Mycotoxins in poultry feeds – current issues

By Jules Taylor Pickard, Technical Team Manager, Europe, Alltech

Mycotoxins are toxic compounds produced by moulds (fungi). Such fungi can exist in the soil and contaminate field crops pre-harvest. Global climate change has resulted in more frequent mycotoxin contamination of field crops both because of excess moisture and drought.

Excess moisture is a key factor in promoting mould growth and mycotoxin production. Grains can be stabilised by reducing moisture content to 12%. Drought can also contribute to mycotoxin contamination.

Some moulds increase mycotoxin production when stressed by the high temperatures and low moisture conditions typical of drought.

Shrivelling and cracking of grain kernels can also occur which allows mould spores to penetrate the kernel and to flourish on the starch rich endosperm.

On a global basis, the most significant feedborne mycotoxins affecting poultry production are aflatoxin and the many Fusarium mycotoxins.

Aflatoxicosis in poultry has been well characterised with many literature reports describing tolerance levels for different categories of poultry. Determining the threat posed by feeding aflatoxin contaminated feedstuffs is further simplified by the analytical techniques that are available. They are rapid, reproducible and sensitive.

Only four aflatoxins are commonly found in feedstuffs and these have similar chemical structures. Fusarium mycotoxins pose a much more complex challenge because well over 100 of these toxins have been chemically identified and there is a wide range of chemical structures.

It is not possible to analyse for all these compounds so one or two 'marker' mycotoxins must serve as crude indices of potential harm when contaminated feeds are fed.

A commonly used marker for Fusarium mycotoxin contamination is deoxynivalenol (DON, vomitoxin). Recent reports indicate, however, that plants can modify DON produced by moulds by conjugating DON with a glucose sugar molecule.

Such complexed DON is toxic to birds when exposed to digestive enzymes which remove the glucose molecule in the lumen of the intestinal tract to allow DON to be absorbed into the bloodstream and transported to target tissues.

The conjugated DON, however, is not detected by ELISA quick test assays which are commonly used in industry to rapidly detect mycotoxins in feeds.

A survey of naturally contaminated corn and wheat from central Europe indicated that the relative fraction of conjugated DON was as high as 30%. Glucose conjugates of zearalenone, another Fusarium mycotoxin, have also recently been reported.

This would indicate that all current analyses of feedborne Fusarium mycotoxins are likely underestimating the extent of contamination. This further complicates the use of marker compounds in determining the potential hazard posed by the feeding of contaminated feedstuffs.

Another emerging factor complicating poultry nutrition is the feeding of mycotoxin contaminated distillers' dried grains arising from fuel ethanol production. Increasing diversion of feed grains from poultry and livestock to ethanol production has been accelerated by political developments in North America.

This has led to marked increases in the prices of feed grains as increasing quantities are diverted to fuel ethanol production. At the same time, increasing quantities of feed grade by-products such as distillers' dried grains have appeared on the market at increasingly attractive prices.

During the fermentation process, starches are consumed for ethanol production while fibre, protein and contaminants such as mycotoxins are concentrated in the resulting byproduct. It is generally assumed that the concentration of mycotoxins increases three to four fold when comparing distillers' dried grains to the original substrate grains.

A further complication is that ELISA quick test kits commonly yield false positive results when analysing distillers' dried grains, perhaps due to the acidic nature of these byproducts.

It can be concluded that the frequency of feedborne mycotoxins is increasing and that analytical techniques available for quantifying contamination may not be accurate. ■

Global occurrence of mycotoxins

By Jules Taylor Pickard, Technical Team Manager, Europe, Alltech

Mycotoxins are produced by soil fungi infesting field crops pre-harvest and also post-harvest in grains stored under sub-optimal conditions. Excessive moisture is a key promoter of mould growth and mycotoxin production; if moisture content can be maintained at 12% or less, little mycotoxin contamination can be expected.

In the last decade, however, perhaps because of global climate change, growing conditions have been sub-optimal worldwide.

