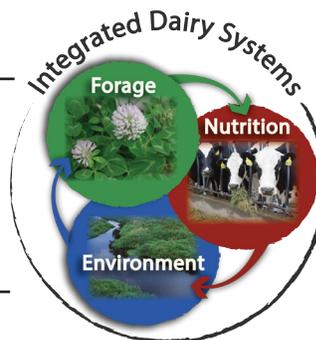


With larger bales . . .

Heating occurs at lower moisture levels; loss of energy can be substantial



U.S. Dairy Forage Research Center

Spontaneous heating in hay, generally caused by too much moisture in the plant at the time of baling, costs livestock producers in terms of dry matter losses and forage quality. With conventional small rectangular bales (80 to 100 pounds), a positive linear relationship between moisture content at the time of baling and heating (as measured in heating degree days*) has been clearly established (Figure 1).

But today's hay producers are using much larger round or square bales, and these larger hay packages have not been studied extensively with respect to spontaneous heating. So we conducted several studies to determine if bale moisture and bale diameter (3-, 4-, or 5-foot bales) had an impact on spontaneous heating. We also measured the amount of dry matter lost and the digestibility of the damaged forages.

The combined effects of moisture content at baling and bale size are shown in Figure 2, which summarizes heat accumulation within large-round bales of alfalfa-orchardgrass hay packaged in 3-, 4-, and 5-foot bales. As observed for small rectangular bales, the heating degree days accumulated during storage increased with moisture content for each bale diameter. However, as bale diameter increased, large diameter bales were more likely to exhibit spontaneous heating at relatively low moisture contents (<20%) and to accumulate more heating degree days during storage. Larger-diameter bales also pose an increased risk of spontaneous combustion. We believe this increase in heating degree days with larger bales is due to two factors: Larger and/or denser packages contain more dry matter within each bale; and larger bale packages have less surface area per unit of forage dry matter, which impedes dissipation of heat and water.

How does heating affect forage quality?

Heat damage in forages is often viewed in binary terms, meaning that the forage is either heat damaged or it is not. In reality, the effects of heating on forage quality are not binary, but are better described as a continuum. Most producers and nutritionists are familiar with the concept of heat-damaged protein; however, this is not necessarily the most important negative consequence of spontaneous heating. Figure 3 describes the relationship between concentrations of forage neutral detergent fiber (NDF) and heating degree days. Concentrations

Figure 1. There is a positive linear relationship between moisture content at baling and heating degree days accumulated during storage for small-rectangular bales of alfalfa hay. The wetter the hay, the greater the chance of heating.

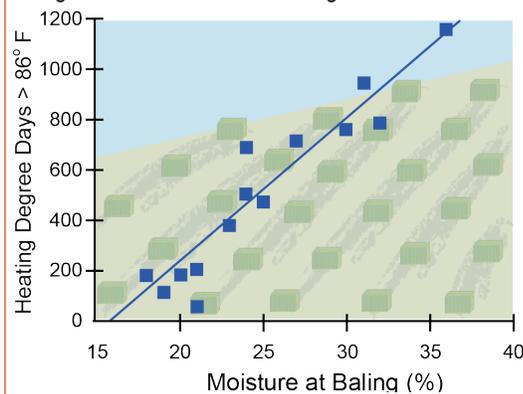
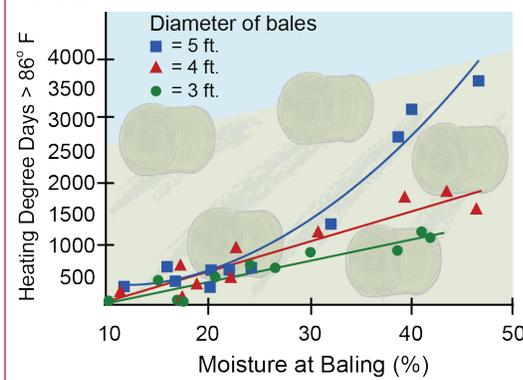


Figure 2. Relationships between moisture content at baling and heating degree days accumulated during storage for large-round bales of alfalfa-orchardgrass hay packaged in 5-, 4-, and 3-ft diameter bales. Chance of heating is now related to two factors: increased moisture and increased bale size.



