

HAY DRYING, PRESERVATIVES, CONDITIONING, ASH CONTENT

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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.

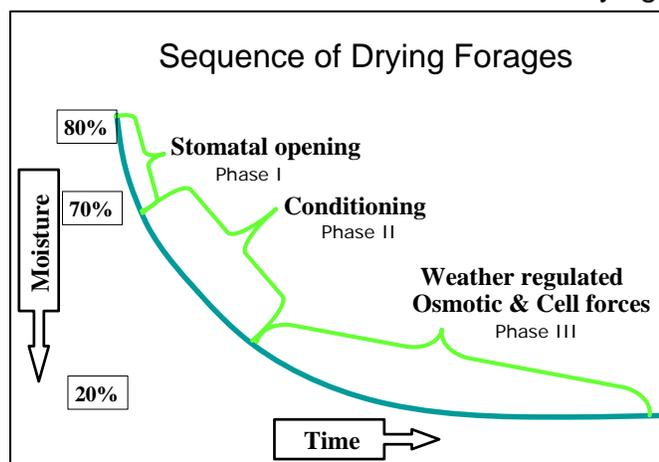
Understanding Forage Drying

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 of water per acre from the crop before it can be baled or 3 t/a 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 the figure below. 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).

The first phase of drying is moisture loss from the leaves through the stomates. (Approximately 60% of plant water is in the leaves.) Stomates are the openings in the leaf surface that allow moisture loss to the air to cool the plant and carbon dioxide uptake from the air as the plant is growing. Stomates open in daylight and close when in dark and when moisture stress is severe. Cut forage laid in a wide swath maximizes the amount of forage exposed to sunlight. This keeps the stomates open and encourages rapid drying, which is crucial at this stage because plant

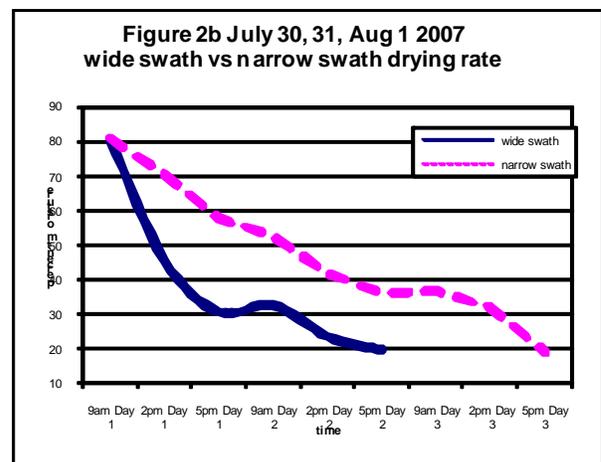
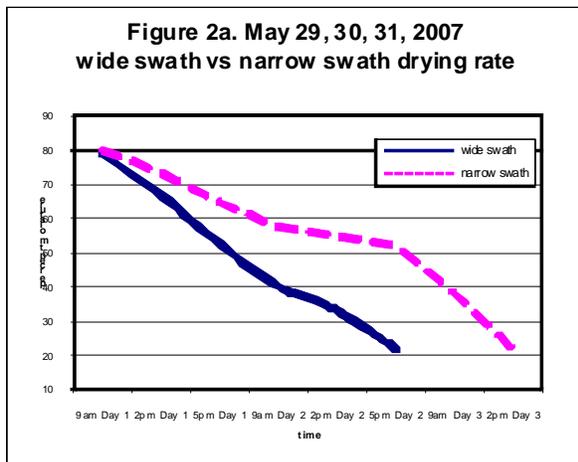


respiration continues after the plant is cut. Respiration rate is highest at cutting and gradually declines until plant moisture content has fallen below 60%. Therefore, rapid initial drying to lose the first 15 to 20% of moisture will reduce loss of starches and sugars and preserve more total digestible nutrients in the harvested forage. This initial moisture loss is not affected by conditioning.

The second phase of drying (II) is moisture loss from both the leaf surface (stomates have closed) and from the stem. At this stage conditioning can help increase drying rate, especially on the lower end.

