The Breakdown of Hay Preservatives and Additives

Hay preservatives such as acids, bacterial inoculants, enzymes and other compounds, allow for hay to be baled at higher moisture levels (18-25%), thus decreasing field drying times. Baling at higher moisture means that there will be reduced in-field dry matter (DM) and leaf loss. While preservatives do not add anything in terms of nutritive value, they prevent heating and mold development if hay is baled above safe moisture levels. In fact, mold will reduce palatability more than high fiber content. Hay preservatives can potentially assist those interested in maintaining high quality hay by reducing the risk of weathering and deterioration of hay in the field.

Cost effectiveness of hay preservatives will vary with product type and application rates. The best returns are achieved when used on high quality hay. Remember, preservatives do not improve the quality of hay, but rather only maintain the quality of the hay harvested.

Considerations for Use

The following should be taken into consideration before using preservatives.

- **Stage of maturity at cutting:** It is recommended that preservatives be restricted to a high quality forage cut early or at the optimum stage; the nutritive value of a poor quality, mature forage is not improved through preservatives.
- **Seasonal timing of cutting:** Bacterial/enzyme-based inoculants respond best in crops with high sugar levels; and thus are not recommended for crops cut in the late season period, when the plant sugar levels are too low for proper mold prevention.
- **Degree of deterioration:** Hay that has undergone severe deterioration and weathering, or hay that has been rained on is not a good candidate for using preservatives); in this case, only acids are recommended.
- **Moisture level at baling:** It is important to know the actual moisture content of forage to be baled so that the appropriate application rate is used. Since safe moisture range for baling can fluctuate during the day, depending on temperature and humidity, preservatives should only be applied during the times when baling conditions are not optimum.
- **Swath characteristics:** It may be advantageous to consider use of preservatives in fields where there is a high degree of variation in moisture level and plant species within the swath, and in fields with numerous wet spots.
- **Stack characteristics:** Since preservatives will not protect hay from rain or melting snow, any hay that has been treated must be covered, either tarped or shedded, in order to protect your investment.

Hay Preservative Types

In Canada, 134 products are registered for use as hay preservatives; however not all are available in Manitoba. Producers can generally obtain the products and applicator equipment from local dealers.

The products registered for hay preservation are mainly acids and bacterial inoculants. Commercial products may also contain a host of other ingredients including enzymes, antioxidants, and nutrients. When deciding which product to use, it is important to understand the differences between each of the products.

When applying any preservative or additive, applicator set-up can be just as important as using the right product. Be sure to properly calibrate your applicator, adjust the nozzle type, pressure, and positioning for maximum coverage. And if using a biological inoculant, be aware of the inoculant's viability.

Biologicals

Many of the biological products available on the market for hay are simply silage products transplanted into the hay scenario. The products are performing the same task as in silage, promoting good fermentation and forage

quality. The products can be either enzyme-based, bacteria-based or a product having a combination of the two types together. The bacteria-based inoculants are the most common type having 85 registered products in Canada, compared to 7 enzyme-based and 20 products with a mixture of the two. The reason biological products are often cheaper than acid-based products is because their results are not typically as consistent; however, when used properly they can be quite effective.

Bacteria Inoculants

When adding bacteria inoculants, you are simply adding more of the same bacteria already present in the plants. The bacteria inoculants contain lactic acid producing bacteria (LAB) which help the LAB already found naturally in the plant to compete against mold forming bacteria, helping to maintain forage quality. Commonly used LAB include Lactobacillus, Pediococcus, Streptococcus, and Bacillus, and may exist as the sole LAB of an inoculant or part of a mixture of a number of different types.