Excess rainfall and flooding at key stages of crop development can lead to significant mycotoxin contamination of feed grains. Drought, however, can also lead to mycotoxin contaminated feedstuffs.

Environmental stress

Many fungi increase their mycotoxin production when environmentally stressed and this includes low moisture conditions. The shriveling of grain kernels which can cause cracking in the waxy outer protective coat of the kernel can also predispose cereal grains to fungal infestation.

In addition to the increased frequency of mycotoxin contamination of feedstuffs, another factor that can increase the severity of mycotoxicoses in poultry is the toxicological interaction between different mycotoxins.

Modern poultry diets contain many different ingredients with widely varying geographical origins. Examples may be cereal grains imported from Eastern Europe combined with soybean meal manufactured in South America.

The result can be combinations of mycotoxins that are toxicologically more harmful than the individual mycotoxins that might have existed in poultry feeds in the past.

Opportunistically priced ingredients such as the increasingly available distillers' dried grains may serve as a further vector for mycotoxin contamination.

Although it has long been recognised that poultry are susceptible to aflatoxicosis, reports from the 1980s indicated that broiler chickens, laying hens and turkeys are quite resistant to Fusarium mycotoxicoses.

These early reports, however, were generated with purified toxin, fungal culture materials or other artificially generated contaminated feedstuffs. This meant that the dominant contaminant was deoxynivalenol (DON, vomitoxin) which was present in the absence of other Fusarium mycotoxins.

Recent reports of the feeding of combinations of feedstuffs naturally contaminated with Fusarium mycotoxins to broilers (Swamy et al., 2002; Swamy et al., 2004), broiler breeders (Yegani et al., 2006a), layers (Chowdhury et al.; 2004, 2005), turkeys (Chowdhury et al., 2005) and ducks (Chowdhury et al., 2005) indicate that combinations of feedstuffs naturally contaminated with Fusarium mycotoxins significantly reduces the efficiency of poultry production.

This may take the form of reduced growth rates or reduced egg production.

Metabolic effects of combinations of Fusarium mycotoxins can include lesions of the gastrointestinal tract, reduced nutrient absorption and reduced utilisation of dietary protein.

More difficult to diagnose are secondary mycotoxic diseases which arise from feedborne mycotoxin induced immunosuppression. This can also lead to failure of vaccination programmes.

Poultry sensitivity

In comparing the sensitivity of different types of poultry to blends of feedstuffs naturally contaminated with Fusarium mycotoxins, laying hens appear to be the most sensitive followed by turkeys, broilers and broiler breeders and ducks.

One factor influencing the sensitivity of poultry to such a challenge is the effect of mycotoxins on avian brain neurochemistry (Yegani et al., 2006b). Elevations in brain serotonin are thought to reduce feed intake and performance.

It can be concluded that the frequency and severity of mycotoxin issues in poultry production are increasing and that poultry industries must take action to minimise the adverse effects of feedborne mycotoxins. ■

References are available on request

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Effects of mycotoxins on performance

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Poultry are generally considered to be less sensitive to feed-borne mycotoxins than monogastric animals such as pigs and horses.

This particularly refers to the tendency for reduced feed intake or feed refusal.

Poultry will often consume contaminated feeds that will be refused by pigs, and diversion of contaminated grains from pig feeds to poultry feeds is common in many countries.

Such feed refusal behaviour, however, is a natural protective mechanism which reduces the potential harmful effects of mycotoxins on metabolism.

Poultry become more susceptible to such effects when contaminated feeds are consumed. Ruminant animals are usually considered to be the least sensitive species because of the detoxifying capacity of rumen micro-organisms.

Globally, the most significant mycotoxins in broiler and broiler breeder diets are aflatoxins and the Fusarium mycotoxins.

Aflatoxins in such feeds have been well researched due to the potential hazard posed by aflatoxin residues in poultry meat. Aflatoxin is a potent hepatocarcinogen which can pose a health hazard to consumers if found at excessive levels in meat.

Acute exposure to feed-borne aflatoxin results in liver damage characterised by fatty infiltration and necrosis. Embryo toxicity is also seen.

