HAY HARVESTING EQUIPMENT AND HARVEST STRATEGIES FOR QUALITY

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ABSTRACT

If we understand and use the biology and physics of forage drying, not only does the hay or haylage dry faster and have less chance of being rained on, but the total digestible nutrients (TDN) of the harvested forages are higher. As mowing and conditioning equipment has evolved, some of the basic drying principles of forage have slipped by the wayside and we need to review them. The general principles are to mow alfalfa with either disc or sickle mower, condition with properly adjusted roller conditioner (flail is for grass hay), put into a wide swath, rake/merge into windrow while plant moisture is above 40%, and bale when adequately dry for storage, with or without preservative as necessary.

Key Words: hay, conditioner, windrow, swath, alfalfa, merger

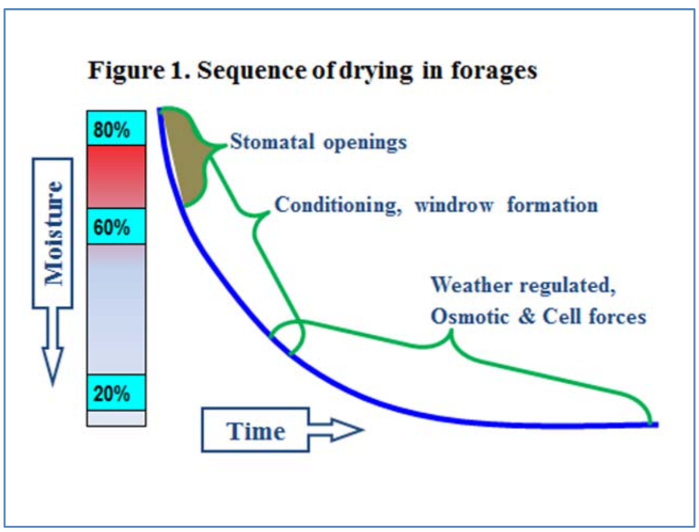
INTRODUCTION

Drying forage for hay has always been a challenge. While we cannot control the weather we can manage cut forage to maximize drying. The purpose of this paper is to give a few principles of hay and silage making and discuss machinery available relative to these principles. Then we will also talk about minimizing ash in hay to optimize the total digestible nutrients of the forage.

Understanding Forage Drying

Our understanding of conditioning and the need for conditioning has changed as we have revisited the factors affecting forage drying. In drying hay we need to maximize use of sunlight to enhance drying to minimize fuel use and cost of drying. Remember that, if we cut a 2 t/a dry matter yield, we must evaporate about 5.7 tons (1,370 gallons) of water per acre from the crop before it can be baled or 3 t/a (720 gallons) of water per acre before it can be chopped for silage.

If we understand and use the biology and physics of forage drying properly, not only does the hay dry faster and have less chance of being rained on, but the total digestible nutrients (TDN) of the harvested forage may be higher.



The general pattern of drying forages is shown in figure 1. When forage is cut, it has 75 to 80% water and must be dried down to 60 to 65% moisture content for haylage and down to 12 to 16% moisture content for hay (lower figures for larger bales).

Initial drying occurs primarily through stomata in the leaves (Figure 1) (Jones and Palmer, 1932). Leaf tissue is high in water content (about 85% water) and contains about half of the whole plant

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water. Leaf tissue has a high surface to volume ratio and numerous stomata, which promote rapid drying. Stomata are the openings in the leaf surface that allow moisture-loss to the air to cool the living plant and provide a path for carbon dioxide uptake from the air as the plant is growing. Stomata open in daylight and close in darkness or when moisture stress is severe. Cut forage laid in a wide swath maximizes the amount of forage exposed to sunlight. This keeps the stomata open and encourages rapid drying, which is crucial at this stage because plant respiration continues after the plant is cut.

