# Reduced feed quality of hay following heating

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**Abstract:** *Heating of hay and hay fires from spontaneous combustion have been a major problem in south east Australia in the last three seasons. Although there is some research available examining risk factors for spontaneous combustion of hay, there is less research available examining changes in feed quality of hay that has been heated but not burnt. The aim of the current study was to examine changes in energy and protein content in lucerne and ryegrass hay following heating. Round bales of lucerne (n=2) and ryegrass (n=2) were baled at 30% moisture content. Temperatures were monitored at 10 cm intervals along the axis of the lucerne bales from the outside to the centre of the bales, while temperatures were only monitored in the centre of the bale for the ryegrass. Temperatures of up to 83°C and 89°C were recorded in the centre of the lucerne and ryegrass bales respectively. Bale weight declined by between 18–31% following heating. Metabolisable energy and digestible protein declined by approximately 4.3 MJ/kg DM and 4.58% respectively. Further work is required to examine the availability of protein from heated hay and the effects of reduced quality on animal production.*

## Introduction

Hay fires have been a major problem in south east Australia in recent years. Hundreds of hay shed fires have been recorded in NSW, Victoria and South Australia due to spontaneous combustion and an unknown amount of hay is likely to have been heated, but not enough to ignite and cause a fire. A range of factors are believed to influence hay heating and the risk of spontaneous combustion. These include moisture (or dry matter) content, crop or pasture species, air temperature and humidity, bale compaction and stacking. Large round and square bales are at greater risk of heating than smaller, less dense bales. Variation in plant water soluble carbohydrate (WSC) levels and types along with changes in waxy leaf cuticle (surface) due to moisture stress, uneven drying due to uneven crops, weeds or machinery used could all have contributed to increased risk of hay heating and fire.

The effect of fire on the loss of hay is clear. However, partial heating of hay without burning is often thought to be beneficial, due to increased palatability. While palatability and potential intake may be increased, the effect of heating on feed value of hay is often not fully understood. Therefore, the aim of the current study was to assess the impact of heating on energy and protein content of lucerne and ryegrass hay.

## Methods

To investigate the effects of heating on hay, two batches of hay with high (approx 30%) moisture content were made into 1.2 m diameter round bales and monitored for weight, temperature and feed quality.

The first batch of hay comprised two round bales of grassy lucerne made in April 2008. Samples were taken before baling and after baling and heating. A sub-sample of lucerne was also baled in small square bales at a higher DM content the day after the low DM round bales were made in order to represent standard non-heated hay.

The second batch of hay (two bales) was made from ryegrass with seed heads emerged. Again, heated hay was compared with samples before baling and when baled dry as normal hay. All bales were weighed when first made and again after heating.

Temperatures were monitored in round bales for 7 months after baling. In the lucerne bales temperature was recorded at 10 cm intervals along the axis of the bales. In the ryegrass temperature was only monitored in the centre of the bale.

Samples of hay were analysed for quality at the Feed Quality Service (FQS) laboratory at the WWAI. In brief, samples of hay were dried at 80°C for 24 hr prior to being ground through a 0.8 mm sieve. Total nitrogen was analysed according to Australian Fodder Industry Association (AFIA) method 1.5R using a Leco autoanalyser FP-2000 (Michegon, USA).

Fibre components (Acid Detergent Fibre, ADF and Neutral Detergent Fibre, NDF) and digestibility (Dry Matter Digestibility) were determined using Near Infra-red Reflectance (NIR) spectroscopy using a BRUKER – MPA (Ettlingen Germany) with calibrations developed by the FQS. Fibre calibrations are based on AFIA methods 1.8A(a):, 1.9A(a):. Pepsin Cellulase digestibility calibrations are based on AFIA method 1.7R.