There is significantly less information regarding the feeding of Fusarium mycotoxins to broilers and broiler breeders. Early literature indicated that broilers had a high tolerance for Fusarium mycotoxins such as deoxynivalenol (DON, vomitoxin), although exposure to T-2 toxin resulted in characteristic oral lesions.

Such studies were usually conducted over short periods (starter phase) and utilised either purified mycotoxin or fungal culture materials. It is now clear that the feeding of blends of naturally contaminated feedstuffs can result in greater production losses than previously thought.

This may be due to the presence of unknown mycotoxins, undetectable forms of mycotoxins or toxicological synergy between different mycotoxins.

Studies by Swamy et al., (2004a) indicated that the feeding of a blend of feedstuffs naturally contaminated with combinations of Fusarium mycotoxins resulted in growth depression and reduced feed intake only in the grower phase (weeks 4-6) and not the starter phase (weeks 1-3).

This may have been due to reduced utilisation of dietary protein as indicated by elevated blood uric acid levels and immunosuppression.

Elevations in circulating red blood cells and haemoglobin concentrations as well as a red discolouration of breast meat were also reported (Swamy et al., 2002).

It would appear that the lack of mycotoxin induced feed refusal in broilers compared to piglets is caused by simultaneous rises in brain serotonin and norepinephrine concentrations (Swamy et al., 2004b).

In piglets, only brain serotonin concentrations are seen to rise.

Less information is available regarding the susceptibility of broiler breeders to Fusarium mycotoxicoses. A recent article by Yegani et al., (2006) indicated that the feeding of a mixture of grains naturally contaminated with a combination of Fusarium mycotoxins tended to depress egg production.

There was, however, a significant reduction in eggshell thickness when birds were fed contaminated diets.

This resulted in a significant increase in early embryonic mortality (0-7 days) as well as indications of immunosuppression.

It can be concluded that broilers and broiler breeders are susceptible to impaired production efficiency due to feed-borne mycotoxins.

Such materials should be fed to these categories of poultry only with extreme caution and strategies to minimise their susceptibility should be used.

References available upon request.

Mycotoxins – laying hens, turkeys & ducks

By Jules Taylor-Pickard, European Technical Team Manager, Alltech

Some species of poultry can be very sensitive to feed-borne mycotoxins. The adverse effects of aflatoxin on performance and health of poultry has been well documented. Attention was first drawn to avian aflatoxicosis in 1960 with the outbreak of Turkey X Disease in the UK.

Extensive research into the issue has indicated that ducks are amongst the most sensitive of all species to aflatoxicosis. Acute aflatoxicosis is characterised by fatty infiltration and degeneration of the liver. Chronic exposure to low doses of aflatoxin results in liver tumours and aflatoxin is one of the most potentially carcinogenic compounds known.

Significantly less is known about the effects of feed borne Fusarium mycotoxins on avian species. One challenge in the study of Fusarium mycotoxicoses is the very large number of mycotoxins produced by this most common variety of fungi.

An excess of 100 different compounds have been chemically characterised. The earlier literature indicated that laying hens (Hamilton et al., 1985) and turkeys (McMillan et al., 1986) were very resistant to feed borne deoxynivalenol (DON, vomitoxin). This work, however, was conducted with artificially inoculated corn which was equivalent to the feeding of an individual purified mycotoxin.

It is now understood that the feeding of natural blends of grains, contaminated with Fusarium mycotoxins, can result in increased sensitivity of birds as a consequence of the toxicological synergy seen when combinations of mycotoxins are present.

It has more recently been shown that the feeding of naturally contaminated grains with Fusarium mycotoxins to laying hens can result in significant reductions in performance (Danicke et al., 2002 and Chowdhury and Smith, 2004).

Reductions in egg production and feed efficiency were seen coupled with metabolic disorders such as an increase in blood uric acid concentrations.

The increase in blood uric acid concentrations was attributed to a reduction in hepatic fractional protein synthesis resulting in increased amino acid oxidation and increased uric acid synthesis (Chowdhury and Smith, 2005a). This increases the possibility of gout and visceral gout and increased ammonia levels in the barn.

