DEPARTMENT OF
PRIMARY INDUSTRIES

Agriculture Notes

Note AG1379

Published: April 2009

Hay Preservatives

This Agnote provides information on the use of preservatives for safer storage of hay in Australia. When deciding which product to use, it is important to understand the differences between each of the products and when each can or cannot be used.

Introduction

Hay preservatives are products that allow the baling of hay at higher moisture contents thereby reducing drying times. They work by limiting the growth of bacteria, yeast and moulds in the hay through different mechanisms.

If used, the cost of the hay preservative must be offset by an advantage being gained in one or more broad areas:

- An increase in the value of the hay due to reduced leaf loss or when potential quality loss from incoming rain is avoided.
- Improvements in nutritional quality that arise when a less mature product can be cut and baled earlier in the season with lower lignin levels
- Increasing machinery running hours across a day or a season, improving the ability of producers to get hay baled at the correct time
- Managing the risk associated with spontaneous combustion that results from high microbial counts in hay.

Most, though not all, hay preservative products require uniform distribution across the fodder being baled. This aspect is very important in some classes of products in order to avoid “pockets” of heating (potential for spontaneous combustion if very moist) and mould growth.

Some products do not require complete coverage of all fodder entering the baler to be effective, but consistent delivery remains important to avoid “hot bales”

Table 1 shows the recommended moisture contents at which to bale hay safely in the normal manner. Baling hay at moisture contents slightly above these levels for each bale type may lead to some heating due to the activity of aerobic micro-organisms and possibly some plant respiration. The hay would be expected to eventually cool to the ambient temperature.

Table 1. Recommended moisture contents (%) for safe storage of various bale types

Bale type	Moisture content range (%)
Small rectangular bales	16 – 18
Round bales (Soft centre)	14 – 16
Round bales (Hard centre)	13 - 15
Large rectangular bales	12 -14
Export Hay	Under 12

However, if hay is baled with moisture contents well above (> 3%) the suggested levels, particularly the large rectangular and round bales, their temperature will rise substantially. The warm, moist conditions in this “wetter” hay will provide the ideal environment for growth of spoilage bacteria, eg. Bacilli and yeasts, moulds and fungi. These organisms utilise the energy and protein of the hay and can lead to a substantial increase in their respective populations. Their action leads to the following reaction:-

Hay (plant sugars) + oxygen → Carbon dioxide + water + heat

The resultant heating causes a reaction between the carbohydrates and proteins rendering both less digestible as temperatures continue to increase (See Agriculture Note *AG1357: What happens to hay when it heats).*

Hay preservatives work by inhibiting or reducing the growth and activity of these aerobic micro-organisms. This stops their activity so stops production of the water and heat and a further build-up in their populations. Moulding and heating is avoided so negligible nutritive value is lost. Note that most hay preservatives do not improve the nutritional quality of the forage, but do prevent the decline in quality caused by the micro-organisms.

Benefits of using hay preservatives

To gain maximum benefit and effectiveness of hay preservatives it is crucial that the instructions on each product label are followed. This is due to the broad range of preservative types and variation within types due to different concentration levels of active ingredients or bacterial types.

Benefits of using hay preservatives are that they:

- allow the safe baling of hay from slightly above target moisture levels up to 25% (or 30%) moisture depending on preservative type
- allow baling after a shorter curing period which reduces risk of rain damage and sun bleaching. It may also allow baling earlier in a season in certain areas, when fodder is less mature and nutritive value higher
- reduce dry matter and nutrient loss caused by leaf loss and shatter, microbial activity and moulds
- enable baling over a longer period each day, resulting in more effective machinery and efficiency of labour usage
- maintain hay colour (due to increased leaf retention) and often smells better
- prevent dry matter and quality loss in storage due to bacterial, yeast and mould activity
- reduce risk of spontaneous combustion
- may increase animal intake
- Animal and human health not affected due to lack of mould spores.

