covered with a waxy, impermeable cuticle slows down the process of water loss.

Forage species

Grasses tend to dry faster than legumes. Among legumes, alfalfa and birdsfoot trefoil tend to dry faster than red clover; among grasses, tall fescue dries faster than ryegrass and timothy (Tetlow and Fenlon 1978), and bermudagrass. The differences in drying rates among forage species are mostly a consequence of a high surface

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area to dry-weight ratio. In addition, forages with greater leaf to stem ratios dry faster because leaves dry faster than stems (Rotz 1995). Perennial crops are usually the best option for hay production to minimize the impact of establishment costs. Table 1 indicates expected yield, by region, of the main crops used for hay production in North Carolina.

2. Weather-related factors:

The most unpredictable variable to deal with when making hay is the weather. In reality, very little can be done to the plant or swath to improve drying rates if the environmental conditions are not conducive to moisture loss. Weather factors are highly correlated among each other, and it is therefore difficult to isolate the effects of each factor. Favorable conditions for hay production include high temperature, high solar radiation, and moderate wind speed (up to 12mph) in conjunction with low air relative humidity and low soil moisture. Although weather conditions can change rapidly, checking the weather forecast may aid in determining days of continuous dry weather (after a front moves through) and limited rainfall to also avoid losses due to nutrient washout.

The drying rate is faster at the beginning of the drying process; however, it slows down and reaches zero when moisture equilibrium with the environment is reached. If humidity in the environment is greater than 70%, moisture loss will cease even if temperatures are high. In most regions, hay moisture follows a diurnal pattern in which drying occurs during the day while the lost moisture is partially replaced from the air during the night as humidity levels rise or dew forms (Figure 1).

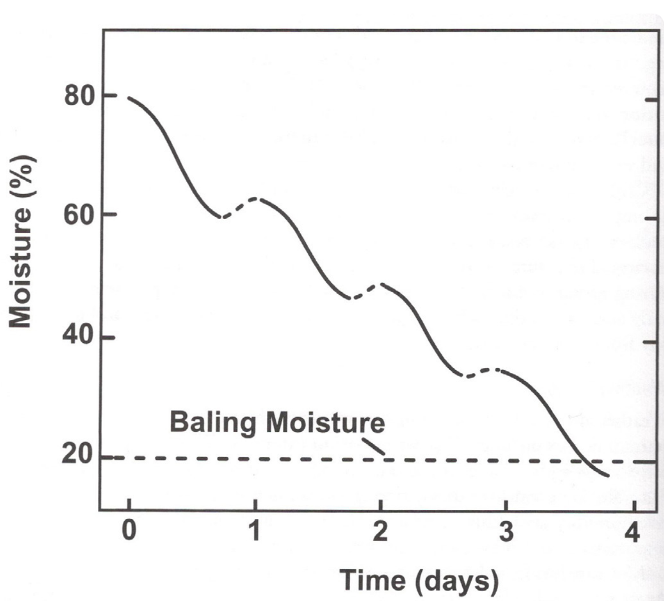

Figure 1.Typical moisture loss pattern in forages during hay curing (Collins and Ownes 2003).

Table 1. Dry Matter Yield by Region of the Most Common Forage Crops Used for Hay Production in North Carolina.

Forage	Region	Dry Matter Yield (lb/ac/yr)
Cool-season forages		
Alfalfa	Coastal Plain	7600
	Piedmont	8000
	Mountains	7600
Ryegrass-Annual	Coastal Plain	7000
	Piedmont	6600
	Mountains	6000
Ryegrass, Perennial	Coastal Plain	NA[1]
	Piedmont	6000
	Mountains	6600
Smallgrain-Oat	Coastal Plain	4000
	Piedmont	3500
	Mountains	3000
Smallgrain-Rye	Coastal Plain	4900
	Piedmont	4500
	Mountains	4000
Smallgrain-Triticale	Coastal Plain	5200
	Piedmont	4500
	Mountains	4200
Smallgrain-Wheat	Coastal Plain	4400
	Piedmont	4000
	Mountains	3600
Timothy	Coastal Plain	NA
	Piedmont	6000
	Mountains	5500
Tall fescue	Coastal Plain	6350
	Piedmont	6350
	Mountains	5850
Orchardgrass	Coastal Plain	NA
	Piedmont	6500
	Mountains	7000
Warm-season forages		
Bermudagrass (common, hybrid, improved seed)	Coastal Plain	7683
	Piedmont	7475
	Mountains	5975
Big bluestem	Coastal Plain	7000
	Piedmont	7000
	Mountains	6000
Gamagrass	Coastal Plain	6350
	Piedmont	6350
	Mountains	5850
Switchgrass	Coastal Plain	8500
	Piedmont	8000
	Mountains	7500

