Drying High Moisture Alfalfa Hay

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Introduction

We all recognize the value of alfalfa in horse, dairy and beef rations. That's why we harvest over 17 million acres of this crop in the United States every year. Hay is a good way to harvest alfalfa because it stores well, provides long fiber in rations and we can market the surplus as a cash crop. Higher yields and higher quality mean more profit so we push to be sure we use the best management practices. All too often though, we lose part of all of a crop to rain damage. Some yield and quality is lost due to leaf shatter and respiration no matter how ideal the conditions. The goal of our research program is to develop hay harvesting and storage systems that minimize these losses at the lowest possible cost.

Field and Storage Losses

The general relationship between forage moisture concentration and losses during the field curing and storage phases is shown in Figure 1. Harvest losses are greatest for very dry forage and are low for wet material like direct cut silage. However, direct cut silage is subject to very large storage losses due to seepage and produces poor quality silage. Storage losses are generally minimized by harvesting at intermediate moisture levels. High moisture hay, baled between 20 and 30 or 35% moisture, has lower harvesting losses than dry hay but can suffer high storage losses of DM and quality if not adequately preserved or dried.

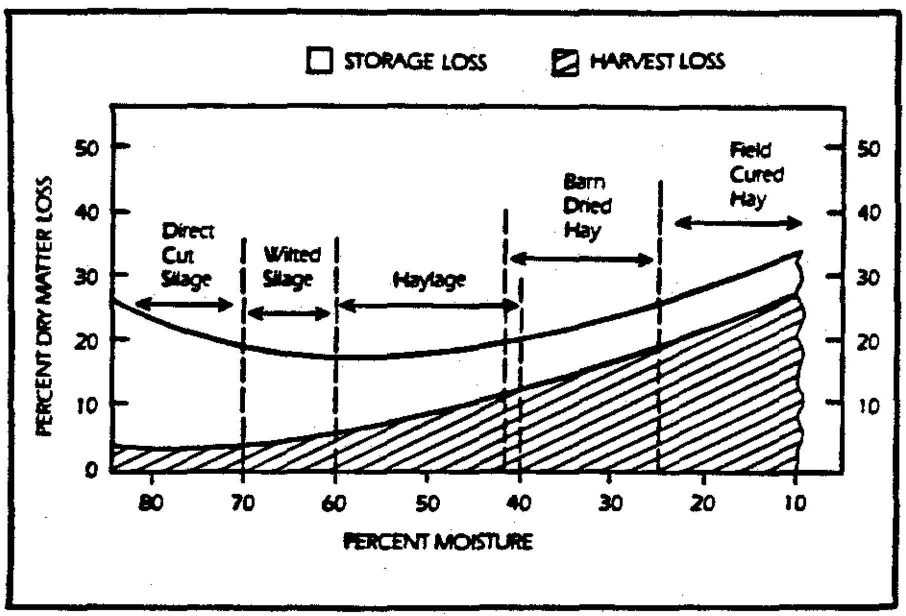

Fig. 1. The relationship between forage moisture concentration at harvest and the amount of dry matter lost during harvest and storage.

Hay Curing Losses

When we combined the information from 64 separate hay harvests over a 4-year period, we found that field cured alfalfa was about 10% lower in crude protein and digestibility than the standing crop from which it was produced (Table 1) (Collins, 1990). Fiber concentrations, which relate closely to forage intake potential by livestock, were increased nearly 20% in hay compared with the standing crop. Since dry matter yields also fell 20% during hay curing, the yields of protein and digestible dry matter were affected even more dramatically than their concentrations.

Table 1. Quality and yield of alfalfa hay over a 4-year period.

	Concentration			Yield		
	Crude Protein	Digest -ibility	NDF	Dry matter	Crude protein	Digestible dry matter
	----------%----------			---------tons/acre---------		
Hay	19.4	59.6	51.8	3.2	0.62	1.91
Standing crop	21.4	66.3	42.2	4.0	0.84	2.65

We found that measurable rain occurred 53% of the time over the 4-year period. The average amount of rain that fell each time was 1.1 inches and conditioned hay took an average of 4.6 days to cure when the whole range of curing conditions were included. Under excellent conditions hay dried in as little as 2 days, but under poor condition well over 1 week was needed. An average of 2.3 days was needed for hay drying when we got no rain during the curing process.

Kentucky receives over 45 inches of precipitation each year and we usually have frequent rains during the growing season. This high precipitation is beneficial for alfalfa production but can cause problems with hay curing. Weather records show that between April and August we have 7 to 9 days each month with more than 1/10 inch of rain. Calculations show that the probability of hay having 4 dry days to cure during May in Iowa is only 26% (26 chances out of 100). One important means of avoiding rain damage to field curing hay is by shortening drying time. For example, reducing field curing time from 3 days to 2 increases the probability of successfully curing hay without rain damage by 46%. Our best opportunity to reduce these hay harvesting losses is by minimizing hay curing time. We can do this by using a combination of good swath and windrow management, mechanical conditioning, chemical conditioning and high moisture baling.

