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Popular Article

Mycotoxins: Unseen Precursors of Cancer in the Food Chain—An Overlooked Public Health Threat

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Introduction:

Food is the cornerstone of health and well-being. However, not all food that appears fresh and wholesome is safe. Hidden within many agricultural commodities are naturally occurring toxic compounds known as mycotoxins. These invisible contaminants can silently enter the food chain during crop cultivation, harvesting, storage, processing, and transportation. Unlike bacterial contamination, mycotoxins are often impossible to detect with the naked eye and may remain in food even after cooking or processing.

The World Health Organization (WHO) and the Food and Agriculture Organization (FAO) recognize mycotoxins as one of the most important food safety challenges worldwide. Millions of people are exposed to these toxins every day through contaminated cereals, nuts, spices, milk, meat, fruits, and animal-derived foods. Long-term exposure has been associated with a range of adverse health effects, including immune suppression, liver and kidney damage, reproductive disorders, impaired child growth, and most alarmingly, cancer.

The burden of mycotoxin contamination is especially significant in tropical and subtropical countries, including India, where warm temperatures, high humidity, and inadequate storage conditions create an ideal environment for fungal growth. Climate change is expected to further aggravate this problem by increasing fungal proliferation and altering the geographical distribution of toxin-producing moulds.

Mycotoxins:

Mycotoxins are invisible toxic secondary metabolites, naturally produced by specific filamentous fungi (moulds) e.g. *Aspergillus*, *Fusarium*, and *Penicillium* that can grow on numerous foodstuffs like crops, food grains (Maize, wheat, rice), peanuts, dried fruits, spices, etc. Mycotoxins appear in the food chain as a result of mould infection of crops both before and after harvest. The growth of toxin-producing fungi can

occur either before harvest, or at the time of harvest or after harvest or during handling and storage, on/in the food itself. Mycotoxin production is often encouraged by plant susceptibility to fungi infestation, the suitability of fungal substrate, temperature, humidity, moisture content, and physical damage of food grains due to insects and pests. e.g., High levels of contaminants like fumonisins are often triggered by hot, dry weather followed by high humidity. Most mycotoxins are chemically stable and can tolerate food processing temperatures and techniques. Exposure to mycotoxins can happen either directly by eating infected food or indirectly from animals that are fed contaminated feed, in particular from milk.

These mycotoxins are pathologically classified as hepatotoxins, nephrotoxins, vomitoxin, and neuro-musculotoxin, some of which are potentially carcinogenic and mutagenic. Aflatoxin, is the most potent hepatocarcinogen and mutagen among mycotoxins.

Numerous mycotoxins have been identified, but the most commonly observed mycotoxins that cause several health hazards to humans and animals and significant economic losses, include aflatoxins, ochratoxin A, patulin, fumonisins, zearalenone, and nivalenol/deoxynivalenol.

More than **500 mycotoxins** have been identified, although only a few are responsible for most human and animal diseases.

Major types of Mycotoxins:

➤ **Aflatoxins:**

The Most Dangerous Cancer-Causing Mycotoxins (specifically linked to liver cancer) Multiple species of the fungus *Aspergillus* produce aflatoxins. The fungi typically grow in soil and decaying vegetation. They can also grow on most crops or foods. Types B1, B2, G1, G2 are commonly found on crops like peanuts, corn, etc., and while metabolites, M1 can appear in milk. Among the different forms, **Aflatoxin B1** is the most toxic and carcinogenic. The International Agency for Research on Cancer (IARC) classifies naturally occurring aflatoxins as **Group 1 Human Carcinogens**, indicating sufficient evidence that they cause cancer in humans.

➤ **Ochratoxin A:**

Produced by *Aspergillus* and *Penicillium* molds, this toxin frequently contaminates cereals, coffee, dried fruits, and wine. It is known to be nephrotoxic (damaging to the kidneys) and potentially carcinogenic.

➤ **Fumonisin:**

Produced mainly by *Fusarium* molds and commonly found in corn and corn-based products. They are linked to esophageal cancer in humans and can cause fatal neurological or liver conditions in animals.

➤ **Deoxynivalenol (DON / Vomitoxin):**

Also known as a type of trichothecene, this is produced by *Fusarium* molds in grains like

wheat, barley, and oats. Ingestion leads to acute gastrointestinal distress, including vomiting and nausea.

➤ **Zearalenone:**

Multiple species of the fungus *Fusarium* produce zearalenone. It commonly affects cereal crops, including corn, oats, rice and wheat.

➤ **Patulin:**

Produced by *Penicillium*, *Aspergillus*, and *Byssosclamyces* molds, this mycotoxin is often found in rotting apples and apple products. It is associated with nausea, gastrointestinal disturbances, and potential DNA damage.

