July 1986

Cooperative Extension Service • Michigan State University

Extension Bulletin E-1994

AG FACTS

FORAGE PRODUCTION AND USE

CHEMICAL PRESERVATION OF FORAGES: Techniques and Economics

C. A. Rotz and J. W. Thomas[1]

A major problem in the production of quality hay has always been the time required to dry the crop in the field to a moisture content suitable for storage. Rain frequently occurs before the hay is dry, increasing loss and decreasing quality. Research data show that 20 percent of the hay crop dry matter can be lost by the time the crop is placed in storage, even in good drying conditions. Adverse drying conditions often cause 30 to 50 percent loss and, of course, very poor conditions can cause complete loss of the crop. Certain nutrient losses are often of the same order or greater than dry matter loss. Field loss is directly related to the length of time the crop is in the field and inversely related to the moisture content of the crop as it is baled. In other words, the quicker the hay is baled and the wetter the hay is when baled, the lower field losses will be.

Products that improve or maintain hay quality during storage are commonly termed preservatives. They are normally applied during the baling operation but may be applied during handling or storage. Major chemicals used as hay preservatives are propionic acid and other acid mixtures. Other materials used as hay preservatives include anhydrous ammonia, urea, sodium diacetate and bacterial inoculants.

The major benefit of any hay preservative is reduced harvesting and storage losses. Leaf loss can be excessive when alfalfa is harvested at a moisture content below 18 percent. Even at optimum moisture for baling—18 to 20 percent—losses are high as leaves shattered by the baler are dropped to the ground. Baling at a higher moisture content—25 to 28 percent—reduces the loss of high quality leaves and cuts field curing time. Special treatment is needed, however, to prevent the development of mold, which causes heating and loss of hay during storage.

Chemical preservatives work primarily as fungicides to prevent the development of fungi (molds). Sufficient acid may also inhibit bacterial growth. Bacteria added as inoculants to hay are supposed to grow and produce compounds that inhibit the growth of fungi and undesirable bacteria. The bacteria used to date produce lactic acid, but lactic acid has no antifungal activity.

Chemical preservation of forages should not be confused with a process called chemical conditioning. Chemical conditioning occurs when a chemical that speeds drying is applied to the crop as it is mowed. Different chemicals and processes are used for these two treatments, but the benefits of each individual treatment will be additive when both are used on the same crop. More information on chemical conditioning can be found in Extension bulletin E-1995, "Chemical Conditioning of Forages: Techniques and Economics."

Equipment and Procedure

Hay preservatives come in three major forms: liquid, granular and pressurized liquid. Each form requires different application equipment.

Liquid materials are generally acid mixtures. Propionic acid is recognized as the most effective acid for hay preservation. Acids sold commercially for hay preservation often include other acids or compounds blended with propionic acid. Bacterial inoculants can also be mixed with water and applied as liquids.

A spray system mounted on the baler is used to apply liquid materials. A tank with a 50 gal capacity is adequate. It can be mounted on either the baler or the tractor. Other components of the spray system include pump, line filter, pressure regulator and nozzles. Spray systems designed for this purpose can be purchased for about $800 to $1,000. You can also buy individual components to fabricate a system.

Uniform distribution of the spray material throughout the bale is important for best results with the treatment. Nozzles are normally mounted just behind or over the baler pickup for best coverage of the hay as it moves into the baler. A flooding type nozzle is often used to improve coverage and distribution.

Propionic acid should be applied to hay in proportion to the amount of moisture in the hay. When hay is in the

[1]Agricultural engineer, USDA/Agricultural Research Service, U.S. Dairy Forage Research Center, Agricultural Engineering Department; and professor, Animal Science Department, Michigan State University, East Lansing, MI 48824.

moisture range of 20 to 25 percent (just about dry), about 15 lbs of acid should be applied to each ton of hay. At 25 to 30 percent moisture (slightly damp), apply a minimum of 20 lbs/ton. At 30 to 35 percent moisture, propionic acid treatment is not recommended, but if it is used, acid should be applied at a minimum of 30 lbs/ton.

Commercial chemicals available for hay preservation contain between 10 and 80 percent propionic acid. University and field research has shown that the best preservation is obtained with mixtures of 60 percent or more propionic acid. Feed-grade, 100 percent propionic acid can also be purchased from the manufacturer by the grower for use on his/her farm. Whether purchased from a supplier or directly from the manufacturer, propionic acid mixtures are normally diluted with water on a 1:1 ratio to improve coverage of the hay as they are applied.

