HAY PRESERVATIVES: PROPIONIC ACID AND MICROBIALS

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Alfalfa is usually wilted 15% or less moisture prior to baling for hay. However, harvesting at low moistures increases loss of leaves (protein) during baling and reduces nutritive value. In addition, long wilting times increases the risk for damage from rain. In order to retain more nutrients and prevent rain damage, hay can be baled at higher moistures but the risk of spoilage from undesirable microbial metabolism during storage increases dramatically. Although much is known about the microbiology of silage, less is known about microbial metabolism in moist hay. Although bacilli can be associated with spoilage of wet hay (> 20% moisture), most suggest that fungi are the microbes that cause spoilage problems in moist hay. Moist hay undergoes several distinct heating cycles when stored in stacks. The significance of the heating peaks and associations with either plant or microbial metabolism are poorly understood. It does appear, however, that if the moist hay does not undergo some heating, the bales never "dry down" during storage. Excessive heating of the hay bale can lead to an increase in heat damaged protein (acid detergent insoluble nitrogen, ADIN). Heat-damaged protein lowers the protein value of the hay.

Various hay preservatives inhibit mold and may be useful in reducing drying time and field losses by allowing baling at higher moisture levels. If properly done, baling at higher moisture levels can reduce dry matter loss (from leaf shattering) and potential damage from rain. The two most commonly used preservatives for high moisture hay are bacterial inoculants and propionic acid-based solutions.

Propionic acid-based preservatives have been used for many years. Propionic acid is most effective in inhibiting growth of molds > yeast > bacteria. Use of concentrated propionic acid has declined primarily because of it is corrosive and volatile. In recent years, there has been much interest in "buffered" propionic acid mixes that have a pH of about 5.5 to 6. These products are based on ammonium or sodium salts of propionic acid. Research shows that use of buffered propionic acid was as effective as unbuffered acid in preserving the quality of moist alfalfa hay (about 30% DM). In one study, significant improvements in nutrient yield were found when a buffered propionic aid product was added to moist (13.8 to 25.2%) large alfalfa bales. However, the improvements were not large enough to pay for the preservative. Researchers at the US Dairy Forage Research Center in Wisconsin tested several propionic acid-based preservatives and found that at high application rates (40 lb/ton) these products limited temperature rises during storage but did not consistently control DM losses or bale quality.

In order for propionic acid to be effective, correct levels must be used. Results of a study are shown below (Table 1). At least 1% propionic acid was needed to preserve hay with 32% moisture.

Table 1. Effect of propionic acid on high moisture hay (32% moisture).

Treatment	Maximum storage temp., ^{o}F	Dry weight loss, %	In vitro DM digestion, %
Control	124	15.1	60.5
Propionic acid			
.02%	127	16.7	61.8
.2%	115	13.2	62.2
.5%	104	11.7	61.0
1.0%	86	7.6	65.0

Knapp et al. 1976.

Recommended levels of propionic acid addition to moist hay are shown in Table 2. Note that these are values for a 100% propionic acid solution. In the market, solutions will vary from 10 to 100% propionic acid. The use of very dilute products are not recommended because larger volumes of water are applied to the crop. (Why add more water to your hay?)

Depending on the product and application rate, it will cost $5 to 20/ton of hay to treat with propionic acid-based products. Seldom does the increase in leaf retention pay for the use of the additive. However, acid preservation may be most beneficial when the producer is faced with potential loss from rain damage. Uniform distribution of propionic acid is important since "pocketing" of molds has been observed (only parts of the bale being moldy).

Table 2. Use of propionic acid for high moisture bales.

	% propionic acid[1]/wet forage suggested levels	
% moisture	I[2]	II[3]
20-25	0.9%	0.5% (10 lb/ton)
26-30[3]	1.13%	1.0% (20 lb/ton)

[1]100% propionic acid equivalent

[2]Mathison and Baron 1991.

[3]Walgenbach as cited by above.

Microbial inoculants can improve silage fermentation and animal performance. Because of this success, there has been much interest in using microbial inoculants to reduce spoilage in moist hay. Advantages of an efficacious additive would include lower cost, lower liquid application rate, and use of a biologically safe product (non-corrosive). Early studies tested lactobacillus-type products developed for silage with few positive effects. The logic was that lactobacilli would produce acid, reduce pH and thus reduce mold growth. However, this logic was slightly flawed since many fungi are acid tolerant and many yeasts assimilate lactic acid. In addition, the water activity (moisture available for microbial growth) of moist hay appears to be insufficient to support growth of most lactobacilli. Although there is use and farmer testimony that silage inoculants can be used to preserve moist hay, there is little scientific evidence to support these claims.

Past research has centered on developing microbial inoculants specifically for moist hay. Although some of these products still contain lactic acid bacteria, others contain *Bacillus* sp. Bacilli are spore-forming organisms that grow more readily in an environment with low water activity and are also quite heat resistant. More importantly, these inoculants have been screened in the laboratory for inhibitory effects on storage fungi in hay. The mode of fungal inhibition is unknown, but we do know, for example, that certain bacilli produce antibiotics and some have suggested that bacilli produce a lipoprotein that has antifungal properties. Competition for nutrients and space, and production of unidentified antifungal compounds have also been suggested as modes of action. Caution should be used when interpreting laboratory data since inhibition of fungi on petri plates, under controlled conditions, does not

always equate to improvements in the stability of a moist bale. The recent approach in developing microbial inoculants appears sound but translation of laboratory results to the field have yet to be proven.

Microbial inoculants have been applied at the baler but there is some discussion among researchers on whether application might be more beneficial at mowing. The rationale for this is to suppress fungal populations that may increase while hay is drying; especially at the bottom of a moist windrow.

In general, the responses to microbial inoculants in hay have been poor to inconclusive. One report showed that addition of a bacteria called *Bacillus pumilus* or a silage inoculant (bacteria:*S. faecium* and *L. plantarum*) to moist hay (17 to 31% moisture) improved color, odor and other visual assessments but the inoculants had no effect on chemical composition of the hay. However, more often than not, others workers (including work done at the University of Delaware) using a variety of products have shown no response to microbial inoculation on high moisture hay. Over several years, researchers at the USDA Dairy Forage Center, Madison, Wisconsin, have never seen a positive response from any hay inoculant (R. Walgenbach, personal communication).