Types of hay preservatives

Four main categories of hay preservatives are available; organic acids and their salts, bacterial inoculants, sulphur based preservatives and ammonia-based additives. Some products may also include enzymes, antioxidants and nutrients.

1. Organic acids and their salts

When applied, organic acids act as fungicides by producing an acid environment which is not conducive to mould, yeast or bacterial growth. Two of the main acids used are propionic and acetic and being naturally occurring acids in the rumen, are safe for all types of livestock, including horses. These products are liquid and require spraying equipment to apply the preservative at the hay pick-up area.

However, these products are corrosive on machinery and can be dangerous for operators to use in their pure form. To overcome these problems, "buffered" acids, some times referred to as "neutralised or pH balanced" acids, have been developed and commonly include salts of propionic, acetic and formic acids. Their pH is about 5.5 to 6 so they are much less corrosive and safer to use but more expensive. Although slightly less effective than the pure acids there are fewer losses due to volatilisation.

More than one buffered acid may be included in product mixes such as propionic + acetic acids. The propionic acid is highly effective against mould growth whilst acetic acid is more effective against bacteria and yeast. They are available in liquid and granular form.

To be fully effective the preservative must contact as much of the material as possible. For best results the preservative should be applied across the pick up on the baler, not sprayed onto windrows during raking or conditioning due to the chemical volatilising and consequent reduction in effectiveness.

Figure 1. Spray applicator on baler

Hay baled at high moisture contents, even when treated with preservative, should not be mixed with properly cured low moisture hay as the moisture may migrate to the drier hay and allow moulds to grow.

It is Good Agricultural Practice (GAP) to store bales treated with preservatives separately (or identifiable) from those non-treated bales.

Even though it is not a legislative requirement, it is also a good practice to inform the purchaser and/or receiver of the treated bales of the type or preservative used.

Although hay can be baled up to 30 per moisture content, their weights will be substantially increased and may exceed the capacity of some moving equipment. They would also be misshaped or become misshapen when being picked up or moved, and twine may break.

Rates of application

The rate of preservative application varies according to the moisture content of the forage being baled and the type of bale (Figure 2). Application rates would need to increase as the late afternoon dew descends and decrease as the morning dew lifts. If rates are not altered accordingly, an inadequate rate will result in reduced effectiveness in preventing growth of the aerobic micro-organisms.

Be clear whether the application rate is on a product basis or an active ingredient basis. Be aware that the products containing propionic acid may vary considerably (10 to 100% in America). So using very dilute products will require large volumes which could be impractical to cart on balers. And more importantly, why apply more moisture to a crop being cured?

Read the product label carefully as each product may vary in its application rates according to the concentration of active ingredient, acid type, moisture content, etc.

Pay particular attention to safety aspects and guidelines for protecting machinery and the operator.

Application rates must be estimated as accurately as possible for the moisture content and bale type and strictly adhered to. Truly representative samples of material from the windrow must be used to determine the moisture content of the material to be baled (See Agriculture Note *AG1238 Dry Matter content of conserved forages: Representative sampling)*. Bottoms of windrows, shaded areas, weedy patches, heavier sections, etc. can all be wetter than the remainder of the crop. The application rate must be based on the readings from the "wetter" areas, possibly consider baling these areas last, if confidently well defined.

Table 2 is an example of one product only, which illustrates the substantial increase in rates required as moisture content increases and for each bale type. Each product will have different recommendations, so read the label carefully.

Table 2: Preservative rates required over a range of moisture contents and bale types

Bale type	Moisture content range (%)	Preservative rate (kg/tonne)*
Large rectangular bales	16 - 22	2.81
	23 - 26	4.68
	27 - 30	Do not bale
Small square & large round bales	16 – 22	1.87
	23 – 26	3.74
	26 - 30	7.48

*Converted from US pounds per ton
Source: J. Roberts (2005)

Calculating crop throughput (tonne/hour)

To apply the required amount of preservative, the forage handling capacity of the baler in tonnes per hour must be determined. Then the pressure regulator or nozzle tips of the applicator system must be adjusted to spray the recommended rate of preservative as per the particular product being used. Several sets of nozzles may be required since application rates may increase fourfold (Table 2).