The plant reaches a maximum of starch and sugar content late in the afternoon. Even after cutting, forage plants maintain tissue growth and plant function by metabolizing sugars and starches in a process known as respiration. Respiration rate is highest at cutting and gradually declines with plant moisture content until it has fallen below 40% (Barnes et al. 2003), though microbial respiration may continue to lower moistures. Therefore, rapid initial drying to lose the first 20 percentage points of moisture will reduce loss of sugars and starches resulting in more total digestible nutrients (TDN) retained in the harvested forage (Undersander, 2013; Kung et al. 2007). Research has shown that cutting later in the day can result in higher concentrations of these compounds in the forage at cutting. However, respiratory losses over night and longer total drying time may offset the benefit of afternoon cutting if the forage has not dried to 60% moisture and respiration continues at a high rate over night.

Conditioning and stomata in the stems also contribute to the initial drying of forage, though to a lesser extent than leaf water loss

Conditioning the plant can continue to enhance drying even after the stomata close. The second route for moisture loss is through the stem surface. Stems have a lower surface to volume ratio, fewer stomata, and are covered by a semi-impervious waxy layer. To promote water loss from the plant, this layer needs to be cracked or scraped. Conditioning to break stems at least every two inches allows more opportunities for water loss since little water loss will occur through the waxy cuticle of the stem.

RECOMMENDATIONS

Mowing

Mowing can be accomplished with either a disc or sickle mower. Neither will damage alfalfa stands more than the other. Many have shifted to disc mowers since the maintenance time is less. This is particularly true for modern discs that are individually mounted. Disc mowers can cut faster than sickle bar mowers. However, disc mowers require more horsepower per length of cutter bar.

Time of cutting has been researched. Clearly, alfalfa and grasses cut in the afternoon have higher starch and sugars than when cut in the morning (Lechtenberg, 1971; Fisher, 1999; Fisher, 2002, Morin, 2012). Differences are most pronounced on a bright, sunny day. However, if the forage does not dry to 60% moisture by nightfall, respiration remains high and the differences at harvest may be minimized. Thus AM/PM differences are smaller in the eastern U.S. and drying conditions poorer so that the decision to mow in the afternoon may be more a question of how time of cutting fits into the entire harvesting situation than in the West.

Cutting height for alfalfa should be between 2 to 3 inches to maximize yield whereas grass or legume/grass mixtures should be cut between 3 to 4 inches. Grasses need slightly higher cutting height because many store energy in the stem bases for re-growth and cutting below 3 inches will shorten the life of the grass in the stand. Cutting lower than recommended will not hurt alfalfa stands as long as the crown is not damaged.

Shorter cutting increases the soil contamination of the forage with disc mowers. Most disc mowers have knives at approximately a 15 degree to help pick up lodged forage. These also pick up more soil when ground is dry. Use of a flat knife will reduce ash content of hay and may be beneficial if lodging is not a significant problem.

These cutting heights are also high enough to keep the swath off the ground so that air can move underneath the swath to enhance drying by transporting moist air away from the swath. Putting the swath on wet soil increases drying time since the swath will gain moisture from the humid air near the wet soil as well as through capillary action if the crop comes in contact with the soil.

Conditioning

Mechanical conditioning can increase drying rate by up to 80% (Greenlees et al. 2000). A roll conditioner is recommended for alfalfa because flail/impeller conditioners cause 1 to 4% more leaf loss from legumes, reducing forage quality, if adjusted to condition for similar drying rate to a roller conditioner (Greenless et al. 2000). Flail conditioners were developed for grasses and work well where leaf loss is less of an issue. Numerous studies have indicated that drying rate is more dependent on conditioner adjustment than type.

More recently, several types of “superconditioners” have been developed. These will increase drying rate slightly above standard conditioners by crushing the stem. However, the gain is small with cost and required horsepower and fuel being higher so that these have not been widely adapted.

Roller type is does not significantly affect drying rate, thus other factors, such as wear, stoniness, etc., should be considered when choosing roll type. A crucial consideration is that both spacing and tension must be adjusted, with tension being adjusted on a field by field basis based on tonnage.