➤ **Citrinin:**

Produced by mainly *Penicillium* and *Aspergillus* species; *Monascus*. CIT can contaminate a wide range of foods and feeds at any time during the pre-harvest, harvest, and post-harvest stages. CIT can be usually found in beans, fruits, fruit and vegetable juices, herbs and spices, and dairy products, as well as red mold rice. CIT exerts nephrotoxic and genotoxic effects in both humans and animals

➤ **Ergot Alkaloids:**

Produced by *Claviceps* fungi, these infect cereal grains (especially rye). They act on the nervous system and vascular system, potentially causing hallucinations, severe spasms, and restricted blood flow.

Out of these Aflatoxins are mostly prevalent, followed by okhratoxins.

According to the site of invasion, toxicogenic fungi can be divided into three groups:

- **Field Fungi** (*Fusarium*; *F. moniliforme*, *F. roseus*, *F. tricinctum* and *F. nivale*);
- **Storage Fungi** (*Aspergillus* and *Penicillium*, e.g. *A. flavus* and *A. parasiticus*); and
- **Advanced Deterioration Fungi** easily attack the damaged grains with high moisture content (e.g. *A. clavatus*, *A. fumigatus*, *Chaetomium*, *Scopulariopsis*, *Rhizopus*, *Mucor*, and *Absidia*).

The Root Cause Fungal Contamination in Feed:

Mold spores are present almost everywhere in the environment. Contamination often occurs due to inadequate drying of crops before storage, or poor storage infrastructure including leaking from roofs or improper ventilation in fodder sheds or in storage area. the risk of fungal growth and subsequent production increases dramatically If the moisture content of stored feed exceeds 11-14%.

Common Sources of Contamination:

Mycotoxin contamination commonly occurs in grains, concentrates, fodder, and improperly maintained feeding systems. Cereal grains and feed ingredients such as maize, groundnuts, cottonseed, and sorghum are highly susceptible to fungal invasion and toxin production, especially when stored under

warm and humid conditions. Poorly stored fodder, including dry fodder and high-energy feed pellets exposed to moisture, rain, or excessive humidity, can rapidly develop mould growth. Silage may also become a significant source of mycotoxins when it is prepared, fermented, or stored improperly. In addition, unhygienic feed troughs containing leftover damp feed provide ideal conditions for the growth of toxin-producing fungi, thereby increase the risk of mycotoxin exposure in animals. Thus, mycotoxins can spread from crops to animals and ultimately to humans, making them a classic **farm-to-fork food safety issue**.

Carcinogenic Effects of Mycotoxins:

Cancer develops when normal cells undergo irreversible genetic changes that allow uncontrolled growth. Several mycotoxins contribute to this process through multiple mechanisms. These include:

- **Effect on DNA:** Aflatoxin B1 is metabolized in the liver into highly reactive compounds that bind directly to DNA, and cause mutations. One of the best-known mutations affects the **TP53 tumor suppressor gene**, a critical indicator against cancer development.
- **Oxidative Stress:** Mycotoxins increase the production of reactive oxygen species (ROS), and responsible for oxidative damage of DNA, proteins, and cellular membranes.
- **Chronic Inflammation:** Persistent exposure causes low-grade inflammation that promotes cellular transformation and tumor progression.
- **Epigenetic Alterations:** Some mycotoxins modify gene expression without changing DNA sequences, which is affecting cell proliferation and programmed cell death.
- **Immune Suppression:** Reduced immune surveillance allows abnormal cells to escape destruction and develop into malignant tumors.

Cancers Linked to Mycotoxins:

- **Liver Cancer:** The strongest association exists between aflatoxin exposure and **hepatocellular carcinoma (HCC)**. The risk increases dramatically when aflatoxin exposure occurs alongside chronic hepatitis B and C infection. In many developing countries, this combination is responsible for thousands of preventable liver cancer cases every year.
- **Esophageal Cancer:** Fumonisin produced by **Fusarium** species have been associated with elevated rates of esophageal cancer in populations.
- **Kidney Cancer:** Ochratoxin A primarily damages the kidneys and has been implicated in kidney tumors in experimental animals. Although evidence in humans is less definitive, prolonged exposure remains a concern.
- **Gastrointestinal Cancers:** Emerging evidence suggests possible associations between chronic dietary mycotoxin exposure and cancers affecting the stomach and intestines, although additional research is ongoing.

Other Health Effects of Mycotoxins Beyond Cancer:

Although their carcinogenic potential receives the greatest attention, mycotoxins can also cause a wide range of serious health problems. Chronic exposure may damage the liver and kidneys, suppress the immune system, impair growth and development in children, reduce reproductive performance, and cause neurological disorders. In livestock, mycotoxins lead to reduced feed intake, poor growth, decreased milk and egg production, infertility, and increased susceptibility to infectious diseases, resulting in significant economic losses.

Children: The Most Vulnerable Population:

Children are particularly vulnerable to the harmful effects of mycotoxins because they consume more food relative to their body weight and have developing organs and immature detoxification systems. Chronic exposure during early life can impair growth and cognitive development, weaken the immune system, and increase the risk of malnutrition and long-term health problems, including a greater susceptibility to chronic diseases later in life.

