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Mycotoxins: The Invisible Enemies from the Fungal World

Aditee Baruah[1*], Ibanrishisha Ksoo[2], Meryhun Mallai[1] and Tasvina R. Borah[2]

[1]Dept. of Plant Pathology, Central Agricultural University (Imphal), Umiam, Meghalaya (793 103), India

[2]ICAR-Research Complex for NEH Region, Umiam, Meghalaya (793 103), India

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Corresponding Author

Aditee Baruah

: aditeebaruah@gmail.com

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Abstract

Mycotoxins which are considered as toxic secondary metabolites are low weight molecules produced from filamentous fungi. These secondary metabolites if consumed by humans or comes in contact with the feed of animals can be toxic and can even be carcinogenic, neurotoxic, nephron toxic or immunosuppressive. The term mycotoxin was used in 1960 in the UK after the demise of 100,000 turkeys attributed to the use of feed tainted with secondary metabolites from *Aspergillus flavus*. Warm (25±1 °C) and humid conditions with poor post-harvest handling as well as storage conditions often aggravate the problem.

Keywords: *Aspergillus, Fusarium,* Mycotoxins, *Penicillium*

Introduction

Mycotoxins are mainly secondary metabolites synthesized by fungi, mostly filamentous in form, which contaminate agricultural products and most importantly hazardous to animals and humans. Mycotoxins are thought to be the cause of a number of human clinical disorders. These are transmitted to humans *via* the consumption of meat from animals that have ingested tainted feed (El-Sayed *et al*., 2022). Over 300 mycotoxins have been recognized. The fungi producing mycotoxins are referred as toxigenic fungi. Certain mycotoxins have been utilized in clinical practice. Ergotamine has been utilized in the management of vascular headache. Mycotoxins typically co-occur in agricultural products. Certain fungi are capable of producing several mycotoxins.

Major Mycotoxins

1. Aflatoxins

A collection of mycotoxins is predominantly generated by *Aspergillus flavus*, *Aspergillus bombycis*, *A. pseudotamarii*, *A. nomius* and *A. parasiticus*. Aflatoxin B_1 is considered to be the principal aflatoxin generated from the strains and is also one of the most effective natural carcinogens (Squire *et al*., 1981). They are highly carcinogenic to humans and have also been shown to induce cancer in birds, rodents, non-human primates and several other animal species. Aflatoxin contamination in crops usually occurs pre-harvest as a result of drought or heat induced by stress during the plant's reproductive cycle. Unsuitable storage conditions including insect infestation and excessive moisture, result in post-harvest contamination of crops. Additional elements that elevate aflatoxin production include stresses. Stressors encompass phytopathogens, excessive plant density, oxidative stress, weed competition in plants and inadequate plant nutrition.

2. Fumonisins

First described and characterized in 1988, *Fumonisins* are synthesized by several species of *Fusarium*, which include *Fusarium verticilliodes*, *F. proliferatum* and *F. nygamai*. Fumonisins contaminate several grains and grain products, predominantly found in maize and maize-based products. They preserve their stability at elevated temperatures and their contamination levels may vary yearly. Exposure of fumonisins is linked to many esophageal as well as liver cancer cases. This connection was first observed in Transkei, South Africa, where fumonisins were detected in maize cultivated locally in regions with a high incidence of esophageal cancer.

Article History

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3. Trichothecenes

Trichothecenes (TCT) are a large collection of more than 100 fungal metabolites sharing a common structural framework. Although other fungal genera can synthesize trichothecenes, the majority have been extracted from *Fusarium* spp. TCT primarily impacts actively proliferating cells, including those that constitute the gastrointestinal lining, skin, erythroid and lymphoid cells. The deleterious effects of TCT lead to significant necrosis of the oral mucosa and skin in contact with the toxin, an immediate impact on the digestive system and a reduction in bone marrow and immunological function. The contamination of feeds and food by TCT exhibits significant variability, both geographically and temporally, influenced by meteorological and climatic conditions throughout regions, continents and climatic zones. Local disparities are evident due to variances in crop varieties, soil types and management, agricultural practices and post-harvest storage and processing. The optimum toxin production is seen to be in conditions with higher humidity and a temperature ranging from 6-24 °C.

4. Ochratoxin

Ochratoxin A (OTA) is a harmful mycotoxin, which was isolated and chemically identified in 1965. The deleterious metabolite of *A. ochraceus* was initially identified in cornmeal deliberately inoculated with the microfungus in South Africa. Regular exposure to OTA in animals or people may lead to numerous health complications. Particularly, OTA may present a carcinogenic risk to individuals. Its average concentration typically ranges between 0.1 and 100 ng g^{-1}. In spices such as cayenne pepper, black pepper, caraway, coriander, cardamom, turmeric, chili powder and dried red pepper, OTA levels have been reported to vary between 1 and 100 ng g^{-1}. In foods originating from animals, OTA concentrations typically range between 0.1 and 1 ng g^{-1}. Such concentrations have been reported in products like pork, pork blood, chicken meat and edible offal, as well as dry-cured ham.