* **Heating degree days**, similar to the growing degree day concept used by agronomists, integrates the magnitude of the internal bale temperature over the time period during which bale temperatures were elevated. To

calculate heating degree days, 86° F is subtracted from the maximum internal bale temperature for each day of storage. The daily differential is then summed for each day that the difference was greater than zero.

of NDF increased by as much as 11 percentage units as a result of spontaneous heating. It is important to note that NDF is not really generated during the heating process. Increases in NDF concentrations occur because cell solubles (most specifically, sugars) are oxidized preferentially during microbial respiration. Therefore, the concentration of fiber components such as NDF and ADF increase because the concentration of cell solubles decreases. This is particularly important because sugars and other cell solubles are essentially 100% digestible, while fiber components are not. As a result, spontaneous heating decreases the energy density, expressed as total digestible nutrients (TDN), of the forage (Figure 4).

Many nutritionists hold the view that NDF digestibility is reduced as a result of spontaneous heating. Surprisingly, results of our study suggest that NDF digestibility is not significantly altered by heating unless heating is severe enough to cause charring, which appears as black or dark brown pockets in the bale core. When extreme cases of heating were excluded from our studies, there was little evidence that NDF digestibility and heating degree days were related statistically.

Preventing heat damage

Traditionally, the threshold moisture level for acceptable storage for small-rectangular bales has been about 20%. To limit heating, this must be reduced to 16-18% for large-round or large-square bales. For legume hays, these issues create a difficult management situation for producers because lower moisture levels lead to greater leaf shatter and a drop in forage quality. It may not be possible to completely eliminate heating *and* optimize recovery of leaves in large legume hay bales without preservatives or plastic wrap to eliminate oxygen.

In storage, air movement around bales will help to dissipate both water and heat; therefore, outdoor storage is somewhat more forgiving. Producers storing bales under roof should consider managing moisture at baling even more conservatively.

Lab test for heat damaged protein

Tests for heat-damaged protein in forages are expressed in many ways by commercial forage testing laboratories, including: acid detergent insoluble protein (ADICP), acid detergent fiber crude protein (ADF-CP), acid detergent insoluble nitrogen (ADIN), heat-damaged protein (HDP), and insoluble crude protein (ICP).

Arguably, the best definition is acid detergent fiber crude protein (ADF-CP) because the actual laboratory test measures the amount of crude protein retained in acid detergent fiber. Historic benchmarks suggest that if this fraction comprises <10.0% of the total forage crude protein, then minimal heat damage has occurred during storage.

It is important to note that all forages contain some ADF-CP; in unheated hays, this probably comprises 4 to 8% of the total crude protein. In native (unheated) forms, crude protein in ADF is largely indigestible within ruminants, but some research suggests that crude protein in ADF produced as a result of spontaneous heating may have low bioavailability.

In conclusion, larger bales are more susceptible to heat damage at lower moisture levels. Traditional guidelines defining heat-damage to forage proteins are reasonable, but concurrent reductions in energy density may be the most serious consequence of spontaneous heating. □

Figure 3. Nonlinear relationship between concentrations of NDF and heating degree days for large-round bales of alfalfa-orchardgrass hay. The initial concentration of NDF, which corresponds to 0 (no change) on the y-axis, was 46.5%.

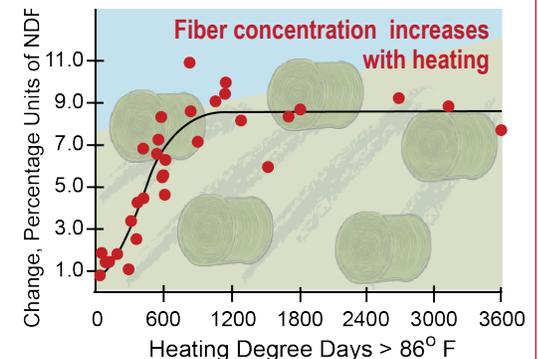
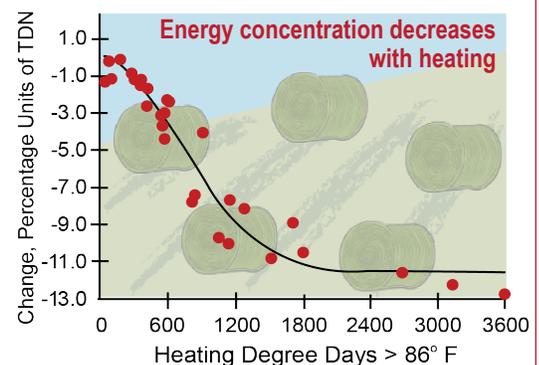


Figure 4. Nonlinear relationship between energy density (TDN) and heating degree days for large-round bales of alfalfa-orchardgrass hay. The initial concentration of TDN, which corresponds to 0 (no change) on the y-axis, was 57.9%.



Contact: Wayne Coblenz
Phone: 715-384-5784
E-mail: wayne.coblenz@ars.usda.gov