Recent developments in spraying technology have included moisture content determination, automatic on/off switches, variation in application rate based on material throughput, etc. So operators need to keep abreast of new developments. However, knowing the forage throughput is still essential for most applicators to date.

Use the following formula to determine the wet tonnes of hay harvested per hour as:
Tonnes hay/hr = (No. bales in 5 min. x wt/bale x 12) ÷ 1000

To determine rate of application of preservative/hour, measure nozzle output in litres/minute, then multiply this by 60 to get litres/hour. Multiply the number of nozzles across the boom by the output/hr to give total output/hr. That is:
Total output/hr = nozzle output/min x 60 x No. nozzles

Longevity of effectiveness of organic acids

Although organic acids and their salts are proven to be reliable in inhibiting mould growth, some research has shown that with time, the acid will dissipate from the hay. This may result in mould growth after 4 to 12 months if moisture levels are still high enough to support their growth but will depend on initial application rate, storage conditions, etc.

Similarly, if bales are left in the open the organic preservative will volatilise, diminishing their effectiveness and rain would dilute or leach the organic acids. The same would occur if moisture migrates into shedded bales e.g. leaking roof.

2. Bacterial Inoculants

Some silage inoculants developed for silage use are also sold as being effective for hay preservation. There are also some biological products that have been developed specifically for hay treatment. These products can be used in hay with moisture contents up to about 25% moisture. No research has examined their effect in the very dense large rectangular bales over a range of moisture contents. So a lower moisture content may be necessary to be effective for safe storage.

There are three basic groups of biological (often referred to as bacterial or microbial inoculants) products used as hay preservatives:

1. Fermentation enhancers
2. Aerobic spoilage inhibitors
3. Antibiotic-producing, bacterial inoculants

1. Fermentation enhancers

Some silage inoculants developed as fermentation enhancers are also sold as being effective for hay preservation. Most contain lactic acid producing bacteria that compete with yeasts and mould forming organisms aiming to maintain forage quality. Commonly used lactic acid bacteria are *Lactobacillus, Pediococcus, Streptococcus* and *Bacillus.* Some inoculants contain a combination of bacteria and enzymes, the latter to break down plant cells, making more cellulose and starch available to the lactic acid forming bacteria.

However, most lactic acid producing bacteria require anaerobic conditions and acidic conditions (under about pH 5.0) to work at their optimum and this situation would probably only occur in the very dense large rectangular bales.

When using this class of inoculants on hay, the plant sugars must be high (substrate for the bacteria) to provide the best protection against moulds and yeasts. For pasture plants this usually occurs when they are vegetative, in mid to late spring.

Inoculant effectiveness depends on the ability of the introduced bacteria strains to compete with those micro-organisms (mould producing types) already existing on the hay. Inoculants are usually ineffective on rained on hay (24 to 48 hours) since the hay micro-organism populations increase exponentially. The inoculant rate needed is usually much higher than for silage and would be most likely uneconomical. Organic acid or Sulphur preservatives would be much more cost effective.

Some non lactic acid producing bacteria have increased the visual quality of moist hay (up to 25% moisture) and improved its odour but has not been shown to improve its feed value.

In general, USA research has shown that this class of microbial products used as hay preservatives do no harm but have shown few benefits. Little, if any, research has been carried out in Australia to investigate the effectiveness of this class of inoculants for hay preservation.

2. Aerobic Spoilage Inhibitors

These recently developed inoculants use *Lactobacillus buchneri* 40788, a group of bacteria which restrict the growth of spoilage type organisms such as yeasts and moulds. Their mode of action is thought to be due to secondary metabolites called "buchnericides" and may reduce the need for paddock curing unless extremely wet. Recent research indicates that they are usually much more effective than the fermentation enhancer group.