Preserving Moist Hay

Under high humidity conditions, hay may never reach the 20% moisture level recommended for baling dry hay regardless of the time spent in the field. Figure 2 shows equilibrium moisture concentrations measured for alfalfa hay over a range of humidity conditions at a temperature of 77°F. At a relative humidity of 80%, this graph indicates that alfalfa would not dry below 25 to 27% moisture. Hay baled at these moisture levels would heat and mold if left untreated. Alfalfa in round bales is more prone to heating than in rectangular bales and needs to be a little below 20% for safe storage. The data in Figure 3 show what can happen to the quality of moist alfalfa hay during storage if it is not dried or treated with an effective preservative. As moisture concentrations increase, hay digestibility after storage decreases sharply. The hay was all identical in digestibility at the beginning

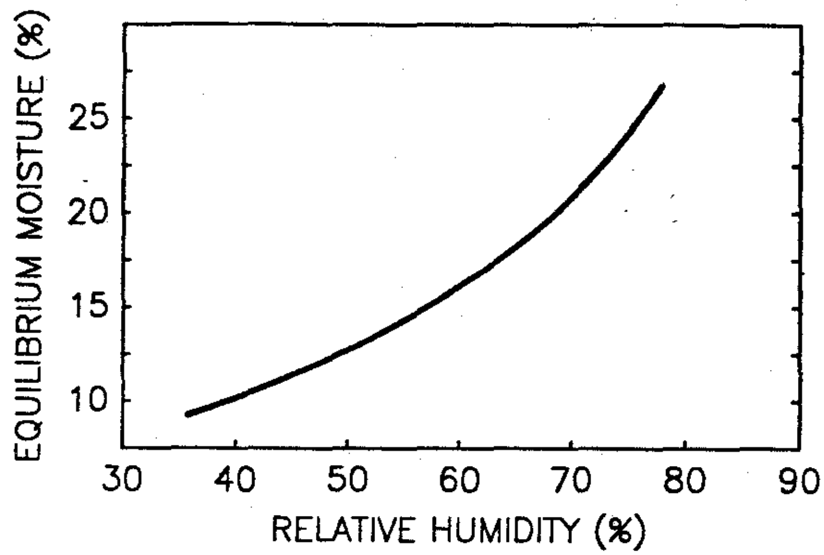

Fig. 2. Equilibrium moisture concentration of alfalfa hay over a range of relative humidity levels (From: Trans. ASAE 20:372-374).

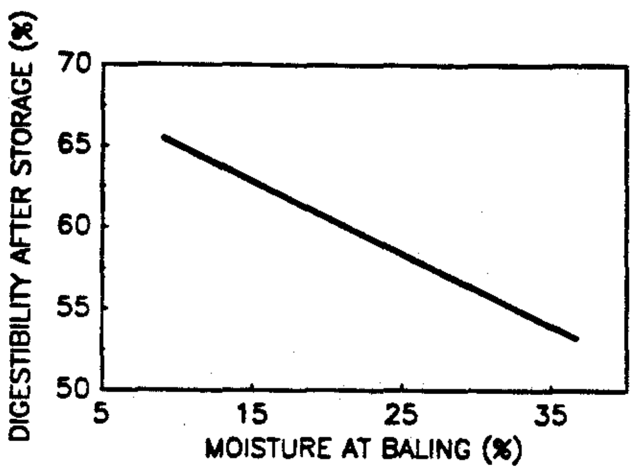

Fig. 3. Relationship between moisture level at baling of alfalfa hay and digestibility after storage (Collins et. al. 1987).

of storage. This sharp decrease in digestibility is caused by the heating and microbial growth that occurs when hay is baled at elevated moisture levels. Certain bacteria grow well at high temperatures and contribute to the attainment of very high temperatures that result in hay fires in some instances. Figure 4 shows temperatures at which fire danger becomes important. Of course, temperatures

70 110 150 190 230 270 310°F

|--------*FIRE DANGER*--------|

|---*PLANT RESPIRATION*---|

|---*FUNGI AND BACTERIA*---|

|---*HEAT RESISTANT BACTERIA*---|

Fig. 4. Hay temperatures and fire danger.

well below these reduce hay yield and quality significantly. We only realize the potential savings in yield and quality that comes from baling at higher moistures by drying or otherwise preserving the hay to avoid deterioration during storage.

Barn Drying

Barn drying is an effective means of insuring preservation of moist hay by reducing its moisture content to acceptable levels for storage. A research facility designed to dry baled alfalfa has been constructed and tested at the University of Kentucky (Parker et al., 1987). Solar heat collected from the roof is used to aid in drying up to 250 to 300 bales in one-half of the dryer building. A similar quantity can be dried in the other side using LP gas heat.