Some indices of immunosuppression were also seen including total numbers of white blood cells, lymphocytes including both CD4+ and CD8+ T lymphocytes and B lymphocytes and biliary IgA concentrations (Chowdhury and Smith, 2005b).

Turkeys have also been shown to be susceptible to feed borne combinations of Fusarium mycotoxins (Chowdhury, 2005). The feeding of diets mainly contaminated with DON significantly reduced growth rates and some indices of immunosuppression were affected (Chowdhury et al., 2005a).

Ducks were the least sensitive of the avian species to be investigated with combinations of Fusarium mycotoxins. While production parameters were not affected by diet, immunosuppression causing increased susceptibility to viruses was detected (Chowdhury et al., 2005b).

It can be concluded that the relative sensitivity of avian species to Fusarium mycotoxicoses would be laying hens, turkeys, broilers and broiler breeders and ducks. It is clear that the practice of diverting grains contaminated with Fusarium mycotoxins from the diets of animals such as swine, which are considered more susceptible due to reduced feed intake than poultry should not take place.

Although poultry will consume contaminated diets more readily than swine, horses and dogs; they are still susceptible to the deleterious effects on metabolism including immunosuppression.

The reduction in feed intake seen in swine and other species could be considered to be a natural protective behaviour as it will minimise the metabolic effects seen in poultry.

It can be concluded that, in contrast to previously held beliefs, feed borne Fusarium mycotoxins should not be included in the diets of laying hens, turkeys and ducks. ■

References available on request

Effects of feed-borne mycotoxins on immunity

By Jules Taylor Pickard, Technical Team Manager, Europe, Alltech

There are specific pathological lesions in poultry associated with most feed-borne mycotoxins particularly when fed in high (acute) concentrations. For example, acute doses of aflatoxin cause liver failure; ochratoxin is a nephrotoxin.

Trichothecene toxins such as deoxynivalenol (DON, vomitoxin), T-2 toxin and diacetoxyscirpenol (DAS) can cause lesions of the oral cavity and haemorrhaging in the intestinal tract. One very non-specific result of the feeding of contaminated feeds can be immuno- suppression. Indeed, aflatoxin, ochratoxin, fumonisin and the trichothecenes have all been shown to be immunosuppressive to varying degrees. This means that birds are more susceptible to secondary mycotoxic diseases, where the result can be lingering health problems in the flock.

The disease conditions may not respond to medications and, even more importantly, there may be failure of vaccination programmes.

The significance of mycotoxin induced immunosuppression will depend on flock health status and the degree of disease challenge. In the absence of such challenge, immunosuppression may not have economic consequences. In light of the constant threat of disease challenge, however, chronic immunosuppression is likely the most significant economic consequence of feed-borne mycotoxins.

The indirect nature of secondary mycotoxic diseases caused by mycotoxin induced immunosuppression makes it often very difficult to identify effective treatments. The possibility that mycotoxins are the underlying cause of the condition is usually only considered after medications fail to result in a cure. The failure of vaccination programmes is also usually first blamed on the vaccine supplier or the technicians involved. The possibility that the birds could not respond to the vaccine due to compromised immune systems arising from feed-borne mycotoxins is seldom considered, and the condition can be further complicated by management practices. Environmental conditions that result in flock stress including housing density and temperature extremes can also cause a degree of immunosuppression. Such environmental stress coupled with chronic consumption of feed-borne mycotoxins could result in reduced performance and increased mortality when flocks encounter a disease challenge. This can explain how it is possible to see significant losses in flocks consuming feed that appears to contain innocuous levels of mycotoxins. The situation can be further confused by the fact that different flocks consuming feed from the same manufacturing site may have different performance. This is usually used to argue that the root cause is not the feed. Low levels of mycotoxins in the feed may be responsible, however, when coupled with adverse management practices.