3. Antibiotic-producing, bacterial inoculant

Another group of bacteria selected from the natural Australian environment, *Bacillus amyloliquefaciens*, was selected to survive desiccation after application to the cut crop and to survive in storage. These bacteria work by:-
a) producing antimicrobial compounds which inhibit, sometimes stopping, the growth and reproduction of moulds and other spoilage micro-organisms.
b) increasing the rate of water loss which makes hay less conducive to spoilage organisms. The increased drying rate reduces the rate and amount of plant respiration, resulting in less nutrient loss and reduces the period for population growth of spoilage organisms.

The use of this product requires specific management to ensure maximum effectiveness. One such requirement is for the product to be applied as the crop is being mowed for hay, the aim being to suppress yeast and mould populations that may increase during hay curing, especially at the bottom of moist windrows and other wet "hot spots".

If using bacterial inoculants, use pure and clean water for mixing. Town water (Fluoridation chemicals kill bacteria), algae and dirty water (affects the ionic charge of the inoculants) and hot water will greatly reduce product effectiveness.

Ensure products have robust scientific data from experiments done by reputable organisations research institutions, preferably independent of company ties.

3. Sulphur based preservatives

Sulphur based preservatives are another product type that offers control of microbial proliferation. Sulphur compounds are widely used in human and animal food sectors as preservatives and work essentially the same way in hay through their oxygen scavenging mode of action.

In fodder, they create an environment within the hay bale that is unconducive to microbial growth stemming mould and yeast development. Sulphur compounds act not only on the actual surface of the particles within baled fodder, but also in the air spaces within the bale.

The application rate at 0.8-1.0 kg or Litres per tonne is much lower then with acids, and complete coverage of all fodder entering the mouth of the baler is neither possible nor totally crucial when using this product type. Even and consistent application always remains preferable however.

The small application rate may potentially be seen as an advantage when considering the running time that a tank of product can provide between stops in baling to refill.

A lower rate of overall moisture being added into bales could also be a potentially advantage.

Sulphur compounds are not acidic, and as such are generally fairly user friendly. The sulphur compounds themselves are salts however and as such, wash down of gear post baling is recommended.

Ensuring that every bale is properly treated is just as important with these products as any other product type. A single bale that missed treatment is a huge risk no matter what product type was applied.

4. Ammonia-based preservatives

Anhydrous ammonia

Although not commonly used in Australia, anhydrous ammonia, when applied at 1 per cent (dry matter basis) to hay containing up to 30 per cent moisture, has been shown to reduce dry matter losses and prevent heating and moulding. The rate is crucial. Applying, say 0.8 per cent (dry matter basis), is much less effective than the 1 per cent rate.

However, it is more commonly used to improve the feeding value of cereal straw, mature grass hay and corn stover when applied at 2 to 4 per cent (dry matter basis).

Higher quality forages such as lucerne and leafy ryegrasses **should only** be treated at the rate needed for preservation (1% of dry matter) due to an unknown toxicity which can cause animal deaths and the toxin is transferred into milk.

The major disadvantage of using anhydrous ammonia is that its application is difficult and it is a hazardous chemical. Equipment has been used to inject the anhydrous ammonia into round bales but no such equipment is commercially available. Covering bales with plastic and then injecting the appropriate amount of anhydrous ammonia is an option but uniform distribution is difficult, resulting in some spoilage in some areas. Ensuring even distribution in both above techniques would be even more difficult with the very dense nature of the large rectangular bales.

Urea

Applying urea, which is then converted to ammonia by the bacteria, is simpler than applying ammonia gas. Relatively large amounts (5 to 7%, as baled basis) of urea applied during baling can be effective up to 30 per cent moisture. However, the treated hay must be covered tightly with plastic sheeting as soon as possible after baling.

Use of salt as a hay preservative

Common salt has often been used between layers of moist bales to both preserve the hay and improve its palatability. However, it is ineffective as a preservative unless applied in such amounts as to be physiologically harmful to animals. The salt itself would be detrimental to microbial and mould growth, and being hygroscopic in nature, absorbs moisture in proximity to the salt granules.