Dry chemicals, including sodium diacetate and urea, can be applied with a granular applicator. Applicators are available from the supplier of sodium diacetate, or they can be purchased directly from a manufacturer. Granular applicators can be mounted on the baler at the entrance of the bale chamber to drop the chemicals into the hay at this point.

Uniform distribution of the chemical throughout the hay can not be accomplished with this applicator alone. A blower device developed at MSU provides for better distribution. The applicator device is mounted on the front of the baler to meter the dry chemical into the blower. Fans are used to create an air stream that carries the dry chemical through sheet-metal "nozzles" to the rear of the baler pickup, where it mixes with the hay (Fig. 1). This device is not commercially available at this time, but someone adept at working with sheet metal can build it.

The most difficult chemical to apply on the field baler is anhydrous ammonia because it must be contained under pressure to prevent vaporizing. Two devices have been developed for this purpose, but neither is commercially available at this time. These devices inject anhydrous ammonia into the bale as it is formed in the baler. The ammonia unites with moisture in the hay, where it is retained as a preservative.

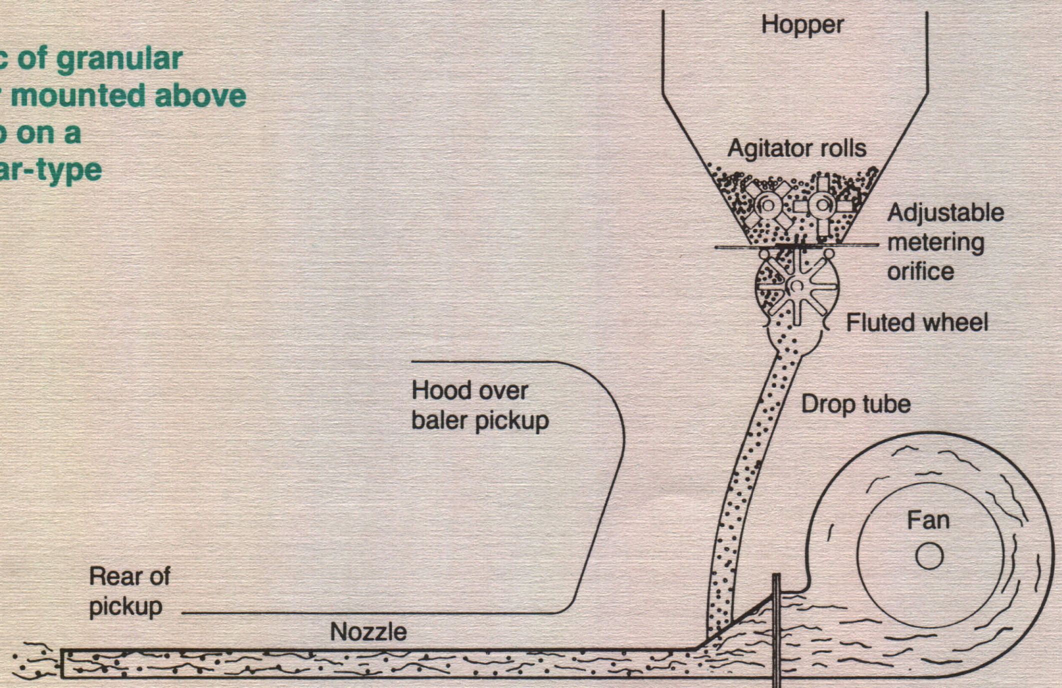
Another method of applying ammonia, developed at Purdue University, can be used during storage. Hay is baled, stacked, covered and tightly sealed in a plastic wrap. The proper amount of ammonia is slowly released from a nurse tank into a container that was previously placed near the center of the stack. The ammonia evaporates and moves through the stack under the plastic, creating an ammonia atmosphere. A good seal is required to prevent molding of the hay and to avoid ammonia loss. Hay is normally kept in the sealed stack until a week before it is fed.

Anhydrous ammonia should be applied to high moisture hay at a rate of 20 to 40 lbs/ton of hay at hay moisture contents of 25 to 35 percent, respectively. When hay has a moisture level greater than 35 percent, treatment with ammonia or any other preservative is not recommended.

What to Expect from Chemical Preservatives

University research has shown that propionic acid and anhydrous ammonia are the best of the available materials for hay preservation. Either of these materials is effective when properly used, but each has major disadvantages.

Figure 1.
Schematic of granular applicator mounted above the pickup on a rectangular-type baler.