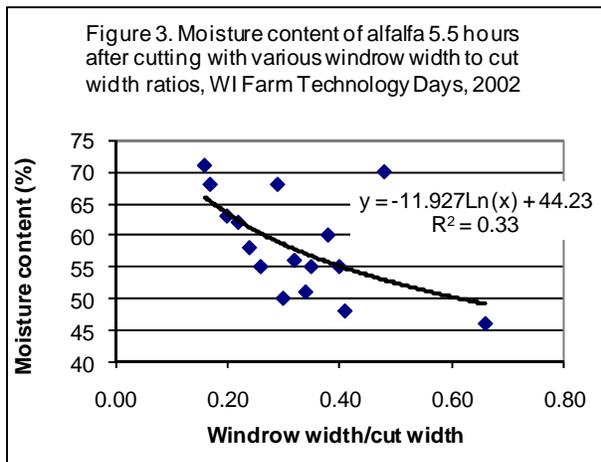
The final phase of drying (III) is the loss of more tightly held water, particularly from the stems. Conditioning is critical to enhance drying during this phase. Conditioning to break stems every two inches allows more opportunities for water loss since little water loss will occur through the waxy cuticle of the stem.

Understanding these principles will allow us to develop management practices in the field that maximize drying rate and TDN of the harvested forage. **The first concept is that a wide swath immediately after cutting is the single most important factor** maximizing initial drying rate and preserving of starches and sugars. 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 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!



In fact, **a wide swath may be more important than conditioning for haylage.**

The importance of a wide swath is supported from drying measurements taken at the Wisconsin Farm Technology Days in 2002 (Figure 3), where different mower-conditioners mowed and conditioned strips of alfalfa and put the cut forage in windrow widths of the operators' choice. Moisture content of the alfalfa was measured 5.5 hours after mowing. Each point is a different machine that included sickle bar and disc mowers and conditioners with, steel, rubber or combination rollers. Across all mower types and designs, the most significant factor in drying rate was the width of the



windrow. The machinery industry is rapidly responding to produce equipment that can make wide swaths.

In Figure 3, note the one outlying point at 70% moisture content and a windrow-width/cut-width ratio of 0.48. This shows how much drying can be slowed by improper adjustment of the conditioner.

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.

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.

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

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. While narrow windrows are not usually driven over, they tend to sag to the ground, causing soil to be included with the windrow when it is picked up. Wide swaths tend to lay on top of the cut stubble and stay off the ground. Further driving on the swath can be minimized by driving one wheel on the area between swaths and one near the middle of the swath where cut forage is thinner.

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 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.

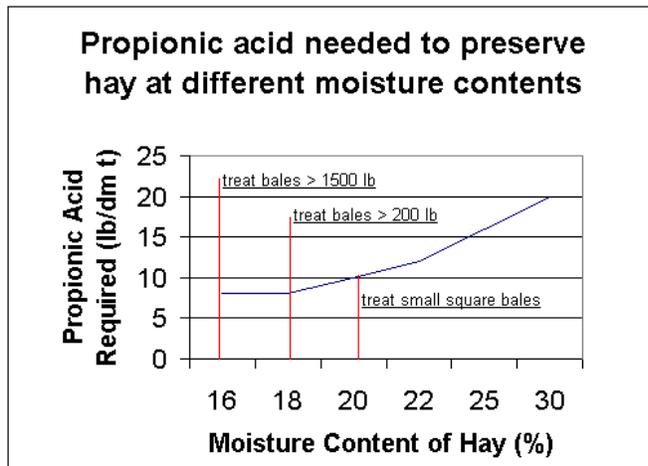
Preservatives/Dessicants. First, it is important to recognize that two totally different types of products with different modes of action are sold: one is a desiccant which is a compound applied to the hay at cutting to increase drying rate and the other is a preservative which is applied to hay as it is baled to allow baling of wetter than normal hay without spoilage during storage. Both products are usually applied through a spray system, which costs \$600 to \$1000, either on the mower (for dessicants) or on the harvesting equipment (for preservatives).

