Strategies of Mold Control in Dairy Feeds

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ABSTRACT

Mold growth can occur in dairy feeds only when nutrients are available, correct temperatures exist, oxygen is present, and unbound water is available. Because elimination of any one of these four factors prevents mold growth, management of feed that accounts for these elements is essential. Use of multiple ingredient mold inhibitors recently has become another tool for affecting successful microbiological control of feed.
(**Key words**: mold, propionic acid, feed management)

DISCUSSION

The nutritional and toxicological implications of microbiological changes in dairy feed ingredients and feeds have begun to be recognized as a critical part of dairy nutrition. Mold growth is perhaps one of the most important of these microbiological changes in that it can degrade the nutritional content of the feed (2, 21) and create mycotoxins (3, 34, 44). Although the metabolism of aflatoxin in dairy cattle has been studied extensively (12, 13, 32, 39, 40), in general, the effects of subacute inclusions of aflatoxin in dairy feeds and the acute and subacute effects of approximately 300 other toxins have received scant attention.

Despite the fact that the exact economic impacts of mold growth in dairy feed have not been quantified, progressive producers have discovered that, when mold growth is controlled, the microbiological quality of the feed increases, and production benefits can be realized. The first step in designing a mold control strategy is to understand the basic requirements of mold for growth. The absence of one of these requirements effectively stops mold respiration, thereby precluding nutritional damage or toxin production by the mold.

The most obvious mold life requirement is the necessity for nitrogen and energy sources. Prevention of mold growth on intact grain relies heavily on this strategy. Intact grains physically protect the nitrogen and energy resources of the seed through use of a cellulose or a polyester covering on the outside of the seed (20, 41, 42). As long as this covering remains intact, mold growth occurs only slowly, if at all. The shelling of grain, especially corn, partially removes this physical barrier because corn kernels are normally buried in the cellulose barrier of the cob. The processing of feed grains may result in structural cracks and fissures, further lowering the integrity of the grain. In addition, insect damage, whether in the field or in storage, can further compromise the grain's physical barrier to mold. Dairy producers and feed manufacturers should undertake management policies that ensure that grain remains intact as long as possible in the feed cycle. Care should be taken to avoid introducing stress cracks during drying, and fines should be eliminated before placement of the grain into storage. Effective insect control strategies should be implemented. Grinding of grain should be delayed until as close to the time of feeding as possible.

A second requirement for mold growth is the correct environmental temperature. The temperature at which hay, silage, or feed is stored often dictates whether mold growth will become a significant problem. Although molds can respire at a variety of temperatures, significant growth or toxin production has defined limits (Figure 1). *Aspergillus* and *Penicillium* species flourish in warmer temperatures, whereas *Fusarium* molds prefer cooler temperatures. These optimal conditions also explain why *Aspergillus* problems are more apparent in southern climates (35, 38) but *Fusarium* incidence is higher in northern regions (34). In

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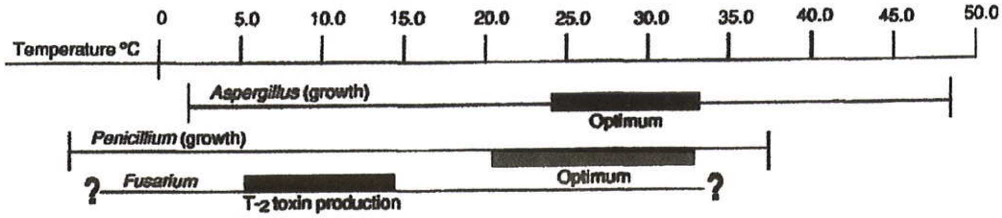

Figure 1. Permissible and optimal temperatures for growth of molds commonly associated with animal feed grains. Adapted from (5, 7, 17, 33).

addition, when feeds are moved from cold storage conditions to warm environments and optimal temperatures (i.e., into stanchion barns or calf housing), *Aspergillus* may become a problem even in a northern climate, (34).

Molds are obligate aerobic organisms; therefore, their proliferation and growth can be controlled by providing oxygen-free storage. Although this control strategy is not practical for most dairy feed ingredients, it is a principle tool in preservation of silage. Molds can respire successfully at oxygen concentrations as low as 4% (28). This condition underscores the necessity of carefully sealing silage storage structures and of rapid feeding of silage after removal from these structures. The first three requirements of mold growth—nitrogen and energy sources, temperature control, and anaerobic conditions—provide management tools to limit mold growth, but all entail practicality problems that preclude their exclusive use. The fourth requirement of "free" water offers a greater possibility.

Water available for metabolism by molds is controlled by the relative water activity of the feed. In turn, this activity is defined as the partial pressure of water vapor above a test sample divided by the partial pressure of liquid water. Molds vary in their ability to grow at various water activities (Figure 2). Some molds, such as *Monascus* sp., can grow at water activities of as low as .62. Total mixed rations normally range in water activities from .50 to .94, depending on the amount of silage and the water content of silage used in the ration. The concept of water activity underscores the danger of free water addition to grains, which is then immediately available for mold growth.