When used properly they improve fermentation in silage and reduce mold and yeast development in hay. However, when applying to hay, they are only recommended for use during mid-summer conditions when plant sugars are high. It also important that when using them for hay preservation to ensure optimum conditions (uniform application, optimum moisture level, temperature, storage, etc) to provide the best protection against molds and yeasts. Research indicates that effectiveness likely depends on the ability of the introduced bacteria strains to compete with existing hay microflora (mold producing bacteria). Inoculants are generally ineffective on rained-on hay, probably because of their inability to compete with exploding hay microflora populations. In figure 2, it becomes apparent that the typically recommended application rate of 500,000 colony forming units (CFU) per gram of DM would be ineffective against the exploding bacterial population of rained-on hay after 24 hours. Inoculant rates would need to exceed 2,500,000 CFU to combat mold development 24 hours after a rain event, and 5,000,000 CFU after 48 hours. Rates of this magnitude quickly become uneconomical, and money would be better spent by using acids.

Enzyme-based Preservatives

The enzymes used in preservatives are simply enzymes taken from inside bacterial inoculant cells. Their purpose in the industry is slightly different than bacteria inoculants in that their main goal is to promote plant cell breakdown and render the cellulose and starch found in the plant fiber (ADF & NDF) more accessible to desirable acid producing bacteria. While they do not directly prevent mold growth, enzymes will make nutrients available to desirable lactic acid bacteria (LAB), thereby increasing the desirable LAB. Some reports have shown improved forage digestibility, but data is dependent on many factors. The greatest effects are often seen on more mature forages with higher fiber and moisture contents, or those forages with limited sugar contents. Their effectiveness is improved as moisture levels increase, therefore good results can be realize in high fiber silage production. They are not recommended for use on dry hay; the Manitoba winter is often better at preserving forage than enzymes.

Common types of enzymes used are Cellulase, Amylase and Protease, and unlike bacterial inoculants, enzymes can be stored for long periods of time. However this is dependant on the process in which they were derived. Consult your sales agent to determine the storage requirements for the product you choose to apply.

It is recommended to spray all inoculants and enzyme-based preservatives directly on the forage as being harvested to maximize application uniformity. These attachments are readily available from your local silage implement dealership.

In comparison to acids and ammonia, bacterial and enzyme-based preservatives are generally not as effective in preventing mold. However, they are less hazardous to handle, readily available, easy to apply, and they are relatively inexpensive.

There are many products on the market that have not been tested completely or registered with CFIA; for those cases it is buyer-beware. Some products may make statements of improved hay quality and show research data to prove it. Although this data is often valid, the studies for some products are conducted in arid regions that are less prone to mold development. Products on the marketplace with a temporary registration are allowed a period of up to one year to substantiate label claims or else be removed from the marketplace.

Reference:

Registered Non-Nutrient Forage Additives List - Canadian Food Inspection Agency (PDF 63 KB)

Organic Acids

Organic acids have been used as a preservative for silage, hay and high moisture grain for many years. Applied at low rates they discourage yeasts and mould growth and may encourage a lactic acid fermentation. When applied at high rates the acids inhibit all microbial activity. They are typically more effective and consistent on controlling molds and yeasts than bacterial inoculants and enzyme preservatives, especially on late season crops with low plant sugar levels. However, their relatively higher cost (approximately 3 times that of inoculants) compared to biological inoculants and enzymes preservatives has been a deterrent to more widespread use. Another significant advantage the organic acids have over inoculants is the fact that the acids may be stored and used at any time, meaning less waste.

Originally, propionic acid used for hay preservation was in its concentrated form, which proved to be unfavorable due to its caustic and corrosive nature. Dilute forms were also used, which reduced corrosiveness, but reduced effectiveness as well. Recent advances in buffered acid products appear to have maintained the effectiveness of the original concentrated acids without the corrosive damage to equipment and undesirable properties for people handling the product. This generation, using labels such as "neutralized", "buffered" or "pH balanced", are now well accepted in the market place. Although these products are slightly less effective than the concentrated propionic acids, there are far fewer losses because of volatilization, which was a problem with the concentrated acids. Today, common acids used include propionic, acetic, lactic, formic acids, and ammonium propionate.