The desiccants that are effective contain potassium or sodium carbonate. This compound disturbs the waxy cuticle of the alfalfa stem to allow it to dry faster. Desiccants work only on legumes such as alfalfa, trefoil, and clovers. Effectiveness varies with climatic conditions. Desiccants reduce drying time most when drying conditions are good. Thus, they tend to work better on second and third cuttings in Wisconsin. They are recommended for hay making and are of less usefulness when forage is harvested as haylage.

Preservatives are applied to the hay as it is harvested and prevent heating and spoilage of hay baled at high moisture contents. Preservatives are cost effective if used only when needed to prevent rain damage to hay and if applied uniformly to windrow as it is entering the baler. The most effective preservatives for alfalfa are organic acids, (primarily propionate and acetate) and their derivatives such as sodium diacetate.

Propionate (propionic acid) has been most commonly used and any product containing a high percentage of this compound will be effective. Use of ammonium propionate (also called buffered propionic acid) rather than propionic acid is recommended because the product is less caustic - therefore safer to handle and less corrosive to machinery. When purchasing preservatives, compare cost on a per pound of propionic acid basis. Other additives do little if anything to preserve hay. Some hay preservative products dilute the propionic acid and require greater product use rates.

Rates of propionic acid required to preserve hay vary with the moisture content of the hay.



As indicated in the chart above, the amount of propionic acid required varies from 10 lb/ton for hay at 20-25 % moisture, 20 lb/ton for 25-30 % moisture and 30 lb/ton for 30-35 % moisture. Note that rates are for pounds of propionate not product. Therefore a product with 50% propionate would need to be applied at twice the above rates.

Use of preservatives for hay above 35% moisture is not recommended.

Anhydrous ammonia is an effective preservative for grasses. Anhydrous ammonia should not be used on alfalfa due to the potential for formation of toxic compounds. Anhydrous ammonia can be injected into bales or released into a stack of bales covered and tightly sealed with plastic. Ammonia should be applied at the rate of 20-40 lbs/ton with higher rates used for hay near 35% moisture and lower rates used when moisture is near 20%.

Currently, evidence is not sufficient to indicate that any microbial hay preservatives are effective in preserving hay.

Raking. Raking should occur when hay is above 40% moisture to reduce leaf loss. 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 tugged and then raked into a windrow) since grass leaves settle together more than alfalfa hay.

Summary of hay drying recommendations

Mowing and conditioning to maximize hay drying rate should:

- Begin with a wide swath (greater than 70% of cut area) to maximize leaf drying and stop respiration.
- Keep the swath off the ground to enhance drying and reduce soil contamination.

Ash in forage

We haven't paid much attention to ash until recently when we have begun using the summative equation to estimate energy of forage. Now instead of estimating energy from acid detergent fiber most estimate energy from the following summative equation:

$$\text{Total digestible nutrients (TDN)} = \text{NFC} \cdot .98 + \text{CP} \cdot .93 + \text{FA} \cdot .97 \cdot 2.25 + \text{NDF} \cdot \text{NDFD}/100 - 7$$

NFC = non-fiber carbohydrates = DM - Ash - CP - EE - NDF, % of DM

CP = crude protein, % of DM

FA = fatty acids = EE - 1, % of DM

EE = ether extract, % of DM

NDF = neutral detergent fiber, % of DM

NDFD = (48 hr in vitro NDF digestion), % of NDF

When estimating energy from ADF, the ash content is unseen. Now that ash content is used to calculate the non-fiber carbohydrates (NFC), it is obvious that each 1% ash is 0.98% less NFC (and therefore TDN). While some minerals are necessary for the forage growth and may be beneficial to animals eating the forage, we want to keep the ash content to the minimum because ash provides no calories and, in fact, ash replaces nutrients.