Building Design. Two 24-inch fans provide 5,000 to 6,000 cfm air flow at 2-inch static pressure. The air moves from the roof collector through a duct beneath the floor and upward through 5 to 7 layers of bales. The roof collector area of 1120 sq. ft. feeds into one-half of the drying area.

Hay Drying. Time requirement for hay drying averages about 5 days and depends on weather conditions since they affect air temperature and humidity. Low humidity air can hold much more additional water than humid air so drying is much better when humidity is low. Increasing the temperature of the air also allows it to hold more water and makes it much better for hay drying.

Unheated air sometimes gives good drying but requires more time for completion of the process, thus reducing throughput of the system. Figure 5 shows the drying potential of solar versus ambient air in one of the barn drying tests conducted during 1987. Higher values for grams H_2O/kg DA (dry air) indicate better potential for water removal from the hay and, therefore, faster drying.

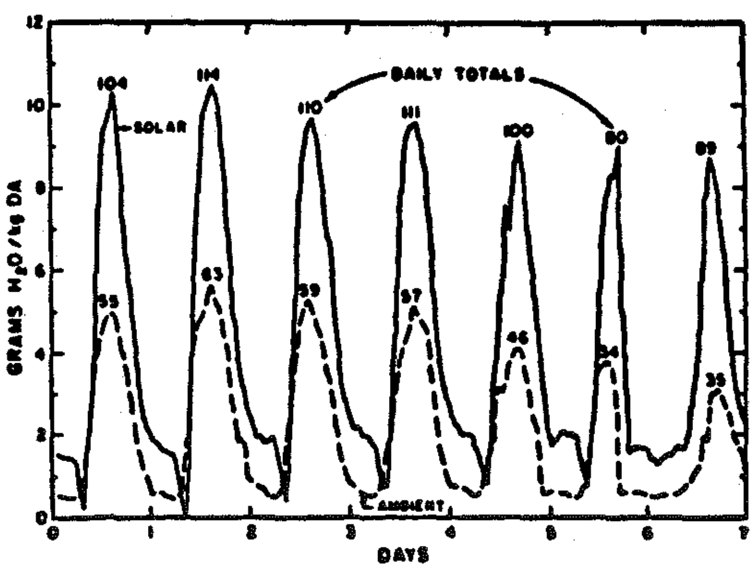

Fig. 5. Drying potential of solar-heated and ambient air.

Increasing air temperature by 15-20°F by solar heating doubles the amount of water it removes from the drying hay.

Supplemental Heat. The absence of solar heat, reduced ambient temperatures and increased humidity levels greatly reduce hay drying at night. Supplemental heat from propane or electrical heaters allows drying to continue throughout the night and completes drying the hay sooner. Off-peak electricity adds 100 - 120 kw hrs. of electricity usage per ton of hay dried.

Drying management. When drying thick layers of material such as stacked hay by blowing air up from the bottom, the upper surface drys last. Hot air enters at the bottom of the stack but this air is cooled before it exits the top of the stack because of the energy used in evaporating water from the hay. A "drying front" develops in the stack. Below the drying front, the hay has been dried and its temperature increases much closer to the duct air temperature. Above the drying front, the air is still being cooled by evaporation. This front proceeds upward until the top layer is dry. Thus, the stack must remain in place until the top layer of bales are found to be dry.

Bale Density and Packing. The drying structure at UK uses inflatable balloons to prevent air loss at the front edge of the stacks. Cracks inside or around stacks allow air loss which reduces drying and wastes heat. Alternating orientation of the bales in different layers helps eliminate cracks that allow air to move through the stack without moving through hay. It is essential to move air through the bales in order to achieve dry, high quality hay.

Uniform bale density is critical to uniform drying. Drying fronts are not as clearly defined in baled hay as they are in drying grain. That is, a tight, wet bale at the bottom of the stack might not be completely dry when the upper bales have completed drying. Mixtures of loose and tight bales in a stack can allow air to avoid moving through the tightest bales by taking the route of least resistance through looser bales.

Cost of Barn Drying. Based on this system, alfalfa hay can be dried using solar heat for $15-20/ton including the costs of the structure, labor and electricity. Since the investment in the hay is increased by drying, we depend upon the improved forage quality and visual characteristics to increase the hay's value. Experience with quality-tested hay auctions in other states indicates that buyers definitely recognize the increased value of high quality hay (Table 2). Knowledgeable marketing, whether through livestock on the farm or to other hay users, is an important aspect of a profitable hay production system.

Table 2. Average price by test standard of hay sold at quality-tested auctions.

Test standard	Number of lots	Average price
		---$/ton---
Prime	8	162
1	34	134
2	29	96
3	18	98
4	2	62
5	1	18

Source: Martin, Univ. of Minnesota, 1989.

References

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