Buffered mixtures of more than one acid are also available. For example, propionic acid and acetic acid mixtures combat mold and bacterial growth simultaneously; propionic acid is highly effective at controlling mold growth while acetic acid is more effective against bacterial growth. Sorbic acid may also be included in mixtures with propionic acid; it is effective against molds over neutral pH range. Recommended application rates of actual acid for small square bales generally range from .5% - 1 % for 20 - 25% moisture bales, up to 1.5% acid for 31 - 35% moisture hay. Large bales require higher rates of application. In some instances, suggested application rates may be too low for the best preservation. In general, the best preservation is achieved with higher rates of application.

Like the biological preservatives, organic acids are not toxic or harmful to animals in any way. Some acids may even have secondary claims of improved nutrition through increased DM retention. However, be sure that the product claims are based on research that has been tested under conditions similar to Canada (in particular Manitoba) and on “farm scale” trials under the supervision of qualified research personnel.

Other Components

There are also a number of other commercial products containing additives suited for a range of particular situations, all of which are cost effective when used correctly. Additives are often defined as products “adding” a nutritional component to the feed. Some are carbohydrate (sugars) sources for improving fermentation and bunk life, some (urea) are protein sources for improving feed value, some (Calcium carbonate and Sodium sulfate) are mineral additives for topping up mineral levels, and some maintain the green color of harvested hay. Regardless of category or claim, always be sure that the product has been tested under conditions similar to Canadian conditions (in particular Manitoban) and on “farm scale” trials under the supervision of qualified research personnel.

Nutritive Additives

Carbohydrate Sources
Carbohydrate sources such as molasses, whey, and cereal by-products can be added to silage crops to increase the supply of energy for the growth of desirable (LAB). The production of LAB can improve fermentation and bunk life, and the extra sugars can improve the energy content of the silage thus reducing the need for supplemental grain at feeding. Sugars can also be used in conjunction with formic acid to guarantee adequate preservation of crops low in sugar content. This normally is a concern for grass and legume crops above 70% moisture. Under these conditions, a sufficiently low pH is needed to prevent clostridial growth and the formation of the undesirable butyric acid. However, clostridial silage can be avoided by harvesting at lower moisture contents (< 65%). Sugars alone should not be used on corn and high moisture silage.

Non-Protein Nitrogen
Non-Protein Nitrogen (NPN) additives may be used in many feed types to inhibit mold growth, and in some

cases they will also increase nutritive values of the feed, namely crude protein (CP). They are commonly used in the production of corn silage and green feed between 25%-50% moisture. In silage production a variety of NPN additives are used including anhydrous ammonia, aqueous ammonia and urea to increase the CP content of the silage and reduce potential for aerobic microbial growth and heating at feed out. In green feed, ammonia and urea are not as practical, therefore, anhydrous ammonia would be the most common source used primarily for reducing mold and yeast development, with secondary benefits of potentially increasing CP. Yeasts, molds and many bacteria are more readily controlled by ammonia than urea due to the increase in pH provided by ammonia. This will in turn increase bunk life and DM recovery. Ammonia may also enhance fiber and DM digestibility by ruminants by breaking down cell wall components. Since anhydrous is attracted to moisture, moist hay will promote even distribution and mold control. Hay below 25%-30% moisture will have areas with inconsistent mold control throughout the stack. It is commonly applied at a rate of 2% of the dry forage weight. Increased intake and animal performance is expected; however not consistently realized. Final silage pH may be higher when treated with these NPN sources.

Although NPN additives are inexpensive in comparison many other additives, they are not suited to all situation. Urea additives are the best used when the main objective is to increase the CP of a silage (e.g. typical application rates will increase CP in corn by 5%) and are most practically used in bunker situations. Ammonia is best used when the main objective is to improve bunk life. However, ammonia has shown to be not as effective on alfalfa silage and may in fact be detrimental to DM recovery if moisture contents are too high. Black, odorous mold can develop on the alfalfa, reducing feed yield and quality. Note, growing calves and early lactation dairy cows are not good candidates for silage treated with NPN sources.

