NEW DEVELOPMENTS IN HAY HARVESTING

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INTRODUCTION

Hay and pasture crops are critical to Kentucky Agriculture and to that of the entire temperate region of the US. The sale of cattle, calves and dairy products provide 29% of Kentucky's farm income compared with 23% for tobacco. Beef cow-calf enterprises comprise the majority of cattle numbers in the state, however, dairy production is also significant. A substantial horse industry also exists in Kentucky which is an excellent market for high quality alfalfa hay. At present a substantial amount of alfalfa for feeding horses in the state is imported.

Forages provide the bulk of the feed supply for these livestock. Some 7 million acres are devoted to the production of forages in Kentucky. Quality hay is an important component of beef and dairy, and horse production systems. Legumes in general, and alfalfa in particular, provide high yields of high quality hay. The acreage of alfalfa in Kentucky has increased 36% since 1975 and 25% in just the last 4 years. The potential exists for even larger increases in alfalfa acreage. Kentucky presently has 350,000 acres of alfalfa, however, estimates of agricultural potentials indicate acreage could be increased to 2 million acres without diverting land presently used for row crops. In addition to production for on-farm use, alfalfa has potential as a cash crop. One of the major limitations to the achievement of the potential alfalfa acreage and to its development as a cash crop is the high incidence of weather damage currently encountered during hay curing (Table 1). Frequent rains during the growing season mean that hay is often exposed to rain during the curing process, which can take 3 to 5 days to complete. Weather records show that we have between 7 and 9 days with more than 1/10 inch of rain each month between April and August. Using probability information from a North Central regional publication, we estimated the probability that hay would have 4 consecutive dry days in which to cure during May at only 26%. Clearly, the likelihood is great that rain will occur during the 4 day period.

Thus, due to the high humidity levels, heavy dews and rainfall, curing may require 4 days or more to produce alfalfa hay with 18% moisture. Moisture levels in this range are needed if heating and mold development are to be avoided during storage.

Table 1. Value of a 2 ton/acre harvest of alfalfa before and after hay curing.

Type of forage	Yield of DM	RFV	Value
	-lb/ac-		-$/ac-
Standing herbage	4000	146	306.60
Hay-no rain damage	3312	129	224.85
Hay-rain damaged	3092	99	134.48

Assumptions: A value of $1.05/unit of RFV was assumed for all materials.

Inaccuracy of weather forecasts over long periods makes timing of hay harvest to avoid rain very difficult. The probability of avoiding rain can be increased by shortening field drying time. Available and developing technologies attempt to reduce the time required for field curing and thereby to reduce field losses of yield and quality. Potassium carbonate as a desiccant and high-moisture baling with preservatives are examples of these techniques to shorten curing time.

HAY STORAGE

Moist Hay

Moist hay baling is sometimes practiced because this is one way to reduce the probability of rain damage during field hay curing, by shortening exposure time. Under typical conditions for alfalfa hay, moisture concentration falls rapidly at first but often very slowly toward the end of the curing process. When the humidity in the air is at or above 70%, it may not be possible to dry hay below 20% moisture. The hay may reach equilibrium moisture with the atmosphere, after which no further drying is possible until temperature increases or humidity decreases. Under these conditions, it can be advantageous to bale moist hay in order to hasten the harvesting process. In addition, leaf loss is reduced by baling at elevated moistures compared with overly-dry hay.

Heat Damage

Heat damage may occur in moist hay as a result of plant and microbial respiration and chemical reactions. The moisture range in which the maximum amount of heating occurs is in the 20-40% moisture range for hay. This is close to the range in moisture for dry haylage at which heating is observed. Dry hay does not heat excessively because it lacks the necessary moisture to support microbial growth. Plant enzymatic activity and microbial growth can elevate temperatures to 160°F within a few days. When the temperature goes above this level, it becomes too hot for continued microbial growth and further heating results from chemical reactions. These reactions are responsible for raising the temperature to levels at which spontaneous combustion may occur.

Heating during hay storage reduces forage quality. The extent of the heat damage is related to the color change during storage is related to the amount of heat damage in composition during heating of hay or silage are detrimental to forage quality. When hay heats sufficiently to cause a very dark brown to black color, its protein may be nearly indigestible.