Crude protein (% DM), Digestible Organic Matter in the Dry Matter (DOMD) and metabolisable energy content (MJ/kg DM)

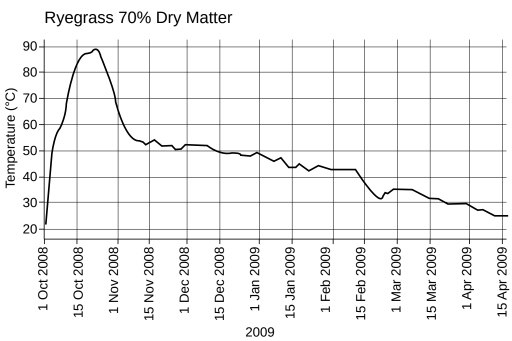


**Figure 1. Change in temperature of two round bales of ryegrass hay.**

were estimated using the following equations [AFIA, 2006 #32];

CP (% DM) = N (% DM) x 6.25

DOMD (%) = 6.83+0.847*DMD (%)

ME (MJ/kg DM) = 0.203 x DOMD (%) – 3.001

Acid Detergent Insoluble Nitrogen (ADIN) was determined in samples of hay using methods as described by Licitra et al. (1995), using Ankom model 220 Fibre Analyser(New York, USA) and Foss Kjeltec 2300.

## Results

### Bale Weight

Although bales looked 'normal' on the surface, bales lost between 18–31% of original bale weight following heating (Table 1).

### Temperature within the bale

In both batches of hay, temperatures peaked 2 to 3 weeks after baling (for example, see Figure 1 for ryegrass hay). Peak temperatures were 83°C and 89°C in the middle of the bale for lucerne and ryegrass respectively and in the lucerne the temperature was generally 10°C to 15°C hotter in the middle of the bale than at 10 cm in from the bale surface (ie. 50 cm between middle and outer temperature measurements). At the peak temperature of 83°C in the lucerne bale, there was a 30°C difference between the middle and outer temperature readings. Bales cooled to ambient temperature after approximately 5–7 months (data not shown).

### Feed quality changes after heating

Metabolisable energy (ME) declined as hay temperatures increased and as hay stayed hot for longer, so the centre of each bale was hottest for longest and had the greatest drop in ME (Tables 2 and 3).

**Table 1. Change in weight of lucerne and ryegrass hay round bales following heating for approximately 7 months.**

| | Lucerne | | Ryegrass | |
|---|---|---|---|---|
| Weight of Bale (kg) | Bale 1 | Bale 2 | Bale 1 | Bale 2 |
| Fresh Bale | 462 | 509 | 546 | 536 |
| Following Heating | 378 | 361 | 377 | 373 |
| Change in Weight (%) | –18.2% | –29% | –31% | –30% |

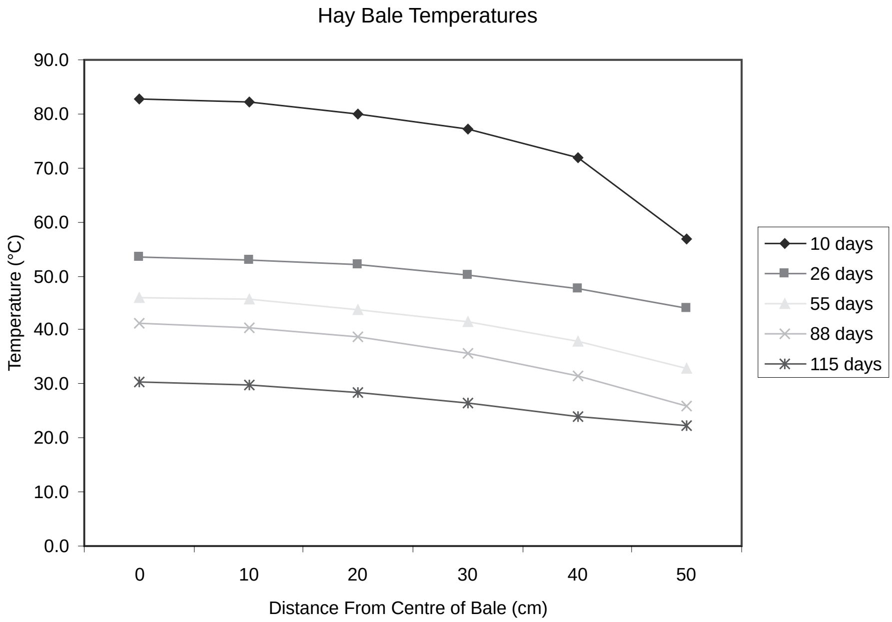


**Figure 2. Change in temperature with increasing distance from the centre of two round bales of lucerne hay. Values are means of two observations per bale with the standard error of the means.**

