Pig feed and fumonisins – a threat to the immune system?

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Fumonisins are produced by fungi of the Fusarium (F. verticillioides, F. proliferatum etc) and Aspergillus (A. niger) species (see photograph). Fumonisin toxicosis in swine has been related to porcine pulmonary oedema (PPE) since 1981, arising from an experimental exposition of pigs to corn contaminated by F. verticillioides.

This was confirmed by outbreaks of pulmonary oedema in pigs due to the ingestion of corn contaminated with fumonisins in the midwestern and southeastern parts of the United States.

Occurrence of fumonisins

Fumonisins are unique among mycotoxins as they are almost exclusively contaminants of corn and do not occur in a wider range of cereals or other commodities.

According to data from the Biomin mycotoxin survey 2012, 86% of all corn samples, 90% of corn gluten meal samples and 79% of corn DDGS samples tested were found to be positive for fumonisins (Table 1).

Corn and corn-based feedstuffs are extensively used in the feeding of farm animals. The main feedstuffs made of corn are maize grain, corn silages (whole plant, corn cob mix (CCM), maize stover) and by-products of the refining industry. Corn oil, corn gluten, corn germ meal and corn germ bran are the most important corn by-products in animal feeding.

Corn grain is a basic component in the diets of monogastric animals because of its high energy content. In fattening pigs, the proportion of corn in diets is usually higher at the beginning of the fattening period than in the finishing period. Starter diets might contain up to 70% maize grains. In contrast, the corn grain content in finisher diets is limited to up to approximately 20% in most feeding systems.

Current legislation

In 1995, fumonisins were subject to regulation in only one country (FAO, 1997). Since then, this number has now increased to six, with limits for maize ranging from 1,000-3,000µg/kg (FAO, 2004).

In Europe, fumonisins are now regulated in Bulgaria (FB_1 and FB_2 in maize and maize products), France (FB_1 in cereals and cereal products), and Switzerland (FB_1 and FB_2 in maize).

Specific EU-harmonised limits for fumonisins in food or feed have not yet been established. Limits for FB_1, FB_2 and FB_3 in animal feeds currently only exist in the USA, as guidance levels for the industry.

How do fumonisins work?

The mode of action of fumonisins is primarily explained by the interference with the de novo synthesis of complex sphingolipids. As a consequence, free sphingoid bases (sphinganine and sphingosine) accumulate in tissues, which results in disturbances of cellular processes such as cell growth, cell differentiation, cell morphology, endothelial cell permeability and apoptosis, leading to detrimental hepato and nephrotoxic effects. The accumulation of sphinganine and sphingosine in the serum is a useful biomarker for the exposure to fumonisins.

Table 1. Worldwide fumonisin contamination levels detected in corn samples in 2012.

	Corn	Corn gluten meal	Corn DDGS
Number of tests	712	41	57
Percent positive (%)	86	90	79
Average of positive (µg/kg = ppb)	1,942	2,836	1,807
Maximum (µg/kg = ppb)	42,120	13,457	11,594

Fumonisin producing Fusarium proliferatum.

Effects on immunity

The sensitivity of the immune system to mycotoxin-induced immune-suppression arises from the vulnerability of the continually proliferating and differentiating cells that participate in immune mediated activities and regulate the complex communication network between single components of the immune system.

The immune system is primarily responsible for defence against invading organisms. Suppressed immune functions by mycotoxins may eventually reduce resistance to infectious diseases as well as the acquired immunity induced by vaccination.

Immunosuppressive agents

Nevertheless, before causing typical clinical symptoms, fumonisins very often act as immunosuppressive agents. Chronic exposure to fumonisin B_1 can reduce the proliferation of undifferentiated porcine epithelial intestinal cells, altering the integrity of intestinal epithelium and consequently facilitating the entry of pathogens into the body.

In fact, exposing weaned pigs to 1mg of fumonisin B_1 per kg body weight over 10 days predisposes them to a longer shedding of F4+ enterotoxigenic E. coli following infection, which deepens intestinal damage.

Fumonisin B_1 gradually deteriorates the hosts' immune system, affecting the recognition and processing of pathogens by the antigen-presenting cells. This causes inhibitory-cytokine signalling in the effector

Continued on page 24

Continued from page 23
cells, which reduces pathogen elimination and leads eventually to prolonged intestinal infection. Fumonisins reduce the clearance of Pseudomonas aeruginosa as well as the phagocytosis of Salmonella typhimurium in the alveolar macrophages of pigs fed fumonisin B_1. Consequently, it increases the susceptibility of pigs to diseases caused by such pathogens.

Reduced antibody titers

Feeding weaning piglets with 8mg fumonisin B_1/kg over 28 days leads to a significant reduction in antibody titers after vaccination against Mycoplasma agalactiae. Feeding pigs fumonisin contaminated feed could lead to an inappropriate vaccination response, reducing the level of specific antibodies and reducing the period of vaccine protection, or just leaving animals unprotected against this specific disease.

Bracarense et al. (2012) also showed that chronic ingestion of low doses of mycotoxins (deoxynivalenol and fumonisin B_1) alters the intestine, and may thus predispose animals to infections by enteric pathogens.

The aforementioned studies describe some of the immunosuppressive effects of fumonisins, and their role as a predisposing factor to diseases in pigs.

Still, more information is needed about the mechanisms by which fumonisins induce these and other effects. One thing is certain: fumonisins represent a risk to animal health and performance, which is why proper mycotoxin risk management is indispensable.

Mouldy corn cob.

Deactivation of mycotoxins

The most widely applied method for protecting animals against fumonisins is the mixing of feed with clay minerals which are supposed to bind the mycotoxins efficiently in the gastro-intestinal tract. So far, no single adsorbent has been tested effective against most types of mycotoxins, including fumonisins.

An alternative way of removing non-adsorbable mycotoxins is via enzymatic detoxification (biotransformation). This method is defined as a degradation or transformation that reduces or removes the toxicity of the mycotoxin.

Specific mycotoxin-degrading enzymes offer an unique and natural way of encouraging biotransformation in the digestive tract of animals.

It is known that the 12,13-epoxide ring of trichothecenes (for example DON, T-2 toxin) is mainly responsible for the toxic activity and their removal will lead to a significant loss in toxicity. Binder et al. (1998) were among the first to describe a novel strain of Eubacterium sp. (BBSH 797) with the capability to biotransform DON to DOM-1.

In the case of fumonisins, fumonisin-degrading enzyme preparation (FUMzyme) is capable of fumonisin B_1 biotransformation into non-toxic metabolite hydrolysed FB_1 (HFB_1).

Conclusion

Biological methods (for example biotransformation) have the potential to become the technology of choice in the field of fumonisin-deactivation, as enzymatic reaction offers a specific, irreversible, and environmentally friendly way of detoxification that leaves neither toxic residues nor any undesired by-products. ■

References are available from the author on request