The most significant factor affecting drying rate is making a wide swath immediately after cutting maximizing initial drying rate and preserving of starches and sugars (Kung et al. 2010; Undersander, unpublished). The forage should be put into a wide swath covering 80 to 100% of the cut area.

In trials at the UW Arlington Research Station (Figure 2a & 2b), where alfalfa was put into a wide swath, it reached 65% moisture in 10 hours or less and could be harvested for haylage the

Figure 2a. May 29, 30, 31, 2007
wide swath vs narrow swath drying rate

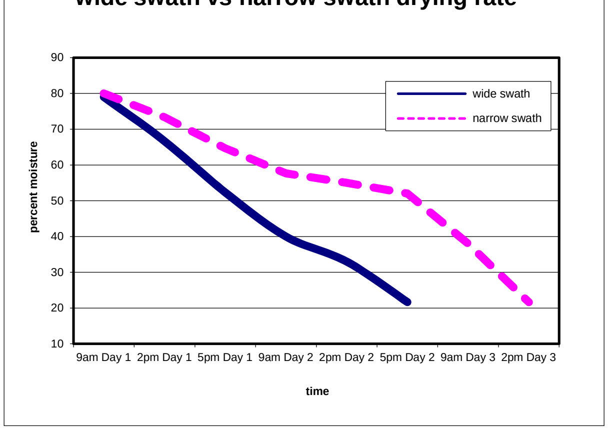
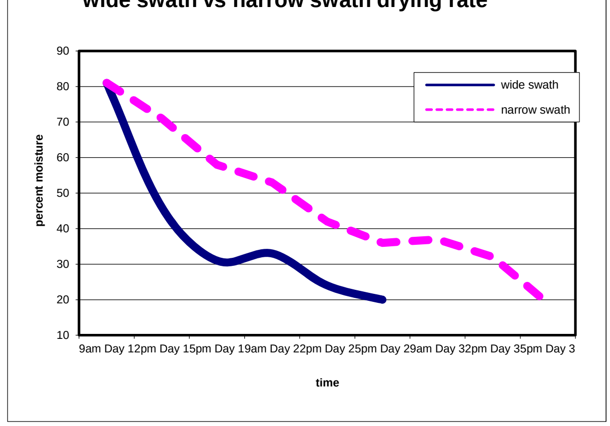


Figure 2b July 30, 31, Aug 1 2007
wide swath vs narrow swath drying rate



same day as cutting. The same forage from the same fields put into a narrow windrow was not ready to be harvested until 1 or 2 days later! This rapid, initial drying is crucial to reducing respiration and sugar loss.

We used to make wide swaths in the past, but have gradually gone to making windrows that are smaller and smaller percentages of the cut area as mowers have increased in size. Generally, as mowers have gotten bigger, the conditioner has stayed the same size, resulting in narrower windrows. There is some variation among makes and models and growers should look for those machines that make the widest swath.

Table 1 Difference in composition of alfalfa haylage made from narrow and wide swaths, UW Arlington, 2005

Factor	Wide	Narrow	Difference
NDF, %	37.8	40.1	-2.3
NFC, %	38.4	36.5	1.8
Ash, %	9.3	9.9	-0.6
TDN, 1X	63.5	62.6	0.9
Lactic acid, %	5.6	4.6	1.0
Acetic Acid, %	2.4	1.9	0.5
Relative Forage Quality	166	151	15

Putting alfalfa into wide swaths (72% of cut width) immediately after cutting results in improved quality of alfalfa haylage compared to narrow windrows (25% of cut width) in a study at UW Arlington Research Station in 2005 (Table 1). Alfalfa was mowed with a discbine, conditioned, and forage was sampled two months after ensiling in tubes. The alfalfa from the wide swaths had 2.3% less NDF, and 1.8% more NFC. The NFC difference is both a quality and yield difference as the 1.8% loss in narrow windrows was to respiration where starch is changed to carbon dioxide and lost to the air. The haylage from the wide swath had almost 1% more TDN and more lactic and acetic acid. The higher acid content would indicate less rapid spoilage on feedout and the overall improved forage quality would be expected to result in 300 lbs more milk per acre.

