

# Mycotoxins in an international and South African context

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The supply of high quality, healthy grains (maize and wheat) is a national priority since these commodities represent the staple food of many South Africans. However, these agricultural products remain prone to contamination by several toxigenic fungi during the pre-harvest (production), post-harvest (storage) and processing stages. These fungi have the propensity to produce some hazardous toxins such as the aflatoxins, zearalenone, fumonisins, ochratoxins, trichothecenes (deoxy-nevalenol and nivalenol) and diplodiatoxins, collectively called mycotoxins. Fortunately the aflatoxins, the most notorious group of highly potent hepatocarcinogens occur extremely rarely on South African grains. See the reference below to a recent *Review*.

The isolation and characterization of the toxin(s) produced by a specific toxigenic fungus is a prerequisite for analysing the mycotoxin in agricultural commodities and foods in order to study the impact of the relevant toxin on human and animal health. A brief background to mycotoxins is presented to establish the enormity of the problems faced by the grain and cereal industries in South Africa.

Mycotoxins are produced by a number of fungi, including members of the genera *Aspergillus*, *Penicillium*, *Fusarium*, *Claviceps* and *Alternaria*. Several of the mycotoxins are important environmental and carcinogenic agents and are ubiquitous in a broad range of commodities, causing toxic responses when ingested by mammals (such as man and higher animals), poultry and fish. During 2005 the Council for Agricultural Science and Technology internationally considered aflatoxins, trichothecenes, fumonisins, zearalenone, ochratoxin A and ergot alkaloids as most relevant for human health. The same toxins, in fact, are also very relevant to animal health.

Mycotoxins pose an enormous threat to the international trade in foods and feeds because of the worldwide distribution of toxigenic fungi in agricultural products. Post-harvest losses in the developing world, in particular, are severe because of inadequate storage facilities and the consequent poor quality of the produce. It is claimed that approximately 60% of Africa's grain supplies are at risk owing to fungal contamination and mycotoxin formation. For the USA's grain industry it is estimated that the annual loss due to mycotoxin contamination amounts to \$ 2 bn.

In nature, most cereal grains, oil seeds, tree nuts, fruits and dehydrated fruits are susceptible to contamination by mycotoxin-producing fungi. In addition, mycotoxins may occur in beer and wine; worldwide OTA is a frequent contaminant of wines. Not all fungal growth on plants and plant products, however, results in mycotoxin production. Therefore, the occurrence of fungi, even toxigenic ones, on foods and feeds does not necessarily imply the presence of mycotoxins.

Several environmental factors such as temperature, humidity and soil or storage conditions influence the production of mycotoxins in agricultural commodities. There can be significant year-to-year fluctuations in the levels of mycotoxins in foods and feeds due to many factors such as adverse climatic conditions that favour fungal invasion, growth and mycotoxin formation. Worldwide and in South Africa progress is

made with modelling of the environmental factors and mycotoxin production in Nature.

Some of the toxins are important environmental and carcinogenic agents and are ubiquitous in a broad range of commodities, causing toxic responses when ingested by mammals (such as man and higher animals), poultry and fish. Initially mycotoxin production was only linked to the so-called storage fungi growing saprophytically (post-harvest) on stored grains and nuts. Today, however, it is well recognized that some fungi, such as *Fusarium verticillioides* and *Stenocarpella maydis* growing parasitically on maize before harvest also have the propensity to produce mycotoxins. Several explanations may be given for their production, such as the likelihood that mycotoxins might play a role in facilitating competition with other micro-organisms for nutrients and space, and the generation of favourable germination conditions for fungal spores