Non-specified Additive Ingredients

Antioxidants are used to enhance the chemical activity of the plants primarily for maintaining the ‘green’ color. These can be valuable for hay destined for export or cash hay markets where visual characteristics of hay are important. Common antioxidants such as vitamin C (Asorbic Acid) and vitamin E, are typically mixed in with another preservatives (e.g. bacterial inoculant, enzyme additive, acid, etc). Although results for these products are often inconsistent, some buyers continue to use them based on the potential economic returns from foreign markets.

Sodium metabisulfite is a compound used to improve the DM recovery and bunk life of silage. It is simply a product taken from the dried fruit industry and is applied to silage at the ensiling stage. While in the bunker/silo it reacts with moisture to form sulfur dioxide gas and a sulfite salt, both which reduce microbial activity and the growth of molds and yeasts. They were typically mixed in with other preservative agents as well, however are not commonly used anymore due the development of better products.

Drying Agents

The purpose of drying agents is to modify the waxy cutin layer on the stem and leaf surfaces. The normal function of the cutin layer is to reduce moisture loss during plant growth; however, it also inhibits wilting during hay harvesting. Two commonly used drying agents are potassium carbonate and sodium carbonate. Drying agents are more commonly used in the US where drying days can be shorter. Studies conducted in the U.S. have shown that these agents can double dry-down, in some cases reaching 15-18% moisture in half a day. Drying agents are known to be more effective on legumes than grasses because of some of the differences in plant morphology.

Drying agents need to be applied evenly at cutting to reduce wilting periods; applying before baling is not effective. To apply evenly, mount the applicator and deflector bars in front of the cutting header about 8 to 10 inches above the ground, and apply using 30 gallons/ac of water. It is not a cheap investment as the cost of the applicator can range from $700 - $1200, although you may be able to find rental rates from some dealers. The cost of the agent depends on the application rate, but can range from $3 to $8 for every ton of treated hay.

Application

Electronic rate controllers and flowmeters make rate adjustments easier and allow variable application in the field so that higher application rates can be used on wet spots. Otherwise, application equipment should provide uniform application to the hay, simple mounting and connection to the power supply, and adequate reservoir capacity.

When Should Preservatives be Used?

The most important consideration is whether the improved quantity and quality of forage from the use of a preservative will offset the cost of preservative and its application.

Economics of Preservative Use:

_____lb preservative/ton hay x $ _____ price = cost of preservative per ton hay $_____.

Price per ton of hay $_____ x percentage increase* with preservative use _____% = gross income per ton of hay.

Gross income $_____ - cost of preservative per ton $_____ = net profit per ton of hay $_____.

* Percentage of increase should take the following into consideration:

- rain damage
- leaf shatter
- protein content
- microbial decomposition
- more timely harvests
- better animal health by preventing mold

In Short...

Bacterial Inoculants

- Less expensive
- Easy to handle
- Not recommended for rained-on hay
- Not recommended for late-season hay
- Require uniform application for consistent results
- Must be applied immediately after mixing

Enzymes

- Less expensive
- Easy to handle
- Reduces fiber content
- Not recommended for rained-on hay
- Not recommended for late-season hay
- Does not directly ferment or prevent mold development
- Require uniform application for consistent results
- Must be applied immediately after mixing

Organic Acids

- More expensive than inoculants
- Non-corrosive, buffered products are readily available
- Higher application rates give the best results
- Guaranteed to give most consistent and positive results
- May be stored and used at will

NPN

- Best for corn and cereal crops only
- Not recommended for hay
- Will inhibit mold development
- May improve crude protein slightly

Considerations

- Best economic returns are found when applied to high quality hay
- Moisture should be determined based on the wettest portion of the field and not the average!
- Treated hay should be covered
- The 3 key points to reducing mold are:
    - Eliminate oxygen (wrapping bales)
    - Minimize amount of acid produced, and
    - Freezing temperatures (something Manitobans are “fortunate” to have)

Good preservation of hay depends primarily on handling, harvest management and storage conditions!