Spontaneous Heating More Likely with Larger Bales

by Wayne Coblentz, U.S. Dairy Forage Research Center and Patrick Hoffman, University of Wisconsin

Spontaneous heating in hay, generally caused by too much moisture in the plant at the time of baling, costs livestock producers in terms of DM losses and forage quality. With small, rectangular bales (80-100 lb), a positive linear relationship between moisture content at the time of baling and heating has been clearly established (Figure 1).

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. A study was conducted at the U.S. Dairy Forage Research Center to determine if bale moisture and diameter (3', 4' and 5' diameter bales) had an impact on spontaneous heating. Also measured was the amount of DM 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' diameter bales.

As observed for small rectangular bales, the heating degree days* accumulated during storage increased with moisture content for each bale diameter. However, as diameter increased, large diameter bales were more likely to exhibit spontaneous heating at relatively low moisture contents (<20%) and accumulate more heating degree days during storage. Larger-diameter bales also pose an increased risk of spontaneous combustion. It is believed this increase in heating degree days with larger bales is due to two factors: larger and/or denser packages contain more DM within each bale; and larger bale packages have less surface area per unit of forage DM, which impedes dissipation of heat and water.

HOW DOES HEATING AFFECT QUALITY?

Heat damage in forages is often viewed in binary terms, meaning that the forage is either heat damaged, or it is not heat damaged. In reality, the effects of heating on forage quality are not binary, but are better described as a continuum. The relationship between concentrations of forage NDF and heating degree days are illustrated in Figure 3. Concentrations of NDF increased by as much as 11 percentage units as a result of spontaneous heating. From a practical standpoint, 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. Fiber components, such as NDF and ADF are generally inert during this process, but concentrations increase because cell solubles are reduced due to oxidation. 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 TDN) of the forage (Figure 4). Many nutritionists believe NDF digestibility is reduced as a result of spontaneous heating. Surprisingly, results of this study suggest that NDF digestibility is not significantly altered by heating unless severe enough to cause charring, which

Figure 1. *Linear relationship between moisture content at baling and heating degree days accumulated during storage for small-rectangular bales of hay.*

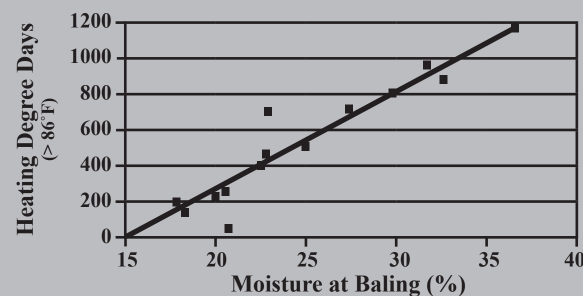


Figure 2. *Relationships between moisture content at baling and heating degree days accumulated during storage for large-round bales of alfalfa-orchardgrass.*

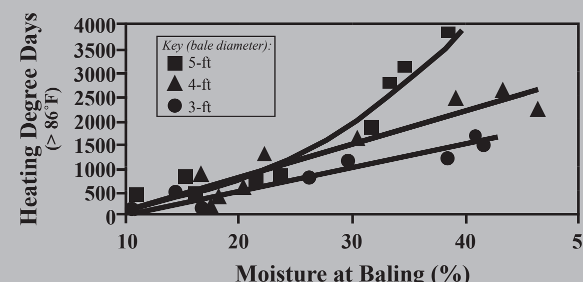
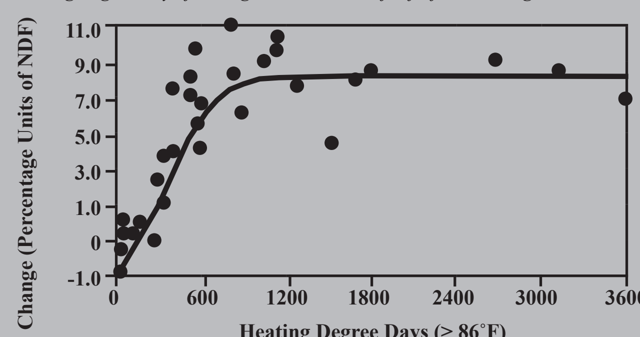
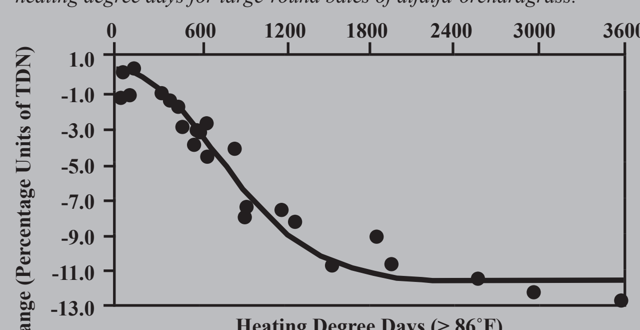


Figure 3. *Nonlinear relationship between concentrations of NDF and heating degree days for large-round bales of alfalfa-orchardgrass.*



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.*



The initial concentration of TDN, which corresponds to 0 (no change) on the y-axis, was 57.9%.

appears as black or dark brown pockets within the bale core. When extreme cases of heating are excluded, there is little evidence that NDF digestibility and heating degree days are related statistically.

LABORATORY TEST FOR HEAT DAMAGED PROTEIN

Livestock producers and nutritionists are familiar with heat damaged protein within heated bales. Tests for heat damaged protein are expressed in many ways by commercial forage testing laboratories. Commonly used terms:

- acid detergent insoluble protein (ADICP)
- acid detergent fiber crude protein (ADF-CP)
- acid detergent insoluble nitrogen (ADIN)
- heat damaged protein (HDP)
- insoluble crude protein (ICP).

In general, these measurements represent the same nutrient and, in many cases, are reported as a percentage of total crude protein (they also can be reported as a percentage of forage DM). 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% 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 4-8% 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 heating.

**Heating degree days, similar to the growing degree day concept used by agronomists, integrates magnitude of internal bale temperature over 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.*