Moisture Loss During Storage

The evaporation of water dissipates the heat generated in moist hay. The thermal conductivity of dry hay is less than that of moist hay. Thus, as hay moisture declines due to heating, the transfer of heat to the outside air becomes less effective. Hay temperature may not rise sharply until most of the moisture has been evaporated. This heat generation in a mass of hay is caused by the growth of microbes that require oxygen. Because of the distance, the centers of large hay stacks tend to be low in oxygen supply and spontaneous combustion occurs outside this zone.

PRESERVING MOIST HAY

When hay is baled above 20% moisture steps should be taken to prevent the microbial growth that is responsible for heat damage and dustiness caused by mold spores.

Hay Additives

Additives are sometimes used to aid in the preservation of hay above 20% moisture by preventing microbial growth during storage. Materials shown to be effective in the preservation of moist hay include sodium diacetate, propionic acid, ammonium propionate, urea, anhydrous ammonia and others. In addition to control of microbial growth, some materials, such as ammonia and urea, may also enhance forage quality by increasing crude protein concentration and increasing fiber digestibility.

The amount of propionic acid needed to ensure control of microbial growth is greater for higher moisture hay. Apparently, the critical factor is to maintain the necessary concentration of propionic acid in the water contained in the hay. Thus, hay with more moisture requires more organic acid for preservation. Hay heating and molding can be controlled by the application of rates as low as 6 lb/ton for 25% moisture hay under controlled conditions but under field conditions about twice that rate is needed to ensure preservation.

Variation of Hay Moisture

Variation in moisture and uneven distribution may limit the effectiveness of hay additives. Variable moisture concentrations increase the difficulty of proper preservative application since higher rates are generally needed to preserve wetter hay. Individual bale moisture concentrations of hay a Maryland study, averaging 40%, ranged from 33 to 45%. Poor distribution of propionic acid within the hay may allow the development of some species of fungi. When insufficient rates of propionic acid are applied on some portions of the hay, this may allow the growth of certain organisms that are able to utilize propionic acid as a food source, leading to further deterioration.

Buffered Propionic Acid Compared With 80:20

During 1990, we compared the effectiveness of a buffered propionic acid product with that of an acid product composed of 80% propionic acid and 20% acetic acid. Buffered products are organic acids adjusted to near pH 6, frequently by the addition of ammonia. Because of their higher pH, these materials are much less volatile and much less corrosive than their unbuffered counterparts.

The initial composition, just after baling, of the moist hays used in this study was very consistent (Table 2). In vitro digestibility averaged 67% and NDF averaged near 45%, indicating generally high forage quality. Acid detergent fiber and cellulose concentrations were very similar for hay from all four treatments. Crude protein was the only variable measured for which any treatment difference existed immediately after baling. In that case, hay that was allowed to remain in the field until it reached a moisture concentration low enough to allow baling without treatment, had lower crude protein concentrations than the buffered-prop. treated hay.

Storage Losses

Moisture concentrations declined during storage for wet control and preservative-treated hays but not for the dry control (Table 3). By the end of the storage period the wet control hay reached a significantly lower moisture concentration than either of the moist, treated hays. This response is frequently observed and is presumed to result from higher temperatures, and thus greater moisture evaporation, in the wet control hay. Dry matter loss during storage in moist hays was about twice that in the dry control hay (Table 3). Slight differences in DM loss were observed for moist hay treatments, with buffered prop. treated hay being significantly higher than the wet control but not the 80:20 treated hay in storage losses.

Visual Characteristics

Organoleptic evaluation of each bale was conducted at the end of the storage period (Table 3). These evaluations indicate that the most dramatic response to treatment with either buffered prop. or 80:20 was a reduction in hay dustiness. Mean dust rating fell from 4.0 for the wet control to 2.3 to 2.6 for treated hay of similar moisture. Dry control hay had lower dust ratings than wet control or buffered prop. treated hays but was not different from the 80:20 treated hay. Visible mold was absent from nearly all bales as reflected in the very low average values for that characteristic (Table 3). The greatest concentration of dust, and the only dustiness in bales rated as very low, was usually observed on the cut side just inside the bale edge. No difference was found among the moist hays in visible mold levels, a common response for alfalfa at this relatively low moisture level. Color did not differ for moist hays and the dry control received better color ratings than moist hay.

Post-storage Quality

Final forage quality measurements conducted at the end of the storage period reflect differences in temperature and microbial activity in wet control versus treated hay (Table 4). In vitro dry matter disappearance was lower for wet control hay than for either of the other treatments. Neutral detergent fiber was highest for the wet control hay, at 50.4%, similar for treated, moist hays and lowest for the dry control. Acid detergent fiber, on the other hand, did not differ between moist, treated hay and the dry control but was also greatest in the wet control hay. Cellulose responded similarly to ADF. Crude protein was similar in wet control and buffered prop. treated hays and slightly lower in 80:20 and dry control hays. The difference, expressed in terms of crude protein, between the buffered prop. treated forage and the dry control was 0.9%.

