The 2009 Wisconsin Corn Crop
High Moisture Corn, Aerobic Stability, Feed Additives and Mycotoxins
Common Questions

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Introduction

Record low growing degree days and suboptimal growing conditions for corn in 2009 significantly delayed corn dry down and harvest in much of Wisconsin. As a result, near optimal environmental conditions (frost before full maturity) were present in the fall of 2009 for field mold growth. Field molds indentified on corn in the fall of 2009 by the University of Wisconsin Department of Plant Pathology include *Cladosporium, Diplodia, Gibberella zeae, Fusarium sp, Nigrospora oryzae,* and *Penicillium oxalicum.* Of greatest concern is the growth of *Gibberella zeae* and *Fusarium sp* of mold as these species are known to produce multiple mycotoxins including deoxynivalenol (DON or vomitoxin), zearalenone, T-2 toxin and fumonisin. *Fusarium sp* of field molds may also produce numerous other mycotoxins. Growing conditions in 2009 did not appear to favor the growth of *Penicillium sp*, or *Aspergillus sp.* which are known to produce the mycotoxins ochratoxin A, PR-toxin, patulin and aflatoxin, respectively. However, because of the severity of these molds and their mycotoxins the potential for their growth and mycotoxin production should not be overlooked.

Because of poor fall drying conditions an abundance of corn on Wisconsin dairy farms was harvested and stored as high moisture shelled corn (HMSC), high moisture ear corn (HMEC) or corn snaplage (SPNL). High moisture corns were harvested and stored at a wide range of moisture contents often using organic acids and/or inoculants as fermentation aids. A high percentage of Wisconsin dairy producers harvested and stored high moisture corn at higher than normal moisture contents, with varying levels of unidentified field molds present often using fermentation aids with which they were unfamiliar. Therefore, numerous questions have been posed regarding the potential impact of the 2009 Wisconsin corn harvest on feeding dairy cattle, animal health, mycotoxicoses, and the use of various feed additives. This paper will address common questions associated with feed molds, mycotoxins and feed additives as they pertain to ensiled high moisture corns. Large acreages of corn were still harvested, dried and stored as dry corn which reduces the risk of continued field mold growth but mycotoxins still maybe present in dry corn therefore a portion of this document as it pertains to feeding corn with mycotoxins and or the use of feed additives would apply to feeding dry corn to dairy cattle.

Will field molds continue to grow after ensiling and produce mycotoxins?

The primary field molds (*Cladosporium, Diplodia, Gibberella zeae* and *Fusarium sp.*) observed on the Wisconsin corn crop in the fall of 2009 have very specific environments for growth. Under field conditions these molds grow and proliferate under the presence of oxygen (aerobic), near neutral pH (6.0-7.0), at high grain moisture (30-40 %) and at temperatures of 25-50^{o} F. When corn is ensiled, pH is reduced by fermentation (or by the addition of an appropriate rate of organic acid) to 4.0-4.5, the environment of the ensiled mass becomes anaerobic (without oxygen), and ensiled mass temperatures range from 25-90^{o} F during fermentation and storage. Therefore, in concept field molds should not continue to grow and produce mycotoxins in storage if pH has been sufficiently reduced and oxygen is not present under ensiled conditions. There are many conditions, however, where storage unit induced exposure to oxygen occurs and other microorganisms such as yeasts will consume fermentation acids, generate heat and or evaporate fermentation acids and raise the pH. Opportunities for storage unit induced exposure to oxygen include the following: holes in plastic silo bags, top surface layers in bunker and tower silos, oxygen permeable silo staves and liners (i.e. mold around the silo wall), poor fitting or silo doors in disrepair, air pockets created by silo bag fillers, air exposure through the hatch of oxygen limiting silos, and oxygen inversion in oxygen limiting silos. Storage unit induced oxygen exposure has the potential create oxygen rich micro-environments in the storage unit and field molds do have the potential to grow and produce mycotoxins in these oxygen rich micro-environments. High moisture corn in an oxygen rich micro-environment often becomes caked and clumpy and visible mold may be present. Obviously moldy, caked, or discolored high moisture corn should be discarded and not fed to dairy cattle.