The effects of a mixed Fusarium mycotoxin challenge (primarily DON) was investigated by Swamy et al. (2004), where it was reported that peripheral blood monocytes decreased linearly in birds fed contaminated grains. B-cell count was also reduced at the end of the experiment. There were no significant effects on serum or bile immunoglobulin concentrations, contact hypersensitivity to dinitrochlorobenzene or antibody response to sheep red blood cells.

It was concluded that a mixed Fusarium mycotoxin challenge could adversely affect immunity in broilers, which was in agreement with earlier studies when broilers were fed purified DON (Harvey et al., 1991).

The feeding to laying hens of diets naturally contaminated with Fusarium mycotoxins showed that the effects were mainly on mucosal immunocompetence, while haematotoxic and systemically immunosuppressive effects were less obvious (Chowdhury et al., 2005a).

Small decreases were seen in haematocrit values, total numbers of white blood cells, lymphocytes including both CD4+ and CD8+ T lymphocytes and B lymphocytes, and biliary IgA concentrations. Similar responses have been seen in turkeys (Chowdhury et al., 2005b).

It can be concluded that the effects of feed-borne mycotoxins on avian immunity can be economically very significant and a challenge to identify under commercial conditions. ■

Is there a safe level of mycotoxins?

By Jules Taylor Pickard, Technical Team Manager, Europe, Alltech

The answer to this question is an unqualified yes. The metabolism of all birds includes detoxification enzymes which promote the degradation and excretion of mycotoxins that have been adsorbed from the intestinal tract.

Mycotoxin induced reductions in performance, adverse metabolic changes and specific lesions arise only when the detoxifying capacity of the bird is exceeded. Unfortunately, however, this can often occur.

The safe or no-effect level of feedborne mycotoxins refers to the detoxification threshold and producers throughout the world ask what is the safe level for different mycotoxins in different species of poultry?

It is not possible to answer these questions with confidence although many governmental agencies have published guidelines and regulations.

Most of the guidelines and regulations that have been made are based on research conducted on individual mycotoxins in a variety of poultry species. Such experiments are usually of short duration and utilise purified mycotoxins or artificially produced fungal culture material.

Modern poultry diets are complex mixtures of ingredients which may have widely varying geographical origins. Multiple vectors for mycotoxin contamination of the diet may be present resulting in complex mixtures of mycotoxins produced by a variety of fungal species. Complete feeds will contain numerous mycotoxins, many of which may be present in very low concentrations.

These can result in additive or synergistic toxicological effects. Although hundreds of mycotoxins have been chemically identified, commercial analytical services routinely assay feeds for only a few different compounds. It is very difficult to extrapolate such an analysis to give an accurate estimate of the potential hazard posed by the feeding of contaminated diets.

Toxicological synergy is seen when the presence of one feedborne mycotoxin multiplies the toxicity of a second mycotoxin. Such a synergy has been demonstrated between fusaric acid and deoxynivalenol (DON, vomitoxin). Fusaric acid, which has low acute toxicity, has been shown to increase the toxicity of low levels of DON (Smith et al., 1997).

Both of these mycotoxins are pharmacologically active. They alter brain neurochemistry to reduce feed intake, reduce muscle coordination and induce lethargy. This is thought to be due to elevated concentrations of the neurotransmitter serotonin, which can produce a sedative like effect.

The mechanisms by which the mycotoxins elevate brain serotonin, however, are different and this is the basis of the resulting toxicological synergy. DON and other trichothecenes such as T-2 toxin and nivalenol, inhibit tissue protein synthesis. Amino acids that would have been incorporated into newly synthesised protein in liver, therefore, spill out into the blood causing an elevation of all amino acids including tryptophan (Wannemacher and Dinterman, 1983). Increasing amounts of tryptophan then enter the brain across the blood-brain barrier.

Serotonin is synthesised from tryptophan by a short and poorly regulated pathway with increasing substrate, tryptophan, resulting in increased serotonin synthesis. Fusaric acid has no effect on tissue protein synthesis. It is, however, a structural analogue of tryptophan. Tryptophan is carried in the blood loosely bound to albumin with only about 15% of total tryptophan in free form.