Table 2. Moisture concentration and chemical composition of alfalfa hay immediately after baling (Trial 2).

Treatment	Initial moisture	Bale density	IVDMD	NDF	ADF	Cell	CP
	--%--	-kg/m³>-	%				
Wet control	25.6# a@	124b	67.2a	44.3a	30.1a	23.9a	20.5ab
Buffered prop.	24.4 b	160a	67.3a	44.9a	29.8a	23.6a	20.7a
80:20	24.2 b	156a	67.3a	45.3a	29.7a	23.7a	20.4ab
Dry control	15.8 c	98c	67.1a	44.1a	30.2a	24.2a	20.1b

> Density values are calculated on a dry matter basis using bale weights immediately after baling. To convert to English units (pounds/cubic foot) divide by 16.

Each value is the mean of 40 observations consisting of 20 bales from each of 2 replicates.

@ Means in the same column followed by the same letter are not significantly different at the 0.05 probability level based on Tukey's test.

Table 3. Moisture concentration and dry matter losses and organoleptic evaluation of alfalfa hay after storage (Trial 2).

Treatment	Final moisture	Final bale density	Dry matter loss	Dust	Mold	Color
	--%--	-kg/m³-	--%--		Rating>	
Wet control	16.7 b#	114 b	6.1 b	4.0 a	1.5 ab	4.9 a
Buffered prop.	21.4 a	147 a	7.9 a	2.6 b	1.6 a	4.9 a
80:20	21.1 a	144 a	6.4 ab	2.3 bc	1.4 ab	5.1 a
Dry control	15.4 c	94 c	3.3 c	1.7 c	1.0 b	2.9 b

> Rating scales are from 1-10 for each organoleptic variable. A rating of 1 for each variable represents a dust-free, visible mold-free, and bright green for the variables dust, mold and color, respectively. A rating of 10 represents extremely dusty throughout, heavy visible mold throughout very dark brown color throughout, respectively.

Means in the same column followed by the same letter are not significantly different at the 0.05 probability level based on Tukey's test.

Table 4. Chemical composition of alfalfa hay after storage (Trial 2).

Treatment	IVDMD	NDF	ADF	Cellulose	CP
			%		
Wet control	66.0 b>	50.5 a	33.5 a	26.1 a	21.1 a
Buffered prop.	67.6 a	48.7 b	31.5 b	24.5 b	20.9 a
80:20	67.5 a	48.5 b	31.6 b	24.5 b	20.3 b
Dry control	67.7 a	45.9 c	32.0 b	24.9 b	20.0 b

> Means in the same column followed by the same letter are not significantly different at the 0.05 probability level based on Tukey's test.

BALE VENTILATOR EVALUATION - 1992

Alfalfa hay was baled in May 1992 to evaluate bale ventilator effects on storage of alfalfa hay at safe storage moistures or at slightly elevated moisture levels. Forty bales of each moisture level, each with and without holes made by attaching a bale ventilator spike measuring approximately 8 in. in length and 3 in. in diameter at the base. Initial moisture values indicate that moist hay was near Kentucky's recommendation for the maximum moisture value for safe baling of alfalfa in rectangular bales.

The presence of the bale ventilator on the baler caused the DM density of bales to be reduced slightly compared with bales made without the ventilator. The difference was substantial, 0.6 lb/cu ft. in the case of moist bales and 0.8 lb/cu ft. in the case of dry bales. Also, as we usually find, moist hay resulted in bales of slightly greater densities even though we made adjustments during the baling process.

