WHAT'S NEW IN FORAGE EQUIPMENT?

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The forage equipment industry is changing in response to farmers' needs. These changes consist of innovations to increase capacity, to improve the usability of the machine, and to improve the quality of the product. Most changes are occurring with existing equipment, but some totally new product innovations are occurring.

The size of machinery has increased to allow more-efficient harvesting. Some of this equipment will be used on larger operations and some will be used for contract forage harvesting, which has expanded rapidly across the U.S. in the last 15 years. Currently, self-propelled disc mowers have increased to almost 32 feet (in three banks), the largest rakes and mergers are 30 feet or wider, and the largest forage harvester has a 1020 Hp V-12 engine and can harvest up to 400 t/hour.

The purpose of this paper is to give a few principles of hay and silage making and discuss machinery available relative to these principles.

MOWERS

Some design improvements in mowers include differing knife types for different needs and changes with weight load distribution. Most growers are rapidly switching from sickle to disc mowers due to reduced maintenance requirement.

Data is clear that the disc mowers do not reduce alfalfa yield or stand life more than that of sickle bar mowers.

Differing knives are available for disc mowers and the choice among them should be made with some deliberation. The most common are knives that are angled at about 14^o to enhance picking up downed forage. Mowers with these knives really do pick up downed forage better than those with flat knives. However, angled knives pick up soil more when the ground is dry. Angled knives can add 1 to 2% ash to the harvested forage. So the grower must decide which is more important – picking up downed forage or having less ash in the forage.

Cutting height should be adjusted according to management goals. Lower cutting height results in higher yield (graph as left) of alfalfa (as long is crown is not cut) but should be 3 to 3.5 inches if grass is included to allow rapid regrowth. Higher cutting height will also reduce ash content

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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**.

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

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.

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.

CONDITIONING EQUIPMENT TO ENHANCE DRYING

As the industry has realized the value of making a wide swath for drying, it has changed equipment designs to allow wider swaths. Some farmers are now asking for disc mowers without conditioners when haylage is the only form of forage to be harvested, since conditioning is not necessary for haylage.

The argument continues as to which of the current conditioner types are best. Flail conditioners were developed in Europe for grasses and are generally the least expensive. Roller conditioners were developed in the U.S. for alfalfa. Some data has shown that roller conditioners will dry alfalfa faster than flail conditioners and that the opposite is true for grasses. However, the difference is small and in individual field trials one may indicate faster drying depending on machine adjustments and drying conditions. Clearly, flail conditioners will increase leaf loss in alfalfa by 1 to 4%, resulting in quality loss. They also make a less uniform windrow, which can result in less consistent chop length.

Steel roller conditioners, rubber roller conditioners, and combinations of the two are available. Data has shown little difference among them. The sharper, firmer corners of the steel rollers may break stems slightly better in some circumstances, but they also suffer more damage from stones and other foreign materials.

The key to increased drying and minimized leaf loss with flail and roller conditioners is proper adjustment for field conditions.

Some new forage harvesting methodology has become available in recent years. This includes macerating, superconditioning, and reconditioning.

Macerator technology was initially invented by the USDA Dairy Forage Research Center, Madison, WI, and further developed by the Prairie Machinery Agricultural Institute (PAMI), Portage la Prairie, Manitoba. It clearly enhanced drying rate (Savoie et al., 1993) and improved animal performance (Charmley et al., 1999) by shredding the forage and pressing it into a mat that is laid on top of the forage stubble. The challenge has been the low throughput and high energy requirement, making development of field units slow. A macerating unit is currently on the market that does enhance drying rate compared to standard conditioning but the unit macerates less than the original design to facilitate throughput.

Superconditioning (breaking/smashing the stems more thoroughly than standard conditioners) has been commercially available for several years. Tests have consistently shown 3- to 6-hour drying advantages of superconditioners with steel rolls over standard conditioners. However, the units have significant additional cost and horsepower requirement. One unit is available with “high impact” conditioning where the rubber rolls are solid except for narrow ‘v’ slits.

Reconditioning is running the windrow through a conditioner a second time after partial drying has occurred. Some farmers have fabricated such units by removing the mowers of mower conditioners, and some units are commercially available. Reconditioners are generally used on the day of baling after the dew is gone to help remove the last 5% of water prior to baling. Such units help in baling timothy for export where forage must be 12% or less at baling. Little advantage has been demonstrated for reconditioning alfalfa. Alfalfa will also suffer some leaf loss during the reconditioning.

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 tedded and then raked into a windrow) since grass leaves settle together more than alfalfa hay.

Swaths or windrows should always be combined to make the largest windrow the harvesting machinery can handle. Large windrows are the most energy and labor efficient for harvesting. Large windrows also reduce wheel traffic on the field resulting in less soil compaction and plant damage.

Raking should occur without the rake tines touching the ground. Tines scraping the ground add soil to hay reducing forage quality. Thus powered rakes are better than wheel rakes which are ground driven by the tines.

Mergers are another excellent tool where the hay is picked up and moved on a conveyer across the field into a windrow. Mergers result in less leaf loss and less ash in the hay than rakes which move the hay across the ground. However, one should examine the cost of mergers and compare to the value of the product obtained.

BALING

The newest thing on the market for balers is bale cutters. This option for either round or square bales cut the hay length. The final theoretical cut length can be as short as 1.5 inches. However, using fewer knives to get final hay to be 4 to 6 inches long will provide the most economical benefit with less knife expense and energy cost. The cut hay has no benefit in hay making or silage fermentation but data has shown that animals will have higher forage intake and less feeding losses. Additionally cut bales will break apart easier when used in a TMR or for straw.

Other new features on bales include more detailed electronic monitoring and control of baler functions, constant bale flake size, tighter round bales and other modifications.

SUMMARY

Mowing and conditioning equipment should be bought with the essentials to drying hay or haylage in mind:

- beginning with a wide swath (greater than 70% of cut area) to maximize leaf drying and stop respiration.
- keeping swath off the ground to enhance drying and reduce soil contamination.
- conditioning/macerating to increase stem drying rate for hay – note that greater conditioning/macerating will increase drying rate but at greater cost in terms of initial capital investment and fuel use.

Raking should occur with tine not touching the ground. Windrows should be merged to the biggest that harvesting equipment can handle. Use of a merger will reduce leaf loss of alfalfa and ash contamination.

Bale cutters will improve quality of final product in terms of reduced feeding losses and improved animal performance.

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