[1] NA: data not available

3. Management-related factors:

Hay will usually require three to five days or more of field curing to reduce moisture to less than 20%. It is especially important to dry hay to less than 40% moisture as soon as possible to prevent nutrient loss due to plant respiration and microbial degradation. The text that follows addresses several management decisions during each step of the haymaking process. These decision can help speed drying and preserve the nutritive value and overall quality of the forage (Rotz 1995; Rotz and Shinners 2007):

Mowing

High quality forage hay production begins when the crop is mown. Forage crops should be mown at the right maturity to achieve the proper balance between adequate yield and nutritive value. While greater amounts of forage accumulate during longer regrowth periods, the nutritive value of the forage diminishes over this time. In addition, the nutritive value in most forages declines rapidly as the crop enters the reproductive stage. As plants mature, there is greater accumulation of cell wall components (i.e., lignin, cellulose, and hemicellulose) compared to cell contents (i.e., protein and carbohydrates), and there is mobilization of nutrients from the vegetative tissue (leaf and stems) to the reproductive tissue, or seedhead. Table 2 indicates two measurements of nutritive value (digestibility and crude protein) and the percentage of dry matter concentration at each physiological stage. As a general rule, this compromise is best reached with legumes, such as alfalfa and clovers, by harvesting at an early bloom stage. With grasses (e.g., fescue and orchardgrass), this compromise is best reached when they are just beginning to produce their seedheads.

There are several types of mowers available for cutting hay, including sickle-bar, disc, rotary drum, and flail (Figures 2 through 5). The type of mower used has little effect on drying, loss of dry matter, and the resulting forage quality; mowing height and frequency, however, have the greatest effect on persistence and nutritive value of the forage.

Figure 2. Sickle bar mower.

Figure 3. Disc mower.

Figure 4. Rotary drum mower.

Figure 5. Flail mower.

Table 2. Nutritive Value and Dry Matter Concentration Estimates at Different Physiological Stages.

Crop	Physiological stage	Digestibility	Crude Protein	Dry matter concentration
		--------------------- %	-----------------------	
Alfalfa	Vegetative (early spring)	75–80	25–30	15–20
	Early bud (top 1/2 of canopy)	70–75	20–25	20–25
	Early bud (bottom 1/2 of canopy)	60–65	16–20	25–30
	10% bloom (top 1/2 of canopy)	68–72	18–22	25–30
	10% bloom (bottom 1/2 of canopy)	55–60	14–18	30–35
Bermudagrass[1]	Vegetative (<4″ tall & 14 days of age)	56–62	15–18	15–20
	Vegetative (6″–10″ & 14–21 days of age)	52–58	12–16	20–25
	Vegetative (10″–15″ & 21–28 days of age)	50–54	11–14	25–30
	Mature (4–6 weeks)	46–50	8–10	30–35
	Mature (8–12 weeks)	40–45	5–7	30–35
Caucasian bluestem	Vegetative (6″–8″)	76+	15–17	18–22
	Vegetative (8″–12″)	70–74	12–14	23–25
	Heading	65–69	10–12	29–33
Fescue / Orchardgrass / Ryegrass / Prairegrass	Vegetative stage (10–21 days of age)	70+	17–22	15–20
	Vegetative (21–35 days of age)	60–70	13–18	20–25
	Vegetative (fall stockpiled)	65–70	12–15	20–25
	Boot	60–65	13–15	20–25
	Heading	55–60	10–12	20–25
	Flowering	50–55	8–10	25–30
	Seeds Forming	45–50	6–8	25–30
Gamagrass	Vegetative (12″–18″)	72+	16–18	18–22
	Vegetative (25″–35″)	65–70	12–15	25–28
	Heading	52–56	8–12	30–35
Small grains[2]	Vegetative (4″–8″ tall)	75+	18–25	10–15
	Vegetative regrowth (4″–8″ tall)	70–75	16–22	10–15
	Stem elongation (8″–12″)	68–72	14–20	12–18
	Boot stage	63–68	12–18	20–26
Switchgrass	Vegetative (12″–20″)	74+	15–17	18–22
	Vegetative (25″–35″)	62–68	10–13	24–27
	Boot stage	56–60	6–8	28–32
	Heading	43–49	3–5	34–40
	Flowering	39–42	3–4	42–45
	Seed set	32–37	3–4	45–48

[1] Seeded and hybrids may vary slightly within stages.