The placing of salt between round bales and layers of large rectangular bales will only be effective near the salt itself, possibly having an effect of 1 to 3 cm (guesstimate) into the bale itself. The only way salt may be effective would be if the salt was spread throughout forage in the round bale and large rectangular bales as they were being baled. To do this would be very expensive, difficult to achieve, would require large quantities and may still not be 100 per cent effective.

Figure 2 summarises the recommended dry matter levels for safe storage of hay and when to use hay preservatives. Each preservative type will vary in its ingredients and mode of action so it is essential that labels are read in detail.

This Agnote is based on information largely from overseas, principally from the USA, which has carried out much research into many aspects of various types hay preservatives. Unfortunately little research has been done in Australia which has some different grass species, different climatic conditions and possibly different spoilage organisms on the stored products. Although it is highly likely that the imported products will work effectively under Australian conditions, some local research would reinforce this claim

Contact/Services available from DPI

DPI Chemical Standards website - *www.dpi.vic.gov.au/chemicalstandards*

Acknowledgements

I wish to thank the outside reviewers and the major suppliers of hay preservatives for their critiquing of the accuracy of the content of this agnote.

This agnote was developed by Frank Mickan, Pasture and Fodder Conservation Specialist, Farm Services Victoria/Ellinbank. April 2009.

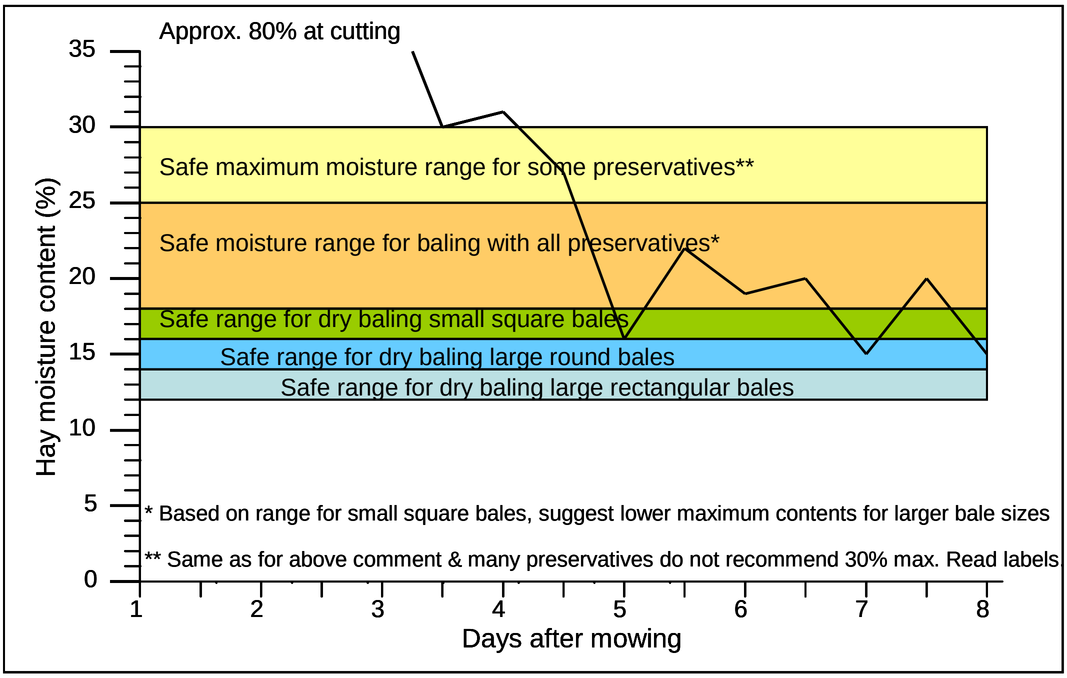

Figure 2. Target DM contents for safe storage of hay and when to use hay preservatives. Example drying rate shown will vary depending on climatic factors and yield, etc.

ISSN 1329-8062

Published and Authorised by: Department of Primary Industries
1 Spring Street
Melbourne, Victoria