It is only the free form of tryptophan that can cross the blood-brain barrier. Fusaric acid competes with tryptophan for binding sites on albumin and therefore increases free tryptophan concentrations in blood and increases the availability of trichothecene-elevated blood tryptophan to the brain. This is how performance can be reduced in birds fed diets that appear to contain safe levels of DON.

It can be concluded that safe levels of individual mycotoxins can only be accurately estimated if the complete mycotoxin content of the diet is known. ■

References are available from the author upon request.

Strategies for preventing mycotoxicoses

By Jules Taylor Pickard, Technical Team Manager, Europe, Alltech

The alternative approaches that can be used to deal with feedborne mycotoxins in poultry rations are therapeutic and preventative. In the therapeutic approach, birds are exposed to mycotoxin challenges and then nutritional therapies can be utilised to minimise production losses.

Supplemental vitamin E and selenium, for example, can be used to minimise T-2 toxin-induced oxidation of avian liver lipids.

Supplemental dietary protein can reduce acute aflatoxicosis. The challenge with the therapeutic approach, however, is that mycotoxins often affect numerous organ systems simultaneously within the bird, and a given nutritional supplement may counteract the action of the mycotoxin at one organ level but have no effect on another organ.

Preventative strategies are likely more economically advantageous than therapeutic approaches because the latter may allow tissue damage to occur, which may be too great to be reversed by tissue regeneration once the mycotoxin challenge has been removed.

A method used internationally but not in the European Union is dilution of contaminated feedstuffs with less contaminated feedstuffs.

This lowers the concentration of mycotoxins below the biological threshold of activity allowing the detoxification enzymes of the bird to prevent harmful accumulation of mycotoxins in tissues.

Diversion of contaminated materials to less sensitive species such as ruminant animals may be another option. Screening of grain allows removal of grain dust and small, broken fractions of grain.

Screenings are often one of the most frequently contaminated categories of feedstuffs and screening grain can significantly reduce mycotoxin contamination.

Physical treatments to remove outer portions of grain kernels, such as the pearling of barley, can also significantly reduce mycotoxin content (House et al., 2003).

Control of mycotoxin contamination pre-harvest, achieved through the use of fungicides, is more difficult than controlling mycotoxin production on grain in storage.

Mould inhibitors are combinations of weak organic acids which can be applied to high moisture grains in storage. This lowers the pH of the stored grain thereby killing live mould spores and stabilising mycotoxin content. The weak nature of these acids, however, will not inactivate mycotoxin molecules formed pre-harvest.

Viability of mould spores may also be reduced through the high temperatures of pelleting, extrusion and other feed manufacturing processes. Mycotoxins already present, however, are too thermally stable to be affected by such procedures. Special feed enzyme supplements are also available which have the ability to detoxify mycotoxins in the intestinal lumen of the bird.

These enzymes are very specific for the chemical structure of a given mycotoxin, however, and this solution becomes unworkable under the usual condition of feed contaminated with multiple mycotoxins.

One of the most common preventative strategies is the use of mycotoxin adsorbents (Ramos et al., 1996). The adsorbents are non-nutritive, non-digestible large molecular weight polymers which are either inorganic silica polymers or organic carbon polymers.

Silica polymers can be effective against aflatoxin but require high levels of dietary inclusion to be effective against Fusarium mycotoxins in vivo (Carson and Smith, 1983).

An organic polymer extracted from the inner cell wall of yeast has been shown to be effective against aflatoxin (Diaz et al., 2004) as well as against combinations of Fusarium mycotoxins when fed to broilers (Swamy et al., 2002; 2004), layers (Chowdhury et al., 2004; 2005), turkeys (Chowdhury et al., 2005; 2007) and ducks (Chowdhury et al., 2005).

In the long term, it is hoped that advances in plant breeding and analytical chemistry will minimise economic losses arising from mycotoxin contamination of poultry feeds. It is clear that the most effective short term strategy, however, is the use of a suitable mycotoxin adsorbent. ■

References are available from the author upon request.