Seeking solutions to the mycotoxin threat to animal health

How TOXINOR, a mycotoxin binder made of materials with suitable geometric and molecular properties protects livestock health.

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The presence of fungi in nature is ubiquitous; we can find them on almost any organic surface. Under adequate conditions, these fungi are able to produce secondary metabolites called mycotoxins. These are toxins produced via the reduction of ketone bodies during the synthesis of fatty acids.

Diverse, ubiquitous and hardy under extreme conditions

Mycotoxins can be found consequently in a great variety of crops and feedstuffs all over the world. The type of mycotoxins that we find in a certain places is influenced by the conditions of the area. Climatic factors, pH, the preference of some fungi for determined substrates are some of the variables. Table 1 details the predominant mycotoxin depending on the geographic location.

Due to the co-existence of different mycotoxins within the same geographic area and the combining of raw materials in feed, animals are not normally exposed to only one mycotoxin but to several at the same time. When mycotoxins are present simultaneously, interactive effects can be additive, antagonistic or synergistic, causing in some cases far more damage than the sum of their individual side-effects.

The main mycotoxin-producing fungi belong to the Aspergillus, Penicillium or Fusarium genus. Their capacity to produce large quantities of mycotoxins is determined by several variables. Water activity (aw) is one of the most important factors; it is defined as the partial vapor pressure of water in a substance divided by the standard state partial vapor pressure of water. In other words, it expresses the amount of available water for microbiological development. High aw values are needed to support fungi activity. Although an aw value of 0.70 is sufficient for fungal growth, values in the range of 0.80 to 0.90 are required to produce mycotoxins in significant quantities.

Temperature is also a very important factor. While the above mentioned genus can grow in temperatures ranging from -3°C to 40°C, optimal growth occurs between 25°C and 30°C. Similarly, if we analyse their preferred pH range, their preferred condition is alkaline and in the 7.0 to 7.5 range. Even so, mycotoxin producing fungi can tolerate acidic environments with pH levels ranging from 2.5 to 6.9.

In the following table (Table 2) we show the type of mycotoxin produced by the prevalent fungi found in crops:

Table 1.

Area	Mycotoxin
Europe (West)	Ochratoxin, Vomitoxin, Zearalenone
Europe (East)	Zearalenone, Vomitoxin
North America	Ochratoxin, Vomitoxin, Zearalenone, Aflatoxin
South America	Aflatoxin, Fumonisin, Ochratoxin, Vomitoxin, T2 Toxin
Africa	Aflatoxin, Fumonisin, Zearalenone
Asia	Aflatoxin
Australia	Aflatoxin, Fumonisin, Lolitrem

(Devegowda and Murthy, 2005; Jorgensen et al., 1996; Sweeney and Dobson, 1998; Barug et al., 2004; Placinta et al., 1999)

Table 2.

Species	Mycotoxin
Aspergillus flavus; A. parasiticus	Aflatoxin
A. flavus	Cyclopiazonic ac.
A. ochraceus; Penicillium verrucosum; P. cyclopium	Ochratoxin A
P. expansum	Patulin
Fusarium culmorum; F. gramineatum; F. sporomchioides;	Deoxynivalenol
F. sporotrichioides; F. poae	T2 toxin
F. sporotrichioides; F. gramineatum; F. poae	Diacetoxiscirpenol
F. culmorum; F. ramineatum F. sporotrichioides	Zearalenone
F. moniliforme	Fumonisin
Acremonium coenophialum	Ergopectins
A. lolii	Alkaloid Lolitrem
Phomopsis leptostromiformis	Phomopsins
Pithomyces chartarum	Sporidesmins

Effects on animal performance

The deleterious effects of the mycotoxins are very well known and this article does not intend to be a summary of them. Both elevated doses and/or long term exposure produce a syndrome called mycotoxicosis. There are some hints that can make us suspect the presence of mycotxicosis syndrome. For example, similar symptoms exist in different animals or groups on the same farm without any contact or transmission between them. In such cases, the symptoms do not respond to antibiotic treatment, are seasonal, or are associated with fungi contaminated feed or feed crops.

When mycotoxins are present in sufficiently high concentrations, the first set of impacted parameters are animal performance indicators. Feed consumption drops and significant decreases in

growth rates and FCRs are observed.

As the immune system is also damaged, the occurrence of opportunistic diseases increases.

Vital organs including the liver, ovaries, kidneys, spleen and even the brain are harmed. On top of that, the accumulation of mycotoxins, or their metabolized forms, in meat, eggs, or milk has a devastating impact on the economic viability of farms due to product refusals or immobilizations.

It is therefore crucial to adopt specific procedures to detect, prevent and remove mycotoxin contamination. In this regard, the widespread adoption of preventative food safety systems such as HACCP has been of great help.