Propionic treatment of moist hay will reduce mold development and thus reduce heating and storage loss. When treated moist hay is compared to field-dried hay, the major difference is in the reduction of field loss. Baling moist hay—21 to 25 percent moisture—may increase yield 5 to 10 percent. Most of this increase is high quality leaf material, so the quality of the hay will also be increased. Crude protein, for example, may be increased by one percentage point.

In general, moist hay treated with propionic acid will store about the same as dry hay. With the proper amount of acid, little mold should occur. Somewhat more heating will occur in the moist treated hay than in dry hay, but the heat developed is insufficient to reduce the quality of the hay. Dry matter loss during storage will be slightly higher for the treated moist material than for untreated dry hay but below that of untreated moist hay.

Treated moist hay may also be more palatable after storage. Some feeding trials with sheep have shown an increase in animal acceptance and a reduction in feeding loss when treated moist hay was compared with field-cured hay. Other feeding trials with dairy cows have shown no difference in feed intake, milk production and milk fat percentage. Treated hay, therefore, is at least as good as field-cured hay and in some cases better.

The major disadvantage of propionic acid treatment is its effect on equipment. The acid is corrosive and promotes rust, which can be very hard on the baler after a couple of years. Removing all treated hay from the baler between periods of use will help reduce rust. Washing the baler after acid use and rinsing with sodium bicarbonate will further reduce rust.

Other potential disadvantages of propionic acid treatment are color and odor. Acid-treated hay will often be brown and have an acid smell. People handling bales in poorly ventilated areas may find acid vapors annoying.

Anhydrous ammonia can be used as a preservative with results similar to those of propionic acid. In addition, the nitrogen in the ammonia will increase the crude protein content of the treated hay. Anhydrous ammonia may also be corrosive, but because it is applied in storage, corrosion of equipment is not a problem.

Anhydrous ammonia applied at a rate of 40 lbs/ton of hay is an effective preservative of alfalfa hay at moisture contents as high as 35 percent. Ammonia treatment reduces molding, heating and dry matter loss in the stored hay. Chemical analyses of treated and untreated hay at the same moisture content have shown increases in measurements of crude protein and digestibility. Our research has shown that the treatment can increase crude protein about two percentage points.

Ammonia-treated hay has been fed to dairy cows with no detrimental effect. Dry untreated and wet treated alfalfa hay fed to dairy cows produced no differences in actual and fat-corrected milk, percentages of milk constituents or dry matter intake. When used with a lower quality grass hay, the ammonia treatment increased palatability and dry matter intake but again did not affect milk production.

Ammoniation of hay was shown to be beneficial in beef production. Feeding treated orchardgrass hay to steer calves increased hay consumption by 17 percent and increased daily weight gain. Feeding treated bermudagrass to lactating beef cows also increased consumption and produced calves with heavier weaning weights.

The major disadvantage of anhydrous ammonia is its threat to human and animal safety. Strong concentrations of anhydrous ammonia vapors can cause severe burns, blindness and death. Because ammonia seeks out moisture, eyes, lungs and bare skin are most susceptible to damage. After ammonia is placed in moist hay, it unites with moisture in the hay and becomes relatively harmless. People handling ammonia-treated bales, however, may find vapors obnoxious and irritating, particularly in poorly ventilated areas.

Ammonia treatment of forages has been reported to cause toxicity to animals if not used properly. Symptoms of the toxicity are hyperexcitability, circling, convulsions and death. Newborn calves nursing cows fed ammoniated forages can be affected. The exact cause is not known, but the toxicity appears to occur as a result of the reaction between the ammonia and soluble sugars in the forage. Toxicity occurs most often when ammonia is applied to high quality forage at greater than recommended application rates. Anhydrous ammonia should be used with care. If any signs of toxicity occur, animals should be removed from the treated feed immediately.

Urea is a much less harmful and objectionable chemical than ammonia. Urea is decomposed by bacteria on the hay to form ammonia and carbon dioxide, and both of these chemicals prevent growth of fungus. Urea can be applied in a granular or powdered form or sprayed as a liquid. Repeated tests at MSU, however, have not shown any improvement of storage of high moisture alfalfa hay with granular or liquid urea treatment. Therefore, urea is not recommended as a hay preservative.

Sodium diacetate has been used with limited success as a hay preservative. Our research indicates that it should be used only when the hay is almost dry (20 to 23 percent moisture). Baling hay at this moisture level does not reduce field losses, however, so little advantage is gained.