The surface of the high moisture corn is heating. Does this imply the field molds are growing and producing mycotoxins?

In general, the answer is no. If the high moisture corn is adequately packed there is a low amount of air (oxygen) permeating from 24-36" into the mass. Yeast can thrive in an oxygen poor, low pH environment and are most often associated with heating in high moisture corn. This heating is most properly called yeast induced aerobic instability. In general, yeast are not mycotoxin producing organisms. Issues with feed palatability, reduced dry matter intake, feed energy loss and reduced milk production may occur, but these effects are yeast induced and not field mold mycotoxin induced. If yeast induced aerobic instability is severe enough and feed removal rates are slow then the surface of the high moisture corn can quickly become an oxygen rich, neutral pH environment and allow the resumption of mold growth. This event is rare under normal feed-out rates of 4 to12" per day.

Will ensiling or organic acid addition kill field molds in storage or detoxify the mycotoxins?

No. Ensiling or addition of organic acids do not kill the mold spores or detoxify the mycotoxins per se. Ensiling corn or adding organic acids to corn at the proper rate (low

pH) creates an environment not suitable for mold growth. If oxygen becomes present (oxygen rich; see above) and pH rises then the mold spores will reacquire an environment for growth and mycotoxin production. If mycotoxins were present in the field at harvest they will remain present in storage at similar concentrations.

What mycotoxins are present in high moisture corn?

Do not use oral discussions, news media, web based or general educational materials to construct what mycotoxins are or may be present in any given feed. Testing and quantification is the first approach to manage mycotoxins. The laboratories listed in Table 1 are able to assist with mycotoxin testing. Quantitative confirmation of the mycotoxin(s) and the concentration of the mycotoxin(s) in a feed can greatly aid the management of a mold/mycotoxin situation. Absence of mycotoxins in a mycotoxin test should be interpreted with caution. An unsuspected mycotoxin may still be present. For example a laboratory may evaluate four mycotoxins (deoxynivalenol (DON or vomitoxin), zearalenone, T-2 toxin and fumonisin) and find no appreciable level of these mycotoxins in the sample. The inability to find deoxynivalenol, zearalenone, T-2 toxin or fumonisin in the sample does not guarantee that another mycotoxin such as aflatoxin is not present.

Will mold spore counts or mold identification provide adequate information about mycotoxin potential in a feed?

No. Molds can be benign or they can be mycotoxin producing. A mold species capable of producing a mycotoxin may not have had the critical environment to do so. A mold could have produced a mycotoxin, but cannot be re-grown in laboratory conditions after ensiling and (or) storage.

Can a black light be used to screen for mycotoxins?

No. A black light is a screening test for the presence of kojic acid produced by *Aspergillus flavus* which has the potential to produce aflatoxin. The primary mold problems with the 2009 Wisconsin corn crop are *Fusarium sp* and *Cladosporium.*

What are the critical levels of a given mycotoxin that effect milk production, reproduction or animal health?

A full review of this issue is beyond the scope of this paper. Detailed publications are available describing animal symptoms and threshold mycotoxin levels. An excellent extension publication "Molds and Mycotoxin Problems in Livestock Feeding" from Penn State University is available at:

http://www.das.psu.edu/research-extension/dairy/nutrition/pdf/mold.pdf

A mycotoxin test was submitted and mycotoxin Y was found in HMSC at x ppb (or ppm). What is the course of action?

A general course of action is as follows.

1) Calculate the feeding rate of the HMSC in the total diet and determine the total dietary concentration of the mycotoxin.
2) Determine if the dietary threshold level of the mycotoxin has been obtained (see "Molds and Mycotoxin Problems in Livestock Feeding")
3) If the dietary concentration is well below the tolerable threshold level consider the feed normal, but monitor animal health and performance.
4) If the dietary concentration is near the tolerable threshold level reduce the amount of the feed fed to dilute the concentration of the mycotoxin in the diet and consider a feed additive which has the potential to adsorb a portion of the mycotoxin. Closely monitor animal health and performance.
5) If the dietary concentration is critically above the tolerable threshold level then dilution of the contaminated feedstuff in the diet is required. Feed additives at a given feeding rate which have the potential to adsorb the mycotoxin may not be totally effective in reducing the mycotoxin to below the tolerable threshold level.