More than 300 mycotoxins are currently known. Most of them are thermally stable and cannot be eliminated during food processing. These toxins induce powerful and dissimilar biological effects in humans and animals. Some are carcinogenic (aflatoxins, ochratoxins and fumonisins), mutagenic (aflatoxins and sterigmatocystin), teratogenic (ochratoxins), oestrogenic (zearalenone), haemorrhagic (trichothecenes), immunotoxic (aflatoxins and ochratoxins), nephrotoxic (ochratoxins), hepatotoxic (aflatoxins, ochratoxins and phomopsins), dermatotoxic (trichothecenes) and neurotoxic (ergotoxins, penitrems, lolitrems and paxilline), whereas others display antitumour, cytotoxic and antimicrobial properties. The human ingestion of mycotoxins is due to the consumption of the mycotoxins in plant-based foods such as grains like maize, barley and rice, coffee, nuts and their residues, and metabolites in animal-derived foods, for example aflatoxin M1 (AFM1) in milk and meat products. In addition they have a tremendous economic impact on the animal and food/feed industry, particularly affecting the emerging economies. See Figure 1 for some representative mycotoxins.

The global health threat to mankind is based on well-documented human mycotoxicoses such as ergotism (St Anthony's fire), which occurred frequently during the Middle Ages in Europe, alimentary toxic aleukia in Russia, acute aflatoxicoses in South and East Asia, and human PLC in Africa and South East Asia. OTA is suspected of playing a role in Balkan endemic nephropathy amongst the population living in the former Yugoslavia, and chronic interstitial nephropathy in North Africa. The fumonisins are implicated in the aetiology of the high incidence of oesophageal cancer among the inhabitants of the former Transkei region of South Africa. Although the role of mycotoxins in diseases among domestic animals is better established, diagnosis of the mycotoxicosis is extremely difficult owing to the numerous pharmacological effects of the causative toxins, for example aflatoxins (Turkey-X disease), fumonisins (leukoencephalomalacia in horses and pulmonary oedema in swine), ochratoxins [nephropathy in swine (Danish porcine nephropathy)], phomopsin A (lupinosis in sheep) sporidesmin A (facial eczema in sheep) and zearalenone (hyperoestrogenism, vulvovaginitis and abortion in swine). Outbreaks of diplodiosis amongst farm animals are linked to maize contaminated with *Stenocarpella maydis*.

Since the discovery of aflatoxins during the 1960s, an increasing number of countries have legislated maximum tolerated levels for an increasing number of mycotoxins with the aim of protecting both human and animal populations from the harmful effects of mycotoxin exposure. The recent regulations of the European Union for the

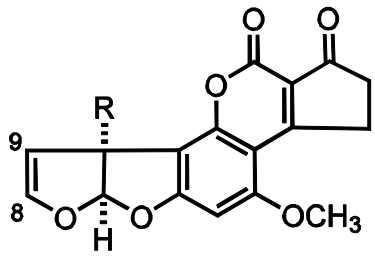
Aflatoxins B1, B2, G1 and G2, Aflatoxin M1, Deoxynivalenol, Fumonisin B1 and B2, Ochratoxin A, Patulin and Zearalenone will be discussed. In South Africa, mycotoxin levels in grains are determined at the well-equipped South African Grain Laboratories. Some of the most recent results will be discussed.

At the Maize Trust it is the mission of the Strategy for Mycotoxin Research to have world-class mycotoxin research undertaken at South African universities and research institutions in order to ensure that safe maize is supplied to the food and animal feed industries, consumers and export markets. The Strategy would do so by setting itself the following main objectives:

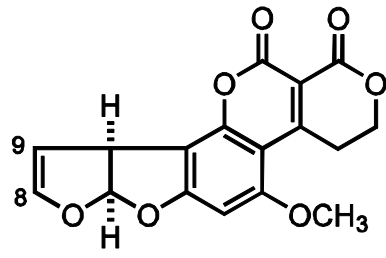
- To support the establishment of the magnitude of mycotoxin contamination of maize during the stages of its production, storage, and processing in South Africa. This objective is to be completed within a three year period
- To support the regular monitoring of the occurrence of the fumonisins, aflatoxins, zearalenone, and trichothecenes (DON and NIV) in locally produced and imported maize.
- To support the determination of the factors which contribute to mycotoxin contamination during the production (pre-harvest), storage (post-harvest) and processing of maize.
- To support the development of practical, affordable and environmentally sound methods to manage toxigenic fungi in maize, with particular emphasis on the introduction of resistance in local maize cultivars.
- To support the development of sound mycotoxin risk management practices in the maize supply chain to ensure the delivery of safe products to the consumer.