**Table 2. Feed quality of lucerne prior to baling or following baling at either 12% moisture (dry hay) or 30% moisture (wet heated hay) when heated to 83°C in the middle of the bale.**

| | | | Time from Baling and Distance from Outside of Heated Hay Bale | | | |
|---|---|---|---|---|---|---|
| Parameter[1] | Pre-baling | Dry Hay | 61 Days | | 365 Days | |
| | | | 0–20 cm | 40–60 cm | 0–20 cm | 40–60 cm |
| DM (%) | | 88.2 | 81.2 | 75.8 | 91.7 | 92.7 |
| NDF | 51 | 56 | 59 | 60 | 65 | 55 |
| ADF | 31 | 31 | 35 | 37 | 42 | 46 |
| DMD | 61 | 61 | 56 | 54 | 51 | 47 |
| Ash | 9 | 8 | 7 | 8 | 12 | 12 |
| ME | 8.6 | 8.4 | 7.6 | 7.0 | 6.3 | 5.5 |
| CP% | 18.8 | 19.8 | 17.1 | 17.9 | 20.0 | 20.6 |
| ADIN% | – | – | – | – | 21 | 44 |
| CP Available (%) | | | | | 15.8 | 11.5 |

[1]NDF = neutral detergent fibre, ADF = acid detergent fibre, CP = crude protein, DMD = dry matter digestibility, ME = metabolisable energy, ADIN = acid detergent insoluble nitrogen. CP Available = estimate of CP available for animal digestion (CP corrected for proportion of protein bound to ADF as ADIN).

Crude protein content as a proportion of the whole bale DM (CP%) increased slightly indicating a greater loss of the non CP fraction, most likely WSC, over time. This result, however, could be misleading as the acid detergent insoluble nitrogen (ADIN%), which indicates if the crude protein can be digested by animals, shows that after heating most of the crude protein cannot be digested. The extreme of this effect was recorded at the centre of the heated ryegrass bales which were hottest for longest and had an ADIN of 63.6% indicating that 63.6% of the crude protein was not digestible by animals where as before baling and heating the ADIN was only 2.6% (Table 3).

**Table 3. Feed quality of ryegrass prior to baling or following baling at 30% moisture (wet heated hay) when heated to 89°C in the middle of the bale.**

| | | Distance from Outside of Bale | | |
|---|---|---|---|---|
| Parameter[1] | Pre-baling | 0–20 cm | 20–40 cm | 40–60 cm |
| DM (%) | 92 | 91 | 91 | 91 |
| NDF | 57 | 68 | 54 | 57 |
| ADF | 30 | 39 | 45 | 52 |
| DMD | 68 | 61 | 52 | 46 |
| Ash | 8 | 9 | 9 | 9 |
| ME | 9.8 | 8.4 | 6.5 | 5.5 |
| CP% | 9.6 | 12.2 | 12.5 | 13.1 |
| ADIN% | 2.6 | 10.5 | 47.8 | 63.6 |
| CP Available (%) | 9.35 | 10.92 | 6.52 | 4.77 |

[1]For abbreviations, see Table 1.

## Discussion

This monitoring of heated hay bales showed that temperatures varied widely within the bale, hence, a long stemmed thermometer was needed to measure temperatures in the centre of the bale. Peak temperatures of 89°c without the bale igniting were higher than expected and further research into the issue of spontaneous combustion is needed.

Analysis confirmed that significant loss of feed quality occurred after heating and that a simple crude protein test could be misleading when used on heated hay. Results showed that crude protein % appeared to increase after heating but the ADIN test showed that much of this crude protein was not digestible. The slight increase in %CP observed may be explained by the loss of carbohydrate in the hay that incurred greater heat damage, and resulting higher proportion of CP.

It is recommended that further work with the ADIN test is needed with heated hay and that it should become a standard test when assessing the feed value of any hay.

## References

AFIA – Laboratory Methods Manual (2009), Australian Fodder Industry Association ISBN 0 642 58599 7

Licitra, G, Hernandez, T.M, Van Soest, PJ (1995) Standardization of procedures for nitrogen fractionation of ruminant feeds, *Animal Feed Science Technology* 57 347–358