A mycotoxin test was submitted and mycotoxins Y,X,Z were found in HMSC at x ppb (or ppm). What is the course of action?

A general course of action is as follows.

1) Calculate the feeding rate of the HMSC in the total diet and determine the total dietary concentration of each mycotoxin identified.
2) Determine if the dietary threshold level of each mycotoxin has been obtained (see "Molds and Mycotoxin Problems in Livestock Feeding")
3) Ascertain which one of the mycotoxins is potentially most toxic and or at the most critical level.
4) If all of the dietary mycotoxin concentrations are far below dietary tolerable threshold levels consider dilution of the feed in the diet assuming additive or interactive effects and monitor animal health and performance.
5) If the dietary concentration of the most critical mycotoxin is near the tolerable threshold level reduce the amount of the feed fed to dilute the concentration of the most critical mycotoxin in the diet and consider a feed additive which has the potential to adsorb the most critical mycotoxin. Closely monitor animal health and performance.
6) If the dietary concentration of the most critical mycotoxin is critically above the tolerable threshold level then dilution of the contaminated feedstuff in the diet is required. Feed additives at a given feeding rate having the potential to adsorb multiple mycotoxins may not be effective in reducing the mycotoxin(s) to below the tolerable threshold level.
7) If all of the mycotoxin concentrations are critically above the tolerable threshold levels then consider discarding the feed.

A mycotoxin test was submitted and mycotoxin Y was found in HMSC at x ppb (or ppm). Which commercial mycotoxin binder (adsorbent) should be used?

The question is very challenging to answer for three primary reasons: varying global use of feed additives for mycotoxin adsorption, global mycotoxin research, and statistics. First, feed additives to mitigate mycotoxins in livestock diets are often called mycotoxin binders or mycotoxin adsorbents. No mycotoxin binder or adsorbent product is approved by the U.S. Food and Drug Administration (FDA) for the prevention or treatment of mycotoxicoses. Several of these adsorbent materials are generally recognized as safe (GRAS) feed additives and are used in diets for various purposes including, flow agents, pellet binders, or immune system enhancers. It is relatively easy to review published research on the ability of various compounds to adsorb mycotoxins, but it is extremely difficult to get detailed information on the actual ingredients in commercially available feed additives. Listed in Table 2 are feed additives in which a feed additive trade name and a manufacturer name has appeared in a scientific publication devoted to mycotoxin adsorption in livestock diets. The research may have been conducted on ruminants, swine, or poultry. The trade name of the product may or may not be found on products sold in the United States. The manufacturer may have alternative or similar feed additive formulations or names and the feed manufacturer may classify their product differently than as described in Table 2.

Many companies producing feed additives that have the potential to adsorb mycotoxins have a global marketing perspective and different countries have different marketing requirements for mycotoxin binders. Often products represented in global research are not sold in the United States or may have a different trade name therefore it is challenging to cross reference commercial feed additives.

It is also challenging to define the efficacy of feed additives to adsorb mycotoxins under a specific field condition because of simple statistics. For example, if there are 20 potentially harmful mycotoxins and four levels of concentration (none, low, medium and high) in a feed and three levels of inclusion of the feed in a diet (low, medium and high) and two types of dairy cattle diets (high or low forage) and ten feed additives with three abilities to adsorb a potential mycotoxin (none, fractional and all) this is defined as a 20x4x3x2x10x3 factorial meaning there are 14,400 possible outcomes. As a result, there are so many feeding possibilities that it is very challenging to construct positive or negative outcomes of feeding a feed additive to mitigate the effects of mycotoxins on a generic basis. Feed additive applications to reduce the effects of mycotoxins on dairy cattle need to be assessed on a case by case basis.