Moisture migration within grains is another source of free water. When grains, feeds, or both are warmer or colder than surrounding ambient conditions, moisture migrates and condenses because of air convections within the bin (9, 14). Thus, even though feed or grain may be stored at a safe moisture, mold

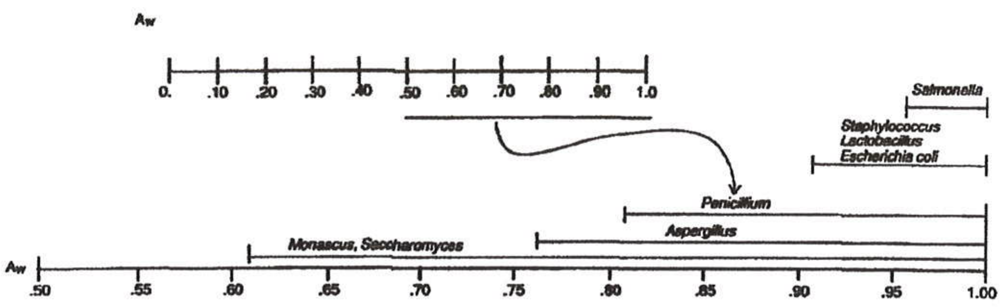

Figure 2. Relationship between water activity (A_w) and mold growth in animal feed and human foodstuffs. Adapted from (4, 6, 30).

growth can occur when recondensation of moisture occurs. Attainment of moisture equilibrium with the environment provides a third source of free water within feeds. The act of grinding exposes grain starches and proteins to ambient humidities from which they had been guarded by the seed coat. Rehydration from 11 to 18% moisture on the surface of feeds exposed to 80% relative humidity has been reported (16).

Elimination of nutrients, nonpermissive temperature conditions, removal of oxygen and of free water, or both are strategies that have always been available to the dairy producer and the dairy feed manufacturer to control microbial growth. Recently, however, mold inhibitors have been used as an additional tool. Mold inhibitors are best formulated from combinations of known antifungal agents because individual compounds have different efficacies against various molds (31). Use of multiple ingredient inhibitors ensures the broadest spectrum of activity within the feed. At the concentrations normally used (.1 to .2%), mold inhibitors are fungistatic but not fungicidal. Concentrations of .5 to 1.0% are necessary to kill molds. The principle ingredient of most mold inhibitors is propionic acid, which is thought to exert its effects by disruption of the electron transport scheme within the mold (18). Propionic acid has a low pH and is corrosive by nature; however, most commercial products are buffered by various salts, making them noncorrosive to both man and machinery.

The control strategies discussed thus far are all protective. Unfortunately, molds often do not become a concern until the damage has occurred and toxins have formed. Detoxification of feeds or feed ingredients has been attempted only on a large scale with anhydrous ammonia for the mycotoxin aflatoxin (19, 22, 29, 36). This procedure is not approved in the US by the FDA, and the safety of the procedure is of concern.

Recently, a great deal of interest has been shown in utilizing hydrated sodium calcium aluminum silicate and other inorganic minerals in feeds to bind aflatoxin. This work is summarized in Table 1. These products have been cleared for use by the FDA as flowability agents or pellet binders only. The use as a toxin binder is prohibited. Review of current

TABLE 1. Effect of hydrated sodium calcium aluminum silicate (HSCAS) and other binding agents on various mycotoxins and nutrients in different species.

Toxin and nutrient	Animal	Treatment	Effect	Reference
Nutrient				
Zn, Mn, P, vitamin A, riboflavin	Chickens	1% HSCAS	Reduced Zn utilization, no effect on other nutrients.	(8)
Mycotoxins				
Toxin				
Fescue toxicosis	Sheep	2% HSCAS	No reduction of toxicosis.	(1)
Aflatoxin	Chickens	HSCAS Ethacal Perlite® Zeobrite	Reduced toxicosis.	(37)
Aflatoxin	Pig Dairy cows	.5% HSCAS	Reduced aflatoxicosis and aflatoxin M_1.	(15)
Citrinin, oosporein	Chickens	1% HSCAS	No effect on toxicosis.	(43)
Aflatoxin	Chickens	.5% HSCAS or activated charcoal	HSCAS reduced toxicosis, charcoal did not.	(24)
Aflatoxin, T-2 toxin	Chickens	.5% HSCAS	Reduced aflatoxin toxicosis but not T-2 toxin.	(23)
Aflatoxin	Swine	.5% Sodium bentonite	Reduced aflatoxicosis.	(27)
Aflatoxin, T-2 toxin, ochratoxin	Chickens	.5% HSCAS	Reduced effects of aflatoxin, but not T-2 toxin or ochratoxin.	(11)
Aflatoxin	Swine	Various bentonites	Reduced effects of aflatoxin.	(26)
Aflatoxin	Turkey	.5% HSCAS	Reduced aflatoxicosis.	(25)

data indicates that the products were efficacious for aflatoxin only and not for any of the other 300 toxins tested to date. Hydrated sodium calcium aluminum silicate will not control mold growth; work in the author's laboratory (data not shown) has shown that the silica may even be slightly stimulatory to mold proliferation.

Two other strategies are available for dealing with mycotoxin problems after they occur. Increases in the crude protein content of the ration decreased the toxic effects of aflatoxin (10). Use of supplemental water-soluble vitamins has good field efficacy. However, no remedial action has been able to reverse the effects of mold and mycotoxin contamination completely; thus, prevention remains the most desirable strategy.

CONCLUSIONS

Refining of nutrient compositions that provide optimal performance for the dairy cow will have little effect on milk production unless steps are taken to ensure that the nutrients reach the cow. The realization that mold growth destroys the nutrient content of feed and the possibility of mycotoxin development necessitate that a producer consider strategies for controlling mold growth. Limiting nutrient availability to microorganisms, storing feed at temperatures that do not encourage microbial growth, limiting oxygen, minimizing free water availability, and utilizing a good mold inhibitor can ensure the microbiological integrity of the ration.

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