Ash in forage comes from two sources: internal, e.g. minerals like calcium, magnesium, potassium and phosphorus, and external, e.g. dirt, bedding, sand, etc. The average internal ash content of alfalfa is about 8% and of grasses is about 6%. Additional ash in a hay or silage sample is contamination with dirt, sand, etc. As shown in table 2, a summary of ash content of forage samples submitted to the University of Wisconsin Soil and Forage Analysis Laboratory, the average ash content of haylage is 12.3% and of hay is 10.3%. Assuming the silage is mainly alfalfa and the hay has a higher percentage of grass, forage samples are averaging about 4% ash contamination from external sources. Note that some samples have been as high as 18%. This means some farmers have fed almost 1 pound of dirt for each 5 pounds of hay or silage!

Type	Statistic	% Ash
Haylage	Average	12.3
	Maximum	18.0
	Minimum	5.7
Hay	Average	10.3
	Maximum	17.6
	Minimum	8.8

Growers can do several things along each step of harvesting, storage and feedout to minimize ash.

- ✓ **Avoid harvesting lodged forage** -as dirt often sticks to the downed forage when the soil is wet. This can't always be avoided but can be reduced by

planting varieties that stand better and by harvesting early in the spring to reduce the potential for a wind storm knocking the alfalfa/grass down.

✓ **Raise the cutter bar of a disc mower** - to lower ash and raise forage quality. Research suggests that alfalfa can be cut as short as 1.5 inches for maximum yield. Each inch above this height will result in 0.5 t/a less yield for the year. (Though, if the mixture includes smooth bromegrass, orchardgrass, or timothy, cutting height should be 3 to 4 inches to avoid shortened stand life of the grass). However, lower cut forage with a disc mower will have higher ash content when the soil surface is dry. Thus, raising the cutter bar lowers ash and raises forage quality while lowering the cutter bar results in greater yield. Each individual must decide on the tradeoffs they want to take but generally a cutting height of 2.5 to 3 inches seems best in most cases.

✓ **Use flat knives on the disc mower** – to pick up the least ash when mowing. Several disk knife types are available as shown in the picture. The flat knife at the left will

pick up the least ash while the middle knife, at a 14 degree angle, will create some suction to pick up more



downed hay and ash (when soil is dry). Generally, those settings that pick up downed hay best also result in the most ash content when the soil is dry so one needs to decide which is most important.

✓ **Keep windrow off the ground** – by starting with a wide swath and placing the cut forage onto dense stubble will eliminate harvesting a layer of soil on the bottom of windrows. Putting hay into a wide swath also increases drying rate. The windrow should be high enough so that it can be raked or merged without the rake touching the ground.

✓ **Keep rake tines from touching the ground** – this can be done if the forage is on top of stubble and the ground is level. Wheel rakes tend to incorporate more ash because they are ground driven. We should visualize that, when we are raking and raising a cloud of dust, we are adding 1 to 2 percent ash to the hay.

✓ **Minimize moving hay horizontally** to reduce stones and other ash. It is better to move two swathes on top of a third in the middle rather than to rake all to one side.

✓ **Using a windrow merger** rather than raking will result in hay or silage with less ash content since the windrow is picked up and moved horizontally by a conveyor rather than being rolled across the ground. Merging can result in 1 to 2% less ash in the hay or silage. Mergers may not be economical for small operations but **Custom harvesters may be an option** to consider if merged hay with lower ash content is desired.

Store hay bales off the ground since bales that set on the ground pick up water from the soil and mold. This molding process causes loss of TDN and increases the ash concentration. More important, the wet hay will pick up a layer of ash on the bottom if bales are sitting on the ground.

Store silage piles/tubes on concrete or asphalt to minimize ash contamination. Silage can be removed with minimal dirt contamination when conditions are dry but dirt may be picked up with the silage when conditions are wet and it is muddy around the silage pile or tube.

There will always be some soil contamination of grass and legume hay or silage. However appropriate harvesting and storage management can reduce the ash content of the hay or silage. We should all try to be 1 or 2 % below the averages in table one. Anyone with 10% or less ash has done a good job of minimizing ash content of hay or silage.

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