FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
POULTRY DEVELOPMENT REVIEW

Poultry feed availability and nutrition in developing countries

Animal feed safety

Velmurugu Ravindran, *Monogastric Research Centre, Institute of Food, Nutrition and Human Health, Massey University, Palmerston North, New Zealand*

POTENTIAL HAZARDS ASSOCIATED WITH FEED

Feed safety and its regulation are of major international concern. Animal feeds are routinely subject to contamination from diverse sources, which may have serious consequences on the safety of foods of animal origin. Public concerns over food safety have heightened in recent years, because of problems such as bovine spongiform encephalopathy (BSE), melamine and dioxin contaminations, outbreaks of food-borne bacterial infections, and potential microbial resistance to antibiotics. Given the direct links between feed safety and the safety of foods of animal origin, it is essential that feed production and manufacture procedures meet stringent safety requirements.

Some sources of feed contamination are high priorities in all production systems and countries: i) mycotoxins (or fungal toxins); ii) pathogenic biological agents; and iii) various chemicals. These agents may contaminate feed at any stage of production up to the point of feeding, and can result in hazards in food of animal origin. Biological agents and chemicals normally enter the feed supply under specific conditions. Mycotoxins are more widespread, however, particularly in developing countries, because of improper agricultural, storage and processing practices. Not only do mycotoxins represent a food safety issue, but they can also have serious consequences on poultry performance, and so are discussed in some detail in this information note.

DISEASE-CAUSING BIOLOGICAL AGENTS

Poultry feed may be the source of human illness resulting from the consumption of poultry products. The agent of major concern in poultry feeds is salmonella, which is associated with food poisoning in humans. The principal manifestation of human salmonellosis is gastroenteritis. Salmonella is widely distributed in nature, and animal feed is only one of many sources for farm animals. Feedstuffs of animal origin are particularly frequently contaminated with salmonella.

Salmonella contamination can be avoided by sourcing and using salmonella-negative feedstuffs in diet formulation. Heat treatments of varying severity are commonly used to ensure the microbiological quality of animal feed.

CHEMICAL CONTAMINATION

A wide range of chemicals can enter the feed production system, intentionally or unintentionally. Potential hazards include veterinary drugs, agricultural chemicals (e.g., pesticides, fungicides), industrial chemicals (e.g., dioxin), heavy metals (e.g., mercury, lead, cadmium) and adulterants (e.g., melamine). These chemicals can accumulate in animal tissues, or are excreted in milk or incorporated in eggs, and cause health problems in humans.

Some veterinary drugs, such as antibiotics and coccidiostats, are routinely included in poultry feeds as additives. In meat-producing birds, the problem of drug residues in meat are overcome by providing a withdrawal diet containing no drugs for seven to ten days prior to slaughter. However, the possible development of microbial resistance due to the use of antimicrobials in animal diets has become a major public concern in recent years. As a result, the use of in-feed antibiotics is either banned or restricted in the poultry industries of developed countries.

Most other chemical contaminants enter feeds through plant materials, especially cereals and treated seeds. The levels of chemicals in plant materials are closely related to the levels of soil contaminants where they are grown. Similarly, animal fats used in formulations may contain high levels of lipid-soluble contaminants if they are produced from feed grown in polluted areas

MYCOTOXINS

The term "mycotoxin" refers to all toxins produced by various types of fungus when they grow on agricultural products before or after harvest or during transportation or storage. The most commonly affected feedstuffs are cereals, oilseeds and oilseed meals. These toxins have the capacity not only to impair bird performance, but also to affect humans through toxin residues that can be deposited in animal tissues. Many mycotoxins with different chemical structures and biological activities have been identified. Table 1 presents a list of major mycotoxins of economic importance in poultry feeds.

When environmental conditions are conducive to fungal growth, mycotoxin contamination of grains may start in the field, and can also take place during processing and storage of har-

TABLE 1

Origins of major mycotoxins found in common feedstuffs

Mycotoxin	Fungal species
Aflatoxins	*Aspergillus flavus; A. parasiticus*
Ochratoxins	*A. ochraceus; Penicillium viridicatum; P. cyclopium*
Trichothecenes	
- Deoxynivalenol	*Fusarium culmorum; F. graminearum*
- T-2 toxin	*F. sporotrichioides; F. poae*
Zearalenone	*F. culmorum; F. graminearum; F. poae*
Fumonisins	*F. moniliforme*

vested products. The moisture content of the harvested product and the ambient temperature are principal determinants of fungal contamination and mycotoxin production. Some fungi, such as *Fusarium* spp., normally infest grains before harvest; others, such as *Penicillium* spp., invade after harvest, while *Aspergillus* spp. can grow both before and after harvest. However, the presence of fungi does not necessarily indicate contamination with mycotoxins.

Different mycotoxins affect animals in different ways. Some are cancer-causing toxins (e.g., aflatoxin B_1, ochratoxin A, fumonisin B_1) and some are oestrogenic (zearalenones). Some affect the nervous system (fumonisin B_1), while others affect the kidneys (ochratoxins) or suppress the immune system (aflatoxin B_1, ochratoxin A, and T-2 toxin). Depending on the degree of contamination, these effects will eventually have negative impacts on performance. It is often difficult to diagnose the effects of a mycotoxin because they are not necessarily unique to a given mycotoxin, but may be shared by others or magnified by interactions with others. Many fungal species are also capable of producing several mycotoxins. Recent evidence has highlighted the co-contamination of feed samples with multiple mycotoxins, which has serious consequences for both feed safety and animal performance. The hazards induced by the simultaneous presence of several mycotoxins are not clearly understood.

