Causes and Prevention of Spontaneous Combustion of Hay

Lester R. Vough
Forage Crops Extension Specialist
University of Maryland

Spontaneous combustion is always a possibility with stored hay but particularly if hay was baled too wet or too green. Hay growers in this area often face the situation that hay really needs one more day of drying but rain is forecast. The choice is sometimes to go ahead and bale rather than have the losses from rain damage. In many cases that is the appropriate decision -- the hay generally ends up being musty or moldy but most of it is feedable to beef and dairy animals. But in other cases it turns out to be a bad decision, resulting in spontaneous combustion and loss of barns or storage structures if the hay was stored inside.

Hay that was too wet from rain or dew or that was not allowed to dry sufficiently in the field will go through a curing process (sometimes referred to as a sweat) in storage. During the curing process, heat is produced. This heat buildup is caused from live plant tissue respiration coupled with bacteria and mold activity. Plant respiration converts plant sugars to water and carbon dioxide, increases neutral detergent fiber (NDF) and acid detergent fiber (ADF) and decreases the net energy content of the hay. Plant respiration slows as moisture content decreases but does not stop until plant moisture is 20% or less. Mold organisms grow in hay having 20 to 35% moisture content. As with plant respiration, molds likewise consume plant sugars, producing water and carbon dioxide, causing loss of dry matter, digestible nutrients and net energy. The production of water through plant and mold organism respiration can actually increase the moisture content of hay in storage (sweating) if the moisture is not able to escape from the bale, mow (the pile of hay in the part of a barn where hay is stored), or stack.

Plant and mold respiration also generate heat. If the hay heats to 100°F or higher, browning reactions begin (also called carmelization). In these reactions, proteins and amino acids combine with plant sugars to form a brown polymer resembling lignin. This results in increased levels of ADF and of acid detergent insoluble protein (bound protein) and reduced digestibility and net energy (Table 1). Browning reactions release heat, and when coupled with heating from mold growth, result in an upward spiral in temperatures of the hay mass. If the water generated by plant and mold organism respiration is not able to escape from the bale, mow or stack, then what initially may have been a relatively small wet spot becomes bigger and bigger as the heating drives moisture into hay surrounding the spot.

Table 1. Problems associated with hay heating.

Temperature (F)	Problem
115° - 125°	When coupled with high moisture, molds and odors develop and decrease palatability.
> 120°	Heating reduces digestibility of protein, fiber, and carbohydrate compounds.
130° - 140°	Hay is brown and very palatable because of the carmelization of sugars; unfortunately, nutritional value is reduced.
> 150°	Hay may turn black and spontaneous combustion is possible.

Source: Orloff (1995)

Heating can occur in all hay unless it contains under 16-18% moisture. Normally, a moisture content considered safe for baling is 20% or less, but even this can result in some heating and a 5-10% loss of dry matter during storage. Bale density and mass have an effect on heating as well. Potential for heating increases with bale density and size and the surrounding hay mass. The higher the bale density and the larger the bale, the drier the hay needs to be at the time of baling. With small rectangular bales, hay can generally be safely baled at 18-20% moisture. With large round bales or large rectangular bales, hay moisture should generally be no higher than 16-18%. Thus hay baled at 18-20% moisture as small rectangular bales will generally store safely while the same hay baled as large round or square bales will likely heat and be musty or moldy.

The interface between dry hay and wet hay is an ideal spot for spontaneous combustion. As a wet or green spot of hay in a mow or a large bale heats, moisture is driven into the surrounding dry hay. The area where the wet and dry hay touch, has the heat, dampness and insulation necessary to start a fire. If there is enough hay mass around the hot spot to prevent the escape of heat and there is a slow infiltration of damp air, conditions for fire exist. If the hay cools as fast as heat is generated, the hay turns brown and may be moldy, but fire is avoided.

Although most problems with spontaneous combustion begin occurring within two weeks after hay has been placed in storage, combustion is possible for two months. Growers, especially those who know that the hay was a little too wet or green when it went into storage, should start checking for temperature rises within two days following storage and monitor on a daily basis for at least 10 days to two weeks. Depending upon storage conditions and initial moisture content of the hay, it may be necessary to continue monitoring for up to two months. But generally, any problems that result from storing hay with an excessive moisture content are most likely to occur during the first month of storage.

Although one may check the top bales in the mow or stack or the surface of large round bales to find out if there is a heat buildup, chances are the problem will occur in the middle or lower bales in the mow or in the middle of large round bales. These areas are difficult to reach but one way to check the temperature of suspected hay is to force or drive a pipe or hollow probe with a sharpened plug deep into the mow or to the center of large bales, then drop a thermometer tied to a string down the pipe or probe and leave it there for 15 minutes. If the temperature is up to 160°F, read and record temperatures at least daily to monitor the temperature trend. If the temperature is in the 160-180° range, consider moving some hay out so it can dry and cool. If the temperature is 180-190° alert the fire department to the situation and stop ventilation of mows or stacks to the extent possible to reduce the air supply. If the temperature is above 210°, call the fire department to the scene immediately. Do not attempt to move hay at that temperature unless water and fire fighting equipment are on the scene as the hay may ignite when it becomes exposed to a greater air supply as it is moved.

Table 2. Final moisture content (%) of baled hay as dependent on air temperature and relative humidity.

Temperature (F)	Relative humidity (%)			
	30	50	70	90
70	10	13	21	39
80	8	12	20	38
85	7	10	18	37
95	5	8	16	36

Source: Hill et al. (1976)

Hay loses moisture during storage until the moisture content drops to 8 to 15%, depending upon atmospheric conditions in the storage structure (Table 2). Hay coming out of storage in the Mid-Atlantic Region will typically have a moisture content around 12%. Relative humidity is more important than temperature in determining final moisture content. The moisture content remains low as long as water is not absorbed from the soil, rain or moist air.

What can be done to reduce heating of wet hay in storage?

If the hay was baled as small rectangular bales and the bales are being manually stacked, build some air channels to the outside of the mow as each layer of bales is placed. Stack the bales on their narrow side ("on edge"), cut side (edge) up, rather than flat. Bales stacked on their side can not be stacked as tightly as bales stacked flat, thus some air movement through the mow is possible. Place wetter, greener, heavier bales at the outside of the mow where they have greater exposure to air — not in the middle where they are surrounded. Very wet or green heavy bales should not be placed in the mow.

Hay storage structures should have as much ventilation as possible. Small herd or flock owners who buy hay out-of-the-field sometimes run into problems with hay storage facilities that lack proper ventilation. This is especially true with paneled wood or metal structures enclosed on all sides. If hay out-of-the-field at 18-20% moisture or greater is placed in these structures and the doors closed to keep out rain and sun, the structure is sealed against ventilation and problems often develop as the hay goes through the curing process (sweat). If the moisture from the hay is not able to readily escape from the storage area, an indoor daily "rain" event can occur. The humidity level within the storage area increases as the hay cures. At night the water vapor may condense on the underside of the roof, especially metal roofs, and "rains" back on the surface of the stack. Warming of the storage area the next day increases the humidity of the air, with condensation occurring on the roof again the next night, thus setting up a perpetual daily rain event inside the barn until the moisture finally escapes. Thus storage structures need to be well ventilated.

Spreading salt between layers of bales is of little, if any, benefit in preserving wet or green hay. Rates of application high enough to be effective in preserving wet or green hay would be so high that the hay would be unpalatable.

References

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