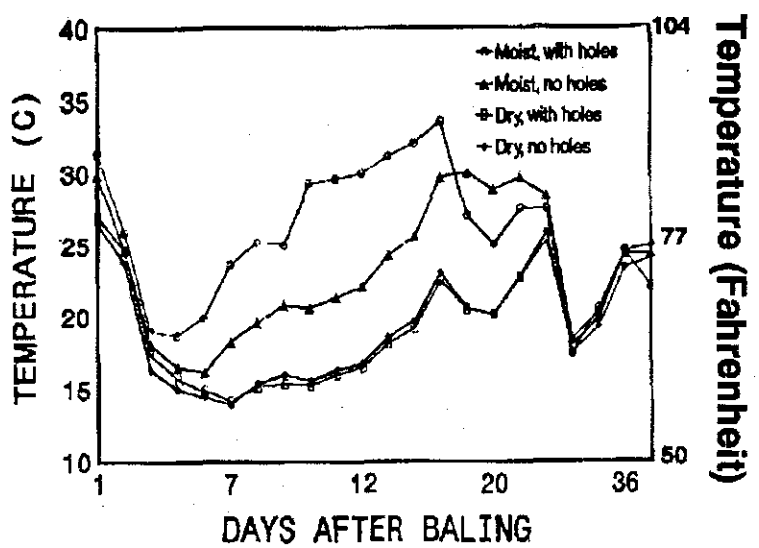
Table 5. Initial moisture, density and post-storage organoleptic data on alfalfa hay at two moisture levels with and without bale-ventilator holes.

Moisture	Holes	Initial moisture	Final moisture	DM density	Mold spores	Visible mold	Color
Moist	No holes	20.4	14.1	6.8	4.1	1.2	4.3
	Holes	21.5	13.6	6.2	4.6	1.2	5.0
Dry	No holes	17.1	14.8	6.4	2.1	1.1	3.1
	Holes	17.6	15.3	5.6	2.0	1.0	3.1

Units: Initial and final moisture (%); DM density (pounds of dry matter/cubic foot); Mold spores, visible mold and color (1-10 scale with 1 being mold spore free, visible mold free, and having excellent green color).

Mold spore, visible mold and color ratings were made on a 1-10 scale with 1 being mold-spore-free, visible mold-free and having excellent, bright green color. Moist alfalfa had more mold spores than dry alfalfa and the bale ventilator had no overall effect. Mold spore ratings were slightly elevated in moist alfalfa with holes compared with similar bales without holes. Visible mold was practically absent but the difference between moist and dry alfalfa was significant. Color was significantly better for the dry hay, although the difference was small.

Storage temperatures were not high, as would be expected at the moisture concentrations present (Fig. 1). Moist hay with holes had the highest temperature during much of the monitoring period. This temperature difference during storage may explain the slightly lower final moisture concentration found in bales from the same treatment.



This trial will be repeated during 1993. Weather during 1992 at this location was particularly wet. This fact may help to explain the unusually large responses of DM loss and mold spore development to moisture differences of only 3 to 4% between moisture treatments.

Fig. 1. Temperatures of ventilated alfalfa bales.

BARN DRYING

Heated or unheated forced air can be used to remove moisture from baled hay prior to storage. Kentucky research showed that electric fans (24 inch, 5-7 hp) maintained static pressure between 1.4 and 2.8 inches of water in the duct beneath alfalfa baled at an average DM density of 10 lb/cu. ft. In eight of thirteen trials drying alfalfa hay from near 35% moisture to final moistures of 6-12%, pre- and post- drying concentrations of CP, NDF, ADF and IVDMD were not different. In the remaining five trials, changes in composition were small. Solar-heated air 20 to 35°F above ambient temperatures hastened drying significantly. Bales ranging in DM density between 5 and 10 lb/cu. ft. were successfully dried except when large variation existed between bales within a batch. Earlier work indicated that the pressure required to force air through bales increased with increasing density and that less pressure was required for bales stacked on edge.

Table 7. Forage quality of alfalfa hay following storage.

Treatment	IVDMD	CP	NDF	ADF	Cel.	ADIN
	----------	----------	%	----------	----------	
Wet control	62.4 bc#	19.2 a	52.2 a	37.0 a	29.4 ab	6.3 a
Buffered prop.	62.8 b	18.9 a	50.1 b	36.4 b	29.3 b	6.0 b
Inoculant	62.2 c	19.2 a	52.4 a	37.3 a	29.7 a	6.2 ab
Dry control	64.2 a	18.4 b	47.7 c	35.2 c	28.5 c	5.4 c

Means followed by the same letter are not significantly different at the 0.05 probability level.

Tennessee researchers dried large round bales of alfalfa and found that pressures of 3.5 inches of water pushed a minimum of 800 cubic feet per minute of air through bales and successfully dried the hay. Soft core bales were more easily dried than hard core bales but these authors concluded that they needed some restriction of the movement of air directly through the middle of the bale in order to dry the edges. With soft core bales, the sealing ring that is considered necessary for hard core round bales.