Climate Change Is Increasing the Threat:

Global warming is altering fungal ecology. Higher temperatures, changing rainfall patterns, floods, droughts, and humidity are favourable for fungal growth and toxin production. Scientists predict that climate change may:

- Increase aflatoxin contamination in maize.
- Expand fungal distribution into new geographical regions.
- Increase contamination of cereals previously considered low risk.
- Increase food insecurity.

Economic Consequences:

Mycotoxin contamination causes substantial economic losses by reducing crop yields, lowering the quality and market value of food and feed, and increasing livestock production losses due to poor health and reduced productivity. It also leads to higher healthcare costs, rejection of contaminated commodities in domestic and international trade, and significant financial burdens on farmers, the food industry, and national economies.

Prevention: The Best Strategy

Important to remember: Aflatoxins are highly heat-stable. Boiling, pasteurization, or standard cooking methods do not destroy aflatoxins. Prevention at the farm level is the only effective defence regarding food safety.

Strategies for Prevention and Control of Mycotoxins:

A combination of preventive measures is essential to reduce or eliminate mycotoxin contamination in feed and food. The first and most important step is to understand the common sources and conditions

that promote fungal growth and toxin production. These include the following measures:

A. Control of fungal infection in field conditions by planting crops:

The step should be initially carried out before the fungal infestation and mycotoxin contamination.

This can be achieved through:

Crop rotation, resistant varieties (Wilt-resistant tomato/chilli varieties; Rust-resistant wheat), intercropping (Maize + cowpea), mixed cropping, proper spacing, timely planting, good drainage (prevent root rot, damping-off, wilt diseases, etc.), trap/barrier crops (Marigold, garlic), field sanitation (Crop residues often harbour fungal spores), and use of antifungal plants (*Trichoderma*, *Pseudomonas fluorescens*, mycorrhizal fungi, etc.) and beneficial microbes help reduce fungal infections in field conditions. These practices improve soil health, reduce humidity and load of fungi, and create unfavourable conditions for fungal growth and transmission.

i. Proper Storage Infrastructure:

- Store all dry fodder, grains, and feeds in well-ventilated, weather-proof sheds.
- The storage area should be constructed on an elevated area with a cemented floor.
- The commodities should be stored on wooden platform above the floor and away from walls to avoid dampness.
- Cold storage helps to suppress fungal multiplication and toxin production.

ii. Storage Containers:

Hermetic containers, Food-grade moisture-resistant plastic bins, Metal drums and silos, Glass, and properly dried traditional earthen bins can be used effectively.

iii. Storage Bags:

Hermetic bags (triple-layer bags), Polypropylene woven bags, Jute bags, Plastic-lined bags, and Vacuum-sealed bags are highly effective.

iv. Regular Visual Inspection:

Regular inspection of representative samples of feeds and foods is an important first step for the detection of fungal contamination and possible mycotoxin risk. Materials should be checked routinely for visible signs of spoilage, musty odours or visible mold growth, damage, and deterioration during storage and handling.

Common visible indicators include:

- Discoloration or unusual color changes (green, black, yellow, pink, or whitish patches)
- Visible mold or fungal growth on the surface
- Clumping, caking, or excessive moisture
- Musty, or foul odour
- Insect infestation, webbing, or rodent contamination

- Damaged, broken, or rotten grains and feed particles
- Heating, condensation, or dampness inside bags and containers

Feeds and foods showing these signs should be separated immediately and not used for human or animal consumption without proper evaluation. Complete destruction of the contaminated products is recommended.

B. Use of Toxin Binders:

Incorporate scientifically approved mycotoxin binders (e.g., hydrated sodium calcium aluminosilicates - HSCAS, or yeast cell wall extracts) into the concentrate mixture. These binders bind to the toxins in the animal's gut, preventing absorption and allowing them to be passed safely in the faeces.

C. Clean Feeding Practices:

Mycotoxin-free feeds, regular cleaning of feed and water mangers help to prevent the accumulation of stale, damp feed.

Further, it is recommended to purchase feed ingredients and pellets from a manufacturer who conducts routine testing for mycotoxins.

Tips to Consumer: Consumers can reduce exposure by:

- Purchasing food from reliable sources.
- Avoiding mouldy grains, nuts, and spices.
- Discarding visibly damaged food.
- Storing cereals in cool, dry places.
- Keeping kitchens free from moisture.
- Following proper food storage practices.
- Consuming a diversified diet to avoid repeated exposure to a single contaminated food.

Conclusion:

Mycotoxicosis is a silent threat that jeopardizes the economic security of livestock farmers and community health, particularly its role in initiating and promoting cancer. As climate change, globalization, and changing food systems increase the risk of contamination, proactive prevention becomes more important. By adopting scientific feed storage practices and remaining vigilant against mold contamination, farmers can protect their flocks and herds, maximize their production performance, and ensure that the milk and meat reaching consumers are safe, healthy, and toxin-free. By recognizing mycotoxins as an overlooked public health threat and investing in prevention today, we can protect future generations from avoidable cancers and ensure a safer, healthier food supply.

**“Healthy animal feed today builds a healthier nation tomorrow —
strengthening the vision of Vikshit Bharat @2047.”**