Despite these challenges, the technology, science and understanding involving feed additives ability to adsorb or detoxify mycotoxins is improving. The first generation of feed additives to adsorb mycotoxins could best be described as homeopathic. The second generation feed additives employed combinations of homeopathic compounds. The present generation of feed additives to adsorb or detoxify mycotoxins has employed more detailed selection of specific and unique clay materials to maximize mycotoxin

adsorption at low dietary inclusion rates, selection of specific organic glucomannans to adsorb mycotoxins, and evaluation of bacteria, enzymes, or other plant compounds which denature mycotoxins by specific and targeted biological activity. These efforts to improve a feed additives ability to mitigate a mycotoxin are promising.

In selecting a potential feed additive for mycotoxin adsorption or detoxification a few general observations that pertain to the 2009 Wisconsin corn crop are provided:

1) The majority of all feed additive research on mycotoxin adsorbents has been conducted on aflatoxin. Numerous research projects have demonstrated success in swine, poultry and in dairy cattle in reducing the effects of aflatoxin by feeding specific clay-silicates commonly defined as hydrated sodium calcium aluminosilicates. *Fusarium sp*. of molds were most abundant on the 2009 Wisconsin corn crop and these molds have the potential to produce *Fusarium* mycotoxins, so feed additives designed to adsorb aflatoxin may not be the best choice. Feed additives containing combinations of selected clays, glucomannans and other bioactive organics may be a better alternative if aflatoxin is not present and one or more *Fusarium* mycotoxins have been quantified in the feed. Feed additives with the ability to adsorb or detoxify *Fusarium* mycotoxins in ruminant diets maybe most appropriate for the 2009 Wisconsin corn crop.
2) Feed additive manufacturers should be asked if they have an active research program on mycotoxins and have mycotoxin technical specialists available to assist.
3) The use of generic or secondary market feed additives to adsorb or detoxify mycotoxins is discouraged because high level technical support is often required to evaluate the efficacy of a feed additive for specific mycotoxins.
4) There are no broad feed additives available to adsorb or detoxify multiple mycotoxins or indiscriminately defined mycotoxins on a consistent, selective, and quantifiable basis.
5) Any feed additive should be monitored for its efficacy and removed from the diet if no apparent changes in animal health or performance are observed, and
6) Do not rely on feed additives alone for the prevention or treatment of mycotoxicoses, but use in concert with other management practices.

Can generic bentonite be feed to adsorb mycotoxins?

The feeding of generic bentonite to cows to adsorb mycotoxins was a first generation homeopathic approach to adsorbing mycotoxins. Typically feeding rates were 1% to 2 % of the diet or 8 to 16 oz per day. Bentonite is clay and clay chemistry is very complex. Bentonite is a form of silicate which includes bentonites, zeolites, clinoptilolites, and various others that are often not completely characterized. Bentonite is a general clay material originating from volcanic ash containing primarily montmorillonite as the main constituent. Montmorillonite clay is a hydrated sodium calcium aluminum magnesium silicate hydroxide. More specific silicates are of high interest to mycotoxin researchers and these silicates have names such as neosilicates (single tetrahedrons), sorosilicates (double tetrahedrons), inosilicates (single and double chains), cyclosilicates (rings), phyllosilicates (sheets), and tectocilicates (frameworks). Silicates investigated as

adsorbent materials are classified primarily as phyllosilicates and tectosilicates. The most extensively studied silicate is designated as hydrated sodium calcium aluminosilicate (HSCAS).

Clay and silicate chemistry is very complex but most mycotoxin experts agree that the type of clay or silicate used is very important. Most dairy consultants and dairy educators do not have the expertise to define the efficacy of a generic bentonite to adsorb a specific mycotoxin. Generic bentonite can be fed but the use of selected clays and or selected silicates to adsorb mycotoxins may be prudent as compared to feeding high rates of a generic bentonite.

A high moisture corn was tested and found to have 1.0 ppm of vomitoxin (DON) and no other Fusarium toxins. Is this a concern?