In addition, depending on the degree of contamination, mycotoxins or their metabolites can be deposited in meat, visceral organs and eggs. Their concentration in animal products is considerably lower than the levels present in the feed consumed by the animals, and will not cause acute toxicity in humans, but residues of carcinogenic mycotoxins, such as aflatoxins and ochratoxin A, can affect human health. In most cases, however, the principal source of mycotoxins for humans is contaminated cereals and legumes rather than animal products.

Alfatoxins

Aspergilli, the fungi producing aflatoxins, proliferate under conditions of relatively high humidity and temperature, and are generally regarded as storage fungi. Aflatoxin contamination is therefore almost exclusively confined to hot climates. Aflatoxin levels in certain types of feeds (cereals and oilseed meals) are a major problem in tropical countries, and require careful monitoring and appropriate treatment. All poultry species are susceptible to aflatoxin, especially young ducks.

Ochratoxins

Ochratoxins are produced by one *Aspergillus* species and two *Penicillium* species. Both are storage species, but *Aspergillus* thrives in hot, humid conditions, whereas *Penicillium* fungi are essentially temperate. Ochratoxins are therefore problems in both tropical and temperate regions. Ochratoxin A and B are two forms that occur naturally as contaminants, with A being more ubiquitous and occurring predominantly in cereal grains and the tissues of animals fed with contaminated feedstuffs.

Fusarium mycotoxins

Fusarium fungi are "field moulds", as arable conditions (high moisture) favour their survival and growth. *Fusarium* fungi are ubiquitous, and cereal grains and animal feed are contaminated with *Fusarium* mycotoxins all over the world. The majority of *Fusarium* fungi have the ability to produce toxins. Of particular importance are the trichothecenes, zearalenone (ZEN) and the fumonisins. The trichothecenes include T-2 toxin and deoxynivalenol (DON; also known as vomitoxin). In addition, a given species can produce several different toxins, and grain crops are often contaminated by several *Fusarium* species at the same time. Thus, several toxins may be present simultaneously in contaminated feeds.

METHODS OF CONTROLLING OR DECONTAMINATING MYCOTOXINS

Mycotoxins are regularly found in feed ingredients such as maize, sorghum, barley, wheat, rice meal, cottonseed meal, groundnuts and other legumes. In general, mycotoxins are relatively stable compounds that are not destroyed by processing of feed, and may even be concentrated by screening. Feeds contaminated with mycotoxins in excess of established levels should not be fed to animals producing eggs or meat for human consumption.

It is not easy to prevent mycotoxins in the environment. Prevention of the contamination of agricultural commodities by fungi and their mycotoxins can be divided into the following three levels.

Primary prevention

The best pre- or post-harvest strategy to use in a particular year depends on the climatic conditions of that year. Unfortunately, avoiding weather that favours fungal infection is beyond human control. Nonetheless, understanding the environmental factors that promote infection, growth and toxin production is the first step in minimizing mycotoxins in feeds. Several practices may help to maintain conditions that are unfavourable for fungal growth: i) development of fungal-resistant crop varieties; ii) control of on-field infection with fungicides; iii) scheduling of harvests in the period suitable for the region; and iv) lowering the moisture content of the feedstuff after harvest and during storage.

Secondary prevention

This level of prevention is required when the fungi are already in the feedstuff. The fungi should be eliminated or their growth stopped to prevent further deterioration and mycotoxin contamination. The following measures may be useful: i) protecting stored products from conditions that favour continuing fungal growth; ii) using mould inhibitors (such as organic acids) against fungal growth; iii) storing commodity at low temperatures, where economically possible; iv) stopping the growth of infested fungi by re-drying the products; and v) removing contaminated material.

Tertiary prevention

When the product is heavily infested by toxic fungi, primary and secondary prevention are no longer feasible. If the mycotoxin levels are known, it may be possible to dilute the contaminated material and produce a final blended feed that contains less than the critical level of the specific mycotoxin. Such blending of feeds to reduce mycotoxin concentrations is officially permitted, with restrictions in several countries.

A number of additives are available for use in practical diets to remove or detoxify mycotoxins and reduce their negative effects

on animals. These additives fall into two categories: mycotoxin binders, which bind and adsorb the mycotoxins and prevent their absorption in the gut; and mycotoxin deactivators, which deactivate specific mycotoxins. The effects of some mycotoxins (aflatoxin, ochratoxin and fumonisin) can be effectively reduced by the inclusion of appropriate adsorbent-type binders, while others (trichothecenes and zearaleone) can be removed only by deactivation. Common mycotoxin binders include hydrated sodium calcium aluminosilicate, esterified yeast-wall polysaccharides, and clays such as zeolites and bentonites. Different sorbents have differing affinities for specific mycotoxins. However, there is a risk that non-specific adsorbing agents may prevent the uptake of micronutrients in the gut. Some effective mycotoxin deactivators that are now available act by enzymatic degradation or biotransformation of mycotoxins.

REFERENCES

Cliver, D.O. & Rieman, H.P., eds. 2002. *Foodborne diseases*. Boston, Massachusetts, USA, Academic Press.

Diaz, D.E., ed. 2004. *The Mycotoxin Blue Book*. Nottingham, UK, Nottingham University Press.

Sinha, K.K. & Bhatnagar, D. 1998. *Mycotoxins in agriculture and food safety*. New York, M. Dekker.

Tollefson, L. 1999. *Chemical foodborne hazards and their control.* Philadelphia, Pennsylvania, USA, Saunders.

Weidenborner, M. 2008. *Mycotoxins in food safety.* New York, Springer.