5. Zearalenone (ZEA)

Zearenone (ZEA) also formerly known as F-2 toxin, is synthesized by multiple *Fusarium* species. Maize, the most contaminated grain, has been proven to have mycotoxins, which are also present in rice, soybean, sorghum, rye, barley, oats and wheat products. Current studies demonstrate that ZEA is metabolized in the liver and has exhibited hepatotoxic, immunotoxic, carcinogenic and nephrotoxic effects in animal experiments. Due to the hazardous nature of this mycotoxin on consumer health, the European Union has instituted ZEA limits (20-350 µg kg^{-1}) for certain processed and unprocessed cereals. The link between the consumption of moldy grains and hyperestrogenism in pigs has been recognized since 1920. Recent studies indicate that dietary zearalenone levels as low as 1 ppm can induce hyperestrogenic symptoms in swine, while elevated levels may result in reproductive disorders such as disrupted conception and abortion.

6. Patulin

Patulin is synthesized by many molds, having been initially identified as an antibacterial agent from *Penicillium patulum* in the 1940s. Although patulin is frequently found in unfermented apple juice, it does not survive the fermentation process to produce cider. Patulin has demonstrated neurotoxic and immunotoxic effects in animals; nevertheless, there is no credible data indicating its carcinogenicity in people. It is now recognized that the main cause of patulin contamination is *Penicillium expansum*, the blue mold that causes soft rot in apples, pears, cherries and other fruits (Vidal *et al*., 2019).

7. Ergot Alkaloids

Ergotism is the earliest recognized mycotoxicosis, afflicting both animals and humans as a result of ingesting food or forage contaminated with ergot alkaloids. From the ninth century to the fourteenth century, ergotism was common in eastern France, Germany and Russia. The word "ergot" comes from the Old French word "argot," which means "cock's spur." The first reported ergotism outbreak occurred in France between 944 and 945 AD, resulting in approximately 10,000 fatalities. Certain EA producers include *Claviceps purpurea*, *C. fusiformis*, *C. africana*, *Epichlo* spp. and *Neotyphodium* spp. Moreover, EAs are synthesized by *Blansia*, *Penicillium* and *Aspergillus*. The designated species has the potential to cause substantial harm and losses to cereal cultivation. In the spring of 1978, 47 individuals perished from ergotism in Ethiopia after consuming barley infested with *C. purpurea sclerotia*. For almost two decades, Electroacupuncture has been employed in medicine to address neurological disorders, migraines, central nervous system diseases, hypertension, Parkinson's disease and prolactin inhibitors in gynecology.

Economic Impact of Mycotoxins

In the past few years, fungal infections have been estimated to result in over 1.6 million deaths annually, with millions affected by fungal diseases. Beyond the direct losses in food and feed, several other parameters add to the overall financial burden. These encompass reduced productivity, forfeiture of foreign exchange revenue, expenses related to inspection, sampling and analysis during pre- and post-shipment stages, compensation for claims, government subsidies to offset farmers' losses, as well as the costs of research, extension activities and detoxification. Collectively, these factors result in substantial economic losses.

Management of Mycotoxins

Control measures for mycotoxins include pre-harvest practices such as crop rotation which helps to disrupt the life cycle of fungus, use of resistant varieties bred for resistance to fungal infections. Contaminated mycotoxins in food and feed must be eliminated, inactivated, or detoxified using physical, chemical, or biological methods, contingent upon the circumstances. Fungi-contaminated seeds can be eliminated through manual removal or photoelectric detection devices. Organic solvents including acetone, chloroform, methanol and hexane have been utilized to remove aflatoxins from agricultural commodities. Apart from this, cooking and heating under pressure can eliminate about 70% of aflatoxin in rice, whereas atmospheric pressure reduces it by only 50% (Coomes *et al*., 1996). Chemical

treatments are regarded as the most efficacious method for eliminating mycotoxins from contaminated commodities. Numerous prevalent compounds have been subjected to testing for their efficacy in detoxifying aflatoxin, including acetic acid, ammonia gas, calcium hydroxide, formaldehyde *etc*.

Conclusion

Mycotoxins in commercial cereal grains can lead to significant economic losses. The prevalence and contamination of agricultural products, food and animal feed are of worldwide concern. Timely and efficient detection is crucial for eradication, ensuring food safety and reducing associated health issues. While complete control is not possible creating awareness with good agricultural practices is the key. With consumers and producers becoming more aware and with efficient control methods we can ensure a food system which is much safer as well as healthy.

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