The finding of any mycotoxin is a concern in a dairy feed but finding 0.5 to 2.0 ppm of vomitoxin (Deoxynivalenol; DON) in high moisture corn and or corn silage is fairly common. In some field studies > 50 % of all corn silage samples contained > 0.5 ppm of vomitoxin. The impact of DON on dairy cattle is not well established, but clinical data has observed an association between DON and poor performance in dairy herds. Dairy cattle consuming diets contaminated primarily with DON (> 2.0 ppm) have responded favorably to the dietary inclusion of mycotoxin adsorbents, providing indirect evidence that DON may reduce milk production. In contrast, in a number of controlled studies feeding DON contaminated diets, no effect on milk production has been observed. Like other mycotoxins, pure DON added to dairy cattle diets, may not have as much toxicity as does DON supplied from naturally contaminated feeds, perhaps due to the presence of multiple mycotoxins in naturally contaminated feeds that are unaccounted for. For example, it is now known that fusaric acid interacts with DON to cause vomiting effects in swine, which earlier was attributed to DON alone and resulted in use of the name of vomitoxin for DON. It is believed that DON may serve as a marker, indicating that feed was exposed to a situation conducive for mold growth and possible formation of several mycotoxins. The totally dietary level of DON in the diet should be calculated or ascertained. Whenever total dietary levels of DON are > 0.5 ppm the performance of the animals should be monitored because mycotoxins other than DON maybe present. Dietary levels > 5.0 ppm of DON should be closely monitored with dietary dilution or feed additive strategies employed if warranted.

Are there additional nutritional strategies that should be considered when mycotoxins are present in the diet?

The answer to this question is largely unknown but nutritional strategies that focus on supporting the immune system of dairy cattle should be considered in any diet. First vitamin supplementation should be evaluated and vitamins should be supplemented at recommended levels paying particular attention to vitamin E and selenium which has been demonstrated to be a critical component of the cow's immune system. Typically vitamin E is supplemented at 500-1000 IU/cow/day but research at Ohio State University has demonstrated that 2000-3000 IU/cow/day of vitamin E may be necessary under

conditions of immune challenge. Vitamin E however is expensive and the cost to benefit ratio of vitamin E supplementation needs to be considered. Selenium concentration of diets should also be monitored and selenium should be supplemented when needed. Absorption of selenium by cows may be improved by feeding a biological source of selenium, such as selenium-yeast.

In addition, trace minerals are critical component of a cow's immune system. Trace minerals concentration in the diet should be monitored and supplemented when needed. Chelated minerals or amino acid mineral complexes have been demonstrated to improve immune function in particular organic zinc complexes. Some specialty feed additives have also been demonstrated to improve immune function in cows.

But the rule of "don't go overboard" with immune enhancing supplements however applies. Over-supplementation can be as detrimental as under-supplementation. Immune enhancing vitamins and trace minerals are costly and have not been evaluated in diets contaminated with mycotoxins so results are uncertain.

Additional nutritional strategies to consider if mycotoxins are present in the feeds is feeding the mycotoxin contaminated feed to a less economically sensitive animal group. For example feeding a mycotoxin contaminated feed to heifers maybe less economically damaging than feeding the feed to high producing lactating dairy cows.

Finally, there are some reports that feeding alfalfa fiber has some ability to absorb mycotoxins but these reports are not well documented.

Is the word adsorb (absorb) misspelled throughout this document?

The word absorb better refers to something organic or social. A paper towel would be an absorbent material. The word adsorbent better defines something inorganic such as activated carbon. The word adsorb is used here to generally fit the nature of feed additives used in diets to reduce the influence of mycotoxins. Use of the word adsorb does not imply preferred use of inorganic feed additives. A yeast-glucomannan feed additive may be better defined as an absorbent.

Table 1. A list of commercial testing laboratories that conduct mycotoxin analysis.