[2] Oats, rye, triticale, and wheat may reach growth stages at different times.

Curing process

Conditioning: An optional step in the haymaking process, conditioning helps accelerate the drying rate. Conditioner equipment (see Figure 6) bends and crushes the forage to create openings that promote moisture loss, especially from stems. This process can reduce hay-curing time by one to two days, and it is mostly effective on steamy forages (i.e., forages with low leaf to stem ratios). Most current mowers can also condition the forage. Excessive conditioning, however, can be counterproductive and result in high harvest losses due to leaf shattering, especially with alfalfa and other legumes.

Figure 6. Roller conditioner.

Swath structure: As the thickness and density of the swath increases, the drying process slows. This correlation exists because a high moisture microclimate that restricts moisture loss—even when weather conditions are optimal—forms inside thick swaths. Once the tops of swaths start drying out, they can be tedded to promote faster, more uniform drying. Some mowers contain adjustable baffles to set the width of swaths or allow forage to be windrowed at cutting.

Tedding: Hay tedders disperse forage across the field so it can intercept greater solar radiation and dry quicker (about half a day faster), allowing uniform drying of the material (Figure 7). Tedding is most beneficial with material containing greater than 40% moisture. A second tedding may also be used to help in the drying process, but, be aware that too much tedding can shatter leaves of forages, lowering the quality of the hay.

Figure 7. Hay tedder.

Raking: Once the hay has been tedded and has almost reached the target moisture, it is time to rake. Raking turns the forage one more time and forms it into a windrow ready to be baled (Figure 8).

Figure 8. Hay wheel rake.

Bailing

Dry forage can be baled in small or large rectangular bales or in large round bales. Small rectangular bales usually measure about 1.5 feet wide and high by 3 to 4 feet deep and weigh 40 to 60 pounds. Large rectangular bales measure 3 to 4 feet wide and high by 6 to 8 feet deep and weigh more than 800 pounds. Large round bales measure 4 to 6 feet in diameter by 4 to 5 feet wide and weigh 1,000 to 2,000 pounds.

Storage

Dry matter losses during storage are usually 5% when bailing moisture is around 15% and hay is covered, which is highly recommended. It has been estimated that dry matter weight loss can average about 1% for each moisture percentage above 10% at the time of storage. Higher moisture concentrations (greater than 20%) at harvest can also cause heat damage due to microbial fermentation, which consumes the most nutritious fractions of the forage, leaving behind the least digestible material and potentially generating mycotoxins. Also, there is the risk of spontaneous combustion and ultimately barn fires.

Figure 9 explains the effect of moisture at bailing on storage temperature over time. When bailing is performed under high moisture conditions (i.e., greater than 20% moisture), extra measures need to be taken to reduce moisture. One option is to artificially dry the hay using heated or unheated forced air. Other alternatives include the use of organic acids (propionic or acetic acids) that provide protection only up to six months; buffered acids (ammonium propionate) that are less corrosive to equipment; or ammonium sources (anhydrous ammonia or urea) that require a plastic seal to retain the ammonia in the forage. Urea is especially attractive because it is not as hazardous as anhydrous ammonia.

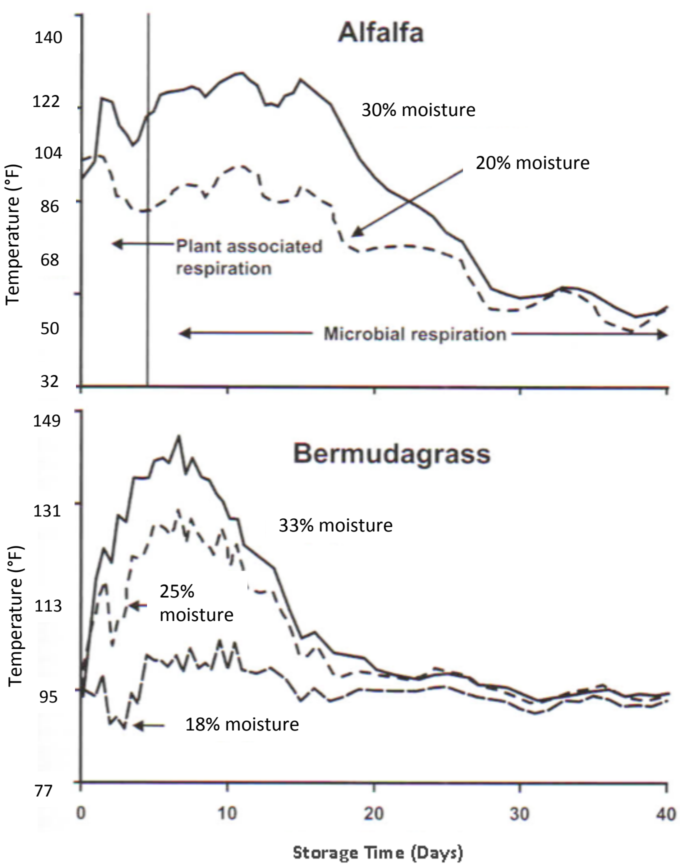

Figure 9. Effect of bailing moisture on temperature during storage of alfalfa and bermudagrass hay. *Adapted from Collins and Coblentz (2013).*

