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Don't watch your forages go up in smoke

PLANTS allowed to continue their growth cycle beyond their reproductive stage have lower nutritive value as a feed. Haying aims to reduce the quality losses due to maturity while maintaining the nutrient content the plants had at harvest time.

Once in the swath the harvested forage dries at variable rates, depending on factors such as its initial moisture content, swath thickness, solar radiation, ambient moisture and air circulation. Although moderate heating (70°F to 110°F) is practically unavoidable, when excessive, it can result in heat damage and potentially become a fire hazard. Three conditions — combustible material, heat production and oxygen infiltration — are necessary for this to happen.

Moisture content critical

Stored forages with high sugar content usually have higher nutritive values. At the same time, they could be at a greater risk of rising temperatures once exposed to air with poor harvesting and storage practices. As long as there is water activity, plant cells in the swath continue to breathe and perform chemical reactions. Energy for these reactions is obtained by oxidizing sugars which leads to heat buildup.

Higher hay temperatures and air availability favor the growth of bacteria and molds that further escalate temperatures. If air repeatedly penetrates the mass, oxidation by microorganisms may continue until spontaneous combustion occurs.

Plant and microbial respiration of sugars to carbon dioxide produce water and heat. In higher moisture bales, the water generated during plant respiration can raise the moisture content of the hay. For this reason, bales stored with excessive moisture are more susceptible to heating as they are an ideal habitat for microorganisms.

Heat drops nutrients

Initial heat generation in hay begins immediately after baling and is characterized by two temperature peaks. The first, two to three days after storage, is generally less intense and persistent. It has been attributed to plant cell respiration. The second temperature spike occurs 5 to 20 days after baling and is started by bacteria, mold and yeast respiration.

Ideal growth conditions for mesophile bacteria, which thrive at moderate temperatures, are achieved when hay reaches approximately 68°F. These bacteria continue to proliferate and generate heat until approximately 113°F. If the cycle stopped at that point, there would be no risks of heat damage or fire hazard.

The problem is that other microorganisms can take over at those higher temperatures and continue to generate heat. Thermophile bacteria, frequently found in moldy hay, start growing at these moderate temperatures, reaching their optimum growth between 131°F and 149°F.

In hay that is dry enough, at or below 18 percent moisture, bacteria will have trouble proliferating, but molds will not. In general, fungal growth in stored hay occurs at temperatures from 50°F to 104°F with optimal conditions at 77°F to 95°F. Mold growth is visually recognized by the presence of the mycelium (white growth in a bale), and their spores (whitish dust) when they arrive to the reproductive stage. Mold proliferation further shrinks the nutritive value of the forage by using up the remaining sugars and even some structural carbohydrates.

Air presence is essential for heating to occur. Bale temperatures above 160°F stimulate heat-generating oxidative reactions that further elevate temperatures. If there is enough oxygen under these conditions, spontaneous combustion may occur.

Research conducted at Kansas State University to investigate changes in temperature during storage showed that hay baled with the greatest moisture concentration exhibited more intense and prolonged heating than drier hay (table).

Why are bales heating?

Bale density: Higher density bales are at a greater risk for spontaneous heating due to a greater quantity of material and reduced heat dissipation. Bale density is affected by the machinery used, experience of the operator and hay type.

Bale size: The capacity of the forage to dissipate heat is associated with the surface to core distance, both for an individual bale and a stack. In addition, large bales generally have higher densities. Large round or rectangular bales have a greater risk of maintaining high core temperatures than small rectangular bales.

Moisture uniformity: Wide swaths lead to more uniform drying which can reduce the presence of wet or green spots in the windrows at baling. The interface between dry and wet hay is an ideal area for spontaneous combustion to occur.

Additives and preservatives: The two most commonly used preservatives for wet hay are organic acids and bacterial inoculants. Organic acids, mainly propionic, limit temperature buildup in wet hay by inhibiting the development of molds, yeasts and bacteria. Their effectiveness depends upon application rate and moisture content of the hay.

Purdue University research tested propionic acid addition to hay with 32 percent moisture at baling and after five days of storage. Maximum storage temperatures were 124, 127, 115, 104 and 84°F for propionic acid concentrations of 0 (control), 0.02, 0.2, 0.5 and 1 percent, respectively.

Propionic acid application rates recommended for controlling heat production in large bales generally range from 20 to 40 pounds per ton of wet forage. Due to high inclusion rates and cost, several researchers conclude that acid preservatives may not be economical. In general, bacterial inoculants developed to improve the fermentation of silage or hay have been ineffective in reducing storage temperatures in wet hay.

Weather conditions: Ambient temperatures also play a role as they can allow for heat dissipation from stored hay or compound the problem. Heat buildup in stored forages depends on ambient temperature, relative humidity and air movement.

Storage site: During storage, bales continue to lose moisture until they reach 12 to 15 percent. The final moisture concentration will remain relatively constant unless water is absorbed from the ground, rain or humid air. Storage structures need to be well ventilated to allow moisture to escape.

Lower your risk

To prevent fire hazard in hay:

1. Bale hay at the proper moisture content: under 20 and 17 percent for small and large bales, respectively. The maximum moisture content at baling can be raised to 23 percent when hay is treated with an effective preservative.
2. If moisture content is slightly higher, do not store bales until it drops to avoid temperature buildup in the core of the stack.
3. Keep the bales under a roof or tarp. For higher heat dissipation, stack the bales with an air gap between loads.
4. Store hay on well-drained surfaces, and raise the bales to prevent direct contact with the soil moisture.
5. Don't store high-moisture baled hay with dry hay or straw.
6. Monitor temperature throughout the storage period.

MODERATE HEATING OF HAY AFTER HARVEST IS INEVITABLE as sugar is burned up. But when it rises excessively, it can cause heat damage or become a fire hazard.

More moisture, more intense heating

Moisture (%)	Temperatures reached during storage: Max.	Min.	30-d avg.	60-d avg.
32.5	143.2	88.5	113.9	103.6
28.7	139.1	88.0	113.5	103.5
24.8	129.6	86.5	108.1	100.2
20.8	110.3	86.2	99.9	95.7
17.8	104.4	86.0	96.6	93.7

Source: Coblentz et al. (2000).

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