Several inoculant products are being marketed for hay preservation. We have tested several of these products at MSU and have found no improvement in hay preservation. Other investigations have had similar results. We do not recommend inoculant products as hay preservatives.

Economics of Chemical Preservation

Propionic acid and anhydrous ammonia are the chemicals most feasible for use as preservatives for high moisture hay. The costs and average expected benefit of these two chemical treatments are given in Table 1. Conditions will vary widely. At times the treatments will be of little value, while at other times they may save the crop. This analysis simply describes what could be expected on the average if the treatments were used on all hay under all conditions.

This analysis shows that propionic acid treatment is not economical because the cost of the treatment exceeds the expected benefit gained by reducing losses. The price of the chemical will influence this estimate. The price assumed—65 cents/lb—was based on a marketed hay preservative. If the propionic acid is bought directly from a manufacturer at 45 cents/lb, the farmer will just break even.

Propionic acid should not be used on all hay. It can be used to get into the field a little earlier, but as hay dries further, the treatment can be discontinued. Other times when an acid treatment should be used are in the evening, when hay is no longer drying, or when rain is anticipated. When used only under these conditions, the treatment can be more cost effective.

An analysis for anhydrous ammonia shows this treatment to be very economical. The high economic benefit is primarily due to the increased protein obtained with the treatment. This analysis assumes that the protein provided through the nitrogen in the ammonia is as beneficial to the animal as any other protein source. (This assumption has not been proven.) Even without the protein benefit, this treatment is more cost effective than propionic acid, primarily because of the lower cost of the chemical.

The cost not considered in this analysis is the cost of safety. Anhydrous ammonia is a hazardous material. The cost of a serious accident could well offset any economic benefit obtained with the treatment. Likewise, the treatment must be assured to be safe for the animals. Losing animals could again be very costly and outweigh any benefit from the treatment.

Summary

Chemicals can be used both to speed the drying and to improve the preservation of hay. Different chemical treatments are required for the two processes, but both treatments can be applied to the same alfalfa.

For preservation of high-moisture hay, only propionic acid and anhydrous ammonia have been shown to be effective. Applying these chemicals during or immediately after baling can preserve hay up to 25 to 30 percent moisture. The major benefit is reduced leaf loss at harvest, which results in a higher quality hay. In addition, anhydrous ammonia treatment will enhance the protein content of the hay.

Propionic acid treatment costs about $15/ton of hay treated. It can be economically used only when conditions make it difficult to get hay dry.

Anhydrous ammonia treatment costs about $9/ton of hay. The added protein of the ammonia makes the treatment beneficial on essentially all hay. This assumes, however, that the added protein is beneficial to the animal, that the material can be handled safely, and that it poses no threat to animal health when it is fed.

Table 1.
Average cost/benefit of using chemical preservatives to bale high-moisture alfalfa hay.

	No treatment	Propionic acid	Anhydrous ammonia
BENEFIT			
Crop yield (lb/a)	3000	3000	3000
Harvest loss (%)	20	15	15
Harvest yield (lb/a)	2400	2550	2550
Harvest crude protein (%)	16	17	17
Storage loss (%)	5	8	5
Storage yield (lb/a)	2280	2346	2423
Storage crude protein (%)	16	17	19
Gain in feed value[1] ($/a)	—	12.50	33.56
($/ton)		10.65	27.70
ADDED COST			
Equipment ($/ton)	—	1.00[2]	1.50[3]
Labor ($/ton)	—	.70	2.00
Chemical ($/ton)[4]	—	13.00	5.00
Total treatment cost ($/ton)	—	14.70	8.50
NET RETURN ($/ton)	**—**	**-4.05**	**19.20**

[1]Based upon a dry matter value of 4 cents/lb and a protein value of 29 cents/lb.

[2]Includes initial cost of added equipment depreciated over five years and used to bale 250 tons of hay per year. Does not include a cost for corrosion of baler parts.

[3]Cost of plastic cover @3 cents/ft^2.

[4]Chemical costs were assumed at 65 cents/lb for propionic acid applied at 20 lb/ton and 12.5 cents/lb for anhydrous ammonia applied at 40 lb/ton of hay.

Issued in furtherance of Cooperative Extension work in agriculture and home economics, acts of May 8, and June 30, 1914, in cooperation with the U.S. Department of Agriculture. W.J. Moline, Director, Cooperative Extension Service, Michigan State University, E. Lansing, MI 48824.

1P-5M-7:86-TCM-RP-New. Price 20 cents. Single copy free to Michigan residents.

File 18.15