How toxin binders work

Lately there has been growing interest in detoxifying livestock feed through the use of an adsorption mechanism. Called mycotoxin binders, the effect is a surface phenomenon caused by the adhesion of mycotoxin molecules to a solid surface. The nature of the bonding depends on the details of the species involved.

In all toxin binders, electrostatic and hydrophobic interactions are the causal mechanisms for mycotoxin adsorption. The objective of this kind of product is to prevent mycotoxins from being absorbed through the intestinal wall, thereby limiting their availability and consequently, their metabolically harmful effects. To be effective, mycotoxins must adhere themselves to the toxin binder and remain attached until they are excreted.

These products must comply with the desired characteristics named by Diaz and Smith (2005) for successful mycotoxin decontamination: They must effectively extract, inactivate or destroy mycotoxins without producing toxic, carcinogenic or mutagenic residues in either treated products or in the food products derived from treated animals. They should not alter the nutritive or organoleptic properties of meat from such treated animals and be economic and technologically useful.

Aluminosilicates and diatomaceous earths

Aluminosilicates are a group of clays that present this adsorption capacity. They are divided into two subgroups: phyllosilicates (e.g bentonite) and tectosilicates (e.g. zeolite).

These minerals, due to their physical structure, present an elevated peripheral area value and active surface with binding points, which is the reason why they are able to interact with a wide range of substances, especially polar compounds.

This property also confers elasticity when mixed with water and expansion capacity. Between the different layers of this tridimensional structure, bound cations can be exchanged in water solution for other ions, this is what is called cation exchange capacity (CEC). So some charged molecules are susceptible to substitute these cations and be absorbed by the material.

On top of this sequestering capacity, aluminosilicates are able to reduce digested food's intestinal transit rate, thereby enhancing digestibility and preventing diahorrea.

Diatomaceous earths are another product found to have a great mycotoxin binding capacity. Diatomites consist of fossilized remains of diatoms, a type of hard-shelled algae. Mainly composed of silicon dioxide (SiO_2) along with proportions of aluminum oxide (Al_2O_3) and ferric oxide (Fe_2O_3), diatomaceous earths are very low density. They have extremely porous surfaces in which very reactive radicals such as silanol can be found. As a result, they are able to interact with organic polar compounds, and this property is responsible for their mycotoxin binding capacity.

Depending on the different properties of the toxin binder adsorbent: (e.g. surface structure, CEC, rheological properties, adsorption/absorption capacity) not all the products are able to effectively bind all the mycotoxins. CEC alone is also not enough to objectively measure the effectiveness of a product, as the distance between the binding points must be sufficient to avoid interactions between bound compounds; otherwise captive mycotoxins will be released as easily as they were captured. Therefore a multifaceted approach has to be employed. A proper mix of different materials will be able to cover a wider range of mycotoxins, thereby providing effective, comprehensive protection.

TOXINOR tests, results & conclusions

A study conducted by the University of Madrid's Biological Science Faculty (Microbiology Department, Complutense University of Madrid) tested TOXINOR, a commercial toxin binder produced by NOREL S.A. Based on two aluminosilicates and diatomaceous earth different active compounds, TOXINOR was tested for its effectiveness against the main mycotoxins affecting livestock production: zearalenone, aflatoxin b1, aflatoxin b2, aflatoxin g1, aflatoxin g2, aflatoxin m1, ochratoxin, deoxynivalenol (don), t-2 toxin and fumonisin B1.

Table 3. Percentage of mycotoxins eliminated by TOXINOR at two pH levels

	pH 4.0	pH 7.0
AFLATOXIN B1	99.86%	99.64%
AFLATOXIN B2	99.96%	99.80%
AFLATOXIN G1	100.00%	100.00%
AFLATOXIN G2	99.87%	99.74%
AFLATOXIN M1	100.00	100.00
OCHRATOXIN A	93.25%	95.69%
ZEARALENONE	100.00%	100.00%
FUMONISIN 1	100.00%	69.30%
VOMITOXIN	0.00%	46.00%
T-2 TOXIN	90.10%	92.61%

Samples deliberately contaminated with the above mentioned purified mycotoxins (at 2ppm) were treated with a dose of 0.5% of TOXINOR. Thereafter, the level of the mycotoxins was measured by HPLC. This experiment was repeated at two widely different pH levels in order to detect any possible interaction.

To be able to cover the maximum range of mycotoxins, TOXINOR was designed using 3 different ingredients that combine laminar 3D, fibrous-like and empty spherical structures. In this way, particle surface area is maximised to optimize its binding ability against a wide range of mycotoxins. In particular, TOXINOR's resulting particle geometry and molecular structure offers high toxin binding capability for AFB1, AFB2, T-2, ZEN, fumonisin and ochratoxin.

Therefore, a rational combination of active mineral materials can be used as an effective tool to reduce the mycotoxin contamination caused by the growth of fungi in raw materials and feeds.