FACTORS TO CONSIDER WHEN EVALUATING HAY

Laboratory testing of hay nutritive value provides the most accurate estimate of hay quality. Two of the most commonly used methods to assess the quality of forages are the Relative Feed Value (RFV) and Relative Forage Quality (RFQ) indices. Calculation and interpretation of both indices are discussed in Extension publication AG-792 *Forage Quality: Concepts and Practices* (Romero et al. 2014). Unfortunately, index quality values of hay are not readily available in the hay market. Consequently, other attributes such as proportion of leaves, texture, color, and aroma have been used to try to rank the quality of hays.

Leaves contain two to three times as many nutrients as stems. Consequently, it can be expected that the more leafy the hay, the higher the quality. Texture pertains to stem size (length and diameter) and softness (flexibility). Long, thick stems that are hard and rigid are undesirable to animals; consequently, small, flexible stems are more desirable. A bright, dark-green color in hay usually indicates high vitamin and protein content. Browning of hay usually indicates a loss of nutrients. Heat-damaged hay turns dark brown, whereas unbleached hay is a lighter shade of brown. A moldy odor indicates that the hay was baled too wet. When this odor is present check for evidence of mold, which appears as a grayish-white, flaky substance or "dust," usually located in tightly packed sections of the bale.

SUMMARY

Forage hay production is an effective strategy to provide feed for livestock during periods of a forage-supply shortage or as a supplement, especially when feeding legumes. Successful hay production is more likely in regions and under environmental conditions that are conducive to rapid moisture reduction in the plant material to at least 15%, but no more than 20%, before storage. Perennial forages such as alfalfa, tall fescue, orchardgrass, and bermudagrass are very well suited for hay production because rapid moisture loss can be achieved in order to minimize nutrient and dry matter losses.

LITERATURE CITED

Brink, G., F. D. Matthew, and R. E. Muck. 2014. Field Drying-Rate Differences among Three Cool-Season Grasses. *Forage and Grazinglands*. DOI 10.2134/FG-2013-0104-RS.

Collins, M., and V. N. Owens. 2003. Preservation of Forage as Hay and Silage. In *Forages: An Introduction to Grassland Agriculture*, edited by R.F. Barnes, et al. Vol. 1, 6th ed., 443–471.

Collins, M., and W. K. Coblentz. 2013. Post-Harvest Physiology. In *Forages: The Science of Grassland Agriculture*, edited by R. F. Barnes, et al. Vol. 2, 6th ed., 583–599.

Romero, J. J., M. S. Castillo, J. C. Burns, P. Moriel, and S. Davidson. 2014. *Forage Quality: Concepts and Practices*. AG-792. Raleigh, NC: North Carolina Cooperative Extension Service. http://www.forages.ncsu.edu/assets/forage-quality.pdf.

Rotz, C. A. 1995. Field curing of forages. In *Post-harvest Physiology and Preservation of Forages*, edited by K. J. Moore and M. A. Peterson, 39–66. Madison, WI: Crop Science Society of America.

Rotz, C. A. and K. J. Shinners. 2007. Hay Harvest and Storage. In *Forages: The Science of Grassland Agriculture*, edited by R.F. Barnes, C.J. Nelson, K.J. Moore and M. Collins, 601–616. Ames, IA: Blackwell Publishing.

Tetlow, R. M. and J. S. Fenlon. 1978. Pre-Harvest Desiccation of Crops for Conservation. 1. Effect of Steam and Formic Acid on the Moisture Concentration of Lucerne, Ryegrass, and Tall Fescue before and after Cutting. *J. Br. Grassl. Soc*. 33:213–222.

Prepared by
J. J. Romero, Research Associate
M. S. Castillo, Assistant Professor and Forage Specialist
Departmet of Crop Science, NC State University

J. C. Burns, Professor
Department of Crop Science and Department of Animal Sciences, NC State University

J. P. Mueller, Professor Emeritus
J. T. Green, Professor Emeritus
Department of Crop Science, NC State University

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