*Review: Mycotoxins with a Special Focus on Aflatoxins, Ochratoxins and Fumonisin.*  
PS Steyn, WCA Gelderblom, GS Shephard, and FR van Heerden. *General and Applied Toxicology*, Third Edition (Eds. B Ballantyne, TC Marrs, T Syversen), John Wiley and Sons, 2009, **6**, 3467-3527.

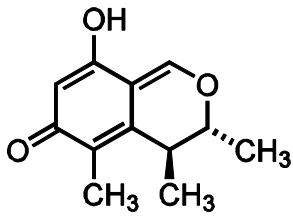
- **Figure 1:** Some representative mycotoxins associated with human and animal mycotoxicoses



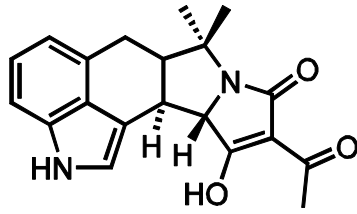
Aflatoxin B<sub>1</sub>: R=H  
 Aflatoxin B<sub>2</sub>: 8,9-dihydro, R=H  
 Aflatoxin M<sub>1</sub>: R=OH



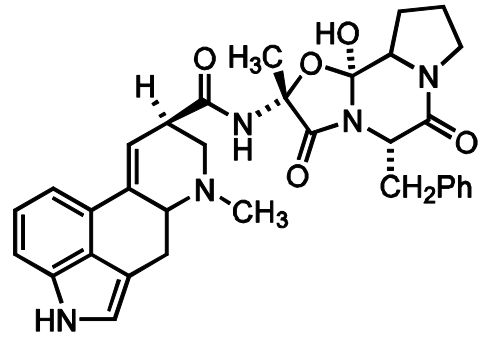
Aflatoxin G<sub>1</sub>  
 Aflatoxin G<sub>2</sub>: 8,9-dihydro



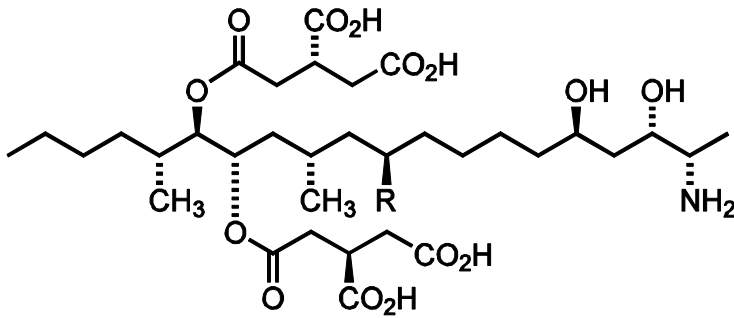
Citrinin



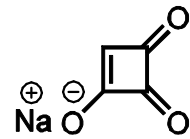
Cyclopiazonic acid



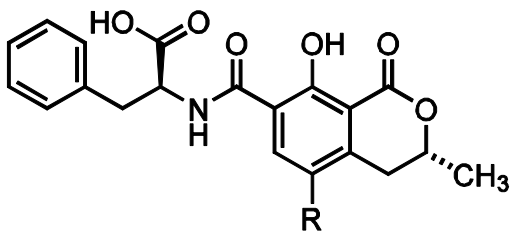
Ergotamine



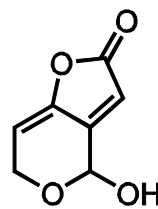
Fumonisin B<sub>1</sub>: R=H  
 Fumonisin B<sub>2</sub>: R=OH



Moniliformin



Ochratoxin A: R=Cl  
 Ochratoxin B: R=H



Patulin

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