Physiology of Hay Drying
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Introduction:
For each ton of hay that needs to be dried down to 12% moisture, an estimated 1.7 tons of water must be removed. Reducing the drying time is very critical as there are losses due to respiration.

At cutting, the enzymes in the plant continue to function by breaking down the plant sugars and producing carbon dioxide. This results in losses such as:
   a) 4-10% of the total dry matter
   b) Feed value in terms of TDN can be lost in the range of 2-6 units
   c) Relative Feed Quality (RFQ) up to 27 units

The objective of good haymaking is to have a very fast dry down of the forage so as to reduce the potential damage from rain and to remove the hay from the field as quickly as possible for maximum quality. Also, the longer the forage stays in the field after cutting the yield reduction due to wheel traffic can be quite high.

Physiology of Hay Drying

There are a number of factors, which affect the drying rate of forage and must be considered when developing a haymaking plan.

1: The physical nature of the forage has a major influence on how quickly it will dry down. For example, from this chart, it is apparent that the leaves dry much faster than the stems. This can result in excessive dry matter loss if we wait for the stems to dry down to the same moisture as the leaves.

In most hay making systems, the forage is conditioned, or the stems are crushed so as to try to get the stems to dry more like the leaves.

2: Temperature: does have an influence on the drying rate however, this chart indicates that the relative impact of temperature on the drying rate is marginal at best.
3: Sunshine & Wind

Sunshine makes some difference to the rate of drying, however, wind speed makes a lot of difference.

4: Humidity:
When hay is drying, as the water evaporates out of the leaves and the stems, the area close to the leaf surface very quickly rises to 100% humidity. This boundary layer which is right at the surface of any wet material is always at 100% humidity. If there is air movement, the moisture will be drawn off and dry moisture will be brought in which will allow the plant to dry. Unless that very wet air is taken away, the plant will quit drying.

Humidity is the second important factor in drying. From this chart, if the RH is at 60%, the driest this hay can be harvested at is about 16% regardless of how hot, or how much wind or how much sunshine. Until the humidity levels are below 40%, there will be minimal drying of the crop if the target is 10%-12% dry.

If the crop has been swathed and it appears that the RH is not going to drop, the use of preservatives such as propionic acid or some high moisture harvesting system should be considered.

In this chart the effect of a 20% change in the drying rate on the crop indicates that:
- Increasing the temperature by 20% had some effect
- An increased wind speed of 20% had a major effect.
- 20% more sun did increase drying but not to a great degree
• Decreasing the humidity had the major effect on the drying rate almost doubling the drying rate of the alfalfa

What can we do about this? Perhaps the answer is to do a better job evaluating weather reports.

This chart indicates some normal temperature ranges.
• Temperature does not make a great difference
• Wind speed makes a great difference – more than a 50% difference.
• Sunshine by itself does not make that much difference but it is usually in combination with the effect of temperature and humidity.
• Relative humidity is the second biggest factor.

5: Type of Hay Package:
The type of hay package also can be changed to accommodate different drying conditions. Generally, the larger and more dense the package, the lower the moisture level required for safe storage. The large square bales should be in the 14% range, the medium and round bales at 16% moisture and the smaller square bales can be harvested at 18-20% moisture as there is more surface areas for drying on the outside of the package.
The Relative Humidity at the time of harvest will limit the type of bale package you can use.

6: Options to Promote Drying:
i) Drying Agents
Use of drying agents is another technique used in some areas, to hasten the moisture loss from the plant. Potassium or sodium carbonate is sprayed onto the plant at cutting and affects the waxy cutin or outer layer of the plant stems allowing the movement of water through the stems or leaves. The carbonate essentially breaks up the waxy surface allowing the moisture out.

The product is applied as the plant is cut by the use of a deflector bar mounted in front of the header about 8-10 inches off the ground. This bends the plant over so that an effective coverage of the plant is possible. The effectiveness is only as good as the coverage you get.
The potassium carbonate solution (usually a mix of the two carbonates) is applied at a rate of 30 gallons per acre. This process does work but the application of the high water rates discourages the general use of the product. There has been some work on lower water rates, but they have not been as successful. Another factor is the drying agents work better as the weather improves. In this graph, essentially the drying agent will reduce the drying by one day.

**ii) Conditioning of Hay**

Use of conditioners is an accepted practice to break the waxy surface of the stem to allow the moisture to escape. There is minimal difference between the use of steel or rubber rollers. There are two essential adjustments required for conditioners; one is tension, which needs to be adjusted according to the tonnage of the forage, the other adjustment is the spacing. Spacing should be the diameter of a quarter to allow enough breaks in the stem for fast drying. Another benefit of the roller conditioner is that they tend to keep the stems in line, will lie up on top of the stubble and will result in faster drying compared to flail conditioners.

Flail conditioners tend to lay the stems in different directions and the swath has a greater tendency to settle into the ground. Flail conditioners are not recommended for alfalfa but are commonly used for grass forages. Studies also indicate a 1%-3% dry loss compared to roller conditioners in alfalfa crops. They are also less expensive and as the swath is less uniform, difficult to obtain an even feed for silage choppers.

Super conditioners are now being used and involve smooth or grid rollers, which crush the stems. This chart indicates some of the different systems that are used to promote rapid dry down. This chart indicates, that the more the stems can be cracked, the faster the forage will dry.