Rock River Laboratory, Inc.
710 Commerce Drive
P. O. Box 169
Watertown, WI 53094-0169
www.rockriverlab.com
(920) 261-0446

Dairy One Forage Lab Services
730 Warren Road
Ithaca, NY 14850
www.dairyone.com
(607) 257-1272

AgSource Soil and Forage Laboratory
106 North Cecil Street
Bonduel, WI 54107
agsource.crinet.com
(715) 758-2178

Cumberland Valley Analytical Services, Inc.
P. O. Box 669
Maugansville, MD 21767
www.foragelab.com
(800) 282-7522

Covance Laboratories
3305 Kinsman Boulevard
Madison, WI 53707
(608) 241-4471

Centralia Animal Disease Laboratory
Illinois Department of Agriculture
9732 Shattuc Road
Centralia, IL 62801-5858
(618) 532-6701

Dairyland Laboratories
217 East Main Street
Arcadia, WI 54612
www.dairylandlabs.com
(608) 323-2123

Midwest Laboratories
13611 B Street
Omaha, NE 68144
www.midwestlabs.com
(402) 334-7770

Romer Labs, Inc.
Attn: Analytical Services
1301 Stylemaster Drive
Union, MO 63084-1156
www.romerlabs.com
(636) 583-8600

Veterinary Diagnostic Laboratory
North Dakota State University
174 Van ES Hall
Fargo, ND 58105
(701) 231-8307

Veterinary Diagnostic Labs
Iowa State University
1600 South 16th Street
Ames, IA 50011
vetmed.iastate.edu/diagnostic-lab
(515) 294-1950

Veterinary Medical Diagnostic Laboratory
1600 East Rollins
Columbia, MO 65211
vmdl.missouri.edu
(573) 882-6811

Woodson-Tenent Laboratories
3507 Delaware Avenue
P. O. Box 1292
Des Moines, IA 50313
(515) 265-1461

Table 2. Example trade names of commercial feed additives evaluated for mycotoxin adsorbtion potential listed in a peer reviewed journal.

Feed Additive[1]	Manufacture	General Classification[2,3]	Reference[4]
Mycofix	Biomin	Combination (Selected Clay and Organics)	Marroquin-Cardona, et al., 2009. Food Addit. Contam. 26:733.
Condition Ade	Oil Dri	Selected Clay (HSCAS)	Stroud et al., 2006. J. Dairy Sci. 89(Suppl.):129.
AB-20	Prince Agri Products	Selected Clay	Diaz et al., 2004, Mycopahologia 156:233 & 157:233
MTB-100	Alltech	Combination (Glucomannan + Selected Clay)	Kutz et al., 2009. J. Dairy Sci. 92:3959.
Mycosorb	Alltech	Combination (Glucomannan + Selected Clay)	Swammy et al., 2003. J. Animal Sci. 81:2792
Novasil	Englehard Corp/BASF	Selected clay (HSCAS)	Kutz et al., 2009. J. Dairy Sci. 92:3959.
Solis	Novus	Selected clay (HSCAS)	Kutz et al., 2009. J. Dairy Sci. 92:3959.
UltraSorb	Micro-Bio Systems	Combination (Selected Clay and Organics)	Stroud et al., 2006. J. Dairy Sci. 89(Suppl.):129.
Toxynil	INVE (BFI/Feed Flavors)	Combination (Selected Clay and Organics)	Stroud et al., 2006. J. Dairy Sci. 89(Suppl.):129.
MilBond	Milwhite, Inc	Selected Clay (HSCAS)	Stroud et al., 2006. J. Dairy Sci. 89(Suppl.):129.
Myco-AD	Specialty Nutrients, Inc	Selected Clay	Avantaggiato et al., 2007. J. Agr. Food Chem. 55:4810.

[1] The feed additive may or may not be sold in the United States. Variants of the trade name may exist. Variants of the general classification may exist.

[2] The general classification of the feed additive is given by the author based on general discriptions in the publication.

[3] The manufacturer may use an alternative classification to describe their product. HSCAS = hydrated sodium calcium aluminosilicate.

[4] The reference only implies a trade name was published in a peer reviewed journal. Efficacy of the product for specific mycotoxins is not implied.