Note that use of a wide swath will reduce the drying time on the field which has the benefit of increased forage yield. This occurs because driving over an alfalfa field after regrowth has started causes the young stems to be broken and reduces the yield of next cutting. This is why alfalfa harvested for silage generally yields 10 to 15% more than fields harvested for hay.

There are some drawbacks to wide swathing. First, the swath must be raked or merged to narrow it to match the pick-up width of the forage harvester or baler, adding cost to the haying operation. However, the cost of raking or merging is offset by increased forage quality and the need to consolidate crop for today's high-capacity forage harvesters Lazarus, 2003; Wild et al., 2009). Additionally, when pull-type mower-conditioners are used, wide swaths are often run over by the tractor tires. Similar problems exist with self-propelled mower-conditioners. Research has shown that running over the swath is detrimental to hay drying (Hoover, 1996). Some are concerned that driving over a swath will increase soil (ash) content in the forage. In Table 1, the ash content of haylage from wide-swath alfalfa was actually less than from narrow windrows. A compromise for pull-type mower-conditioners is to make swath width such that only one side of the tractor runs over the swath. This problem can be avoided with mounted or self-propelled mowers depending on the swath-width and machine configuration.

A further concern of commercial hay growers is bleaching. It is important to recognize that bleaching does not occur as long has moisture is evaporating from the leaf surfaces. Thus, hay can be put into a wide swath for rapid initial drying and then raked/merged into a windrow as moisture falls below 60%.

Grasses, especially if no stems are present, must be into a wide swath when cut. When put into a windrow at cutting, the forage will settle together, dry very slowly and be difficult to loosen up to increase drying rate.

In summary, an extensive series of studies Rotz and Chen (1985) collected 5,000 data points on conditioned alfalfa from 1977 to 1984 in East Lansing, MI. They recorded weather data including temperature, relative humidity, solar insolation and wind velocity, and crop-related data such as maturity, cutting, soil moisture content, swath density (width and yield) and swath surface temperature. When finished, Rotz and Chen had an equation that described 75% of the variability associated with hay drying. Their results state that hay drying is improved with increased plant surface area exposed to the sun, greater solar radiation, higher temperature and lower swath density. Their equation also states that drying is decreased with higher soil moisture. The factors not included in the model (e.g., wind speed and relative humidity) may also play a role in hay drying by either influencing other factors in the equation or making up the 25% of the variance not described by the equation.

Raking/merging. Raking should occur when hay is above 40% moisture to reduce leaf loss (Buckmaster et al. 1990; Digman et al. 2013). Raking provides a 10 to 20% increase in drying rate on the day of raking, but following the initial improvement, the heavy swath formed by raking can slow the drying rate (Rotz, 1995). Tedding and raking/merging can also enhance drying by ‘fluffing’ up the windrow to expose different portions of the hay to sunlight and to allow air movement through the windrow. Each can cause leaf loss in alfalfa (increasingly with greater dryness of the forage). Tedding is seldom necessary for alfalfa if one started with a wide swath but is useful for grasses. Grassy hay often needs to be raked twice (or tedded and then raked into a windrow) since grass leaves settle together more than alfalfa hay.

Mergers can reduce leaf loss and ash content by picking up the forage and moving to a windrow rather than moving the forage across the ground (Digman et al. 2013).

Forage should be moved into a windrow as near to capacity of the baling/chopping machine as possible. Large windrows reduce the time and fuel used per ton harvested. More importantly, large windrows mean that fewer trips are made across the field so that wheel traffic damage to the alfalfa and yield loss of next growth cycle is less.

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