Macerators are becoming more common and involve two sets of rollers with the two steel rollers moving at different speeds which has the effect of tearing the stems apart and the result is a much faster drying rate than the traditional conditioning system.

As the stems now will dry similar to the leaves, there is less leaf loss, therefore higher quality product. One of the disadvantages of this equipment is the additional power required and the capital cost of the equipment. This is of particular use for alfalfa and does not necessarily apply to grasses. The appearance of this hay is different than the traditional conditioned forage.
iii) Windrow Management:
Windrow size is also a major factor in fast drying. The wider the windrow, the more solar drying effect plus wind action on the forage.

In this chart, a windrow width of 1.0 is where the forage was laid down full width. 0.5 means that the windrow is covering 50% of the cut area and 0.25 is 25%, which is quite common for many hay bines. 0.1 is where the swath covers only 10% of the cut area.

At the 1.5 ton/acre yield the evaporation required to dry the swath is very low but as the swath becomes larger and higher, more evaporation will be required to dry it down. This is because there is less surface area and the wind cannot penetrate the swath as easily as a full width or wider swath. Yes, there will be more bleaching; however there will be trade offs that need to be considered.

iv) Soil Moisture:
Soil moisture is another factor in drying of the crop that is too often not recognized as being a major factor. When soil conditions are wet, there is a capillary action that moves the moisture up into the hay as it is drying. The result is that the top and middle of the swath may be dry but the bottom is still wet due to wet soil conditions.

In this chart, for example, at the 26.6 C temperature, it will take an additional; 6 hours to dry from 80% to 20% if the soil is wet. On sunny days the differences are a bit less because the surface will be drier.

The major management practice when soils are wet would be to keep the swath up off the ground by cutting higher. This will avoid the capillary action or sucking the moisture up into the hay from the soil as well as to allow for better circulation of air around the swath. Crops with a higher stand density will also help to keep the swath up off the ground.

v) Effect of Cutting height
However, with alfalfa, the general management practice is to cut short at about 2-inch height. Losses can be quite high if the stubble height is above this level. This is for alfalfa or alfalfa/orchard grass. If there is timothy in the mixture, the cutting level must be above 2 inches.

Wisconsin studies have indicated that the higher the cut, the less yield for an alfalfa stand.
There will be a loss of ½ ton for each additional inch of cutting height. Therefore cutting at 4 inches will result in a loss of an additional ton per acre. The reason is that the plant grows back from the crown. As long as the crown is not damaged, cutting low is preferred.

Some indicate that they will also obtain more bottom leaves by cutting low. However, the higher the cut the higher the feed quality. There is about five points of RFV per inch of cut, as indicated in this chart.

In dollar value this amounts to about $4.50/inch (US). However, it still is better to cut a bit earlier, get that extra ton of hay and still have the higher quality.

**vi) Effect of Wheel Traffic on Crop Yield**

Another reason why we want to get the crop off as quickly as possible is the potential damage that is caused to the next cut by wheel traffic. This is not necessarily by driving on wet soils this is also due to driving on dry soils and is primarily due to stem breakage. In some tests they have measured 30% yield reduction five days after cutting the alfalfa. In some instances the reduction was as high as 70%.

A three-year study was done in Wisconsin, which compared the relative damage to different alfalfa varieties. There was some major difference between varieties in their ability to withstand wheel damage. This indicates a major loss potential as in most fields; about 50% of the total plants will be affected by wheel traffic. That is at cutting, raking, baling and hauling of the crop and most of the damage was due to stem breakage.

Another study involved a survey of a number of States where a comparison was made of wheel traffic damage, 2 days and 5 days after cutting.

Averaging the damage for the 5 days after harvest, there was approximately 20% yield reduction. However the yield reduction after 2 days was only 5%. Considering this data, you likely will lose 7% per day in terms of future yield for each day you wait after cutting.
To reduce these losses, there are some management practices such as:
1) Use the smallest tractor (no dual wheels, take the loader off)
2) Merge windrows where possible (less travel with the baler)
3) Go to larger equipment (22 ft mower less compaction than a 9ft)
4) Take most direct route to the edge of the field (don’t drive all over)
5) Make a field road to drive on

Summary for Quality Hay Production
a) Rapid Drying
   i. Reduces respiratory losses, improved yield and quality
   ii. Reduces chance of rain damage
   iii. Increases yield of next cutting
b) Management to increase drying rate
   i. Cut to keep windrow off the ground
   ii. Use drying agents (?)
   iii. Condition/macerate
   iv. Make wide windrow and rake at 40% moisture

Answers to some questions at seminar:
• **Effect of stubble density**: Stubble density will help to keep swath off the ground. However, high stand density is primarily for increasing yield than for additional quality. Require approximately 55 stems per square ft to give maximum yield.
• **Swath Turners**: Wisconsin has minimal information on swath turners
• **Removal of old stubble (last year’s 3rd growth)**: Not economic to try to remove old stubble – usually not a major amount to be concerned about
• **Drying rates of Grasses compared to Alfalfa**: Drying characteristics of grasses are quite different than for alfalfa
• **How high in terms of RFV is necessary**: May have gone too far in regards to quality by sacrificing yield. Above 150 RFV may be questionable