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Mini Review

# Threat to Human and Animal Health Caused by Mycotoxins and Masked Mycotoxins Occurring in Food and Feed

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## Summary

Fungi, and especially mold fungi, play a very important role in natural environments, as well as in the food industry for the production of many specialized products. However, many of them, under favorable conditions, are capable of producing toxic compounds called mycotoxins. Many of them have an adverse effect on the growth and development of all groups of organisms, including humans. Mycotoxins can appear in all food products and animal feed. Mycotoxins accumulated in food of plant and animal origin and consumed by humans can accumulate in various tissues and organs, which results in disorders in their functioning and may cause cancer. Plants have the ability to defend themselves against mycotoxins by neutralizing them as a result of the glycosidation process. Mycotoxins neutralized in this way are called "masked mycotoxins", which are not toxic to plants, but after entering the body of animals or humans in the digestive tract, they return back to their original toxic form. Let's appeal and spread knowledge about mycotoxins because they pose a constant threat to the health of people and farm animals.

## Introduction

The term "moulds" is a common name for filamentous fungi commonly found in the environment. The most common fungi found in the human environment are fungi from the Zygomycota, Ascomycota, and Deuteromycota groups (so-called Fungi imperfecti), mainly from the genera Aspergillus, Fusarium, and Penicillium. Molds are heterotrophs that feed on living or dead organic matter. Thanks to their low nutritional requirements, they have mastered almost every ecological niche, inhabiting all available environments [1,2]. Despite the huge role that mushrooms - including mold fungi - play in the natural environment and in the food industry by using them for the production of among others, cheese, bread, alcohol, enzyme preparations, especially citric acid, and the production of specific proteolytic, pectinolytic, amylolytic and lipolytic enzymes, which, by decomposing nutrients, give food a characteristic taste and organoleptic properties. However, some species of fungi negatively affect the environment by contributing to the decomposition process, mainly of food, producing enzymes that reduce the nutritional and organoleptic value of food products. Food may also be contaminated with mold toxins, which is often the cause of among others: food poisoning in humans and animals. Toxins from mold fungi (so-called toxigenic fungi) are commonly called "mycotoxins" [3-5]. Mycotoxins are secondary metabolic products of mold fungi, toxic to humans, animals, plants, and microorganisms. The term "mycotoxins" comes from the Greek words *mycos* (fungus) and the Latin *toxicum* (poison). Mycotoxins are low-molecular-weight (M < 1.5 kDa) secondary metabolites of mold fungi that, when introduced into the body even in small doses by food, inhalation, or through the skin and mucous membranes, cause toxic reactions. The most toxic and widespread mold toxins include aflatoxins, ochratoxin A, fumonisins B1, deoxynivalenol, zearalenone, HT-2, and T-2 toxin, as well as some new mycotoxins, such as beauvericin, enniatin type B, srachybotrylactam, sterigmatocystin and the newly discovered group of so-called masked mycotoxins, in particular zearalenone-14-glucoside and zearalenone-16-glucoside [6-8].

### Production and properties of mycotoxins

Mycotoxins are products of various types of fungi, the so-called molds that produce them as a by-product of metabolic processes or as a product used for defense purposes may have strong toxic effects, mutagenic or teratogenic properties, and

may be formed in a wide range of agricultural products and in various environmental conditions. The ability to produce toxins is not a permanent feature. Many non-producing strains become toxigenic under certain conditions, and those that possess this feature may lose it. Generally, the synthesis of mycotoxins by mold fungi is genetically determined and related to basic metabolic pathways, i.e. the metabolism of amino acids or fatty acids, but phenotypically determined by environmental factors, which include: the chemical composition of the substrate, its consistency, the presence of microelements, humidity, temperature and the presence of microflora. Competitive. The synthesis of mycotoxins is most favored by relative air humidity above 70% and humidity of the plant material - above 15% [9,10]. The temperature at which strains produce toxins is often different from the optimal temperature for mycelial growth. In addition, the chemical composition of the substrate is important, including the presence of microelements (zinc, cobalt, magnesium). Fungi produce mycotoxins primarily in conditions of environmental stress when there are changes in temperature, humidity, oxygen availability, or in the event of the action of substances aggressive to fungi. Some mycotoxins are necessary for fungi during infection or facilitate this process (e.g. fumonisins in the Fusarium verticillioides-maize system). These compounds probably also play a role in the competition of microorganisms to colonize a new ecological niche. However, the physiological role of a significant number of metabolites in pathogenesis is still unrecognized. It is possible that they are only by-products of basic metabolism. It should be clearly noted that each mold species and each strain within a given species has different specific toxin-producing properties and develops only on one or several specific substrates. The same mycotoxin can be produced by many different species of fungi, but not necessarily by all strains of a given species. It also happens that one species of fungus produces several types of mycotoxins. Most mycotoxins are chemically stable and resistant to temperature changes, storage conditions, and processing processes [11].

## Toxic effects of mycotoxins on humans and animals

That is why they can be found in food products made from cereals, for example, bread or breakfast cereals, and sometimes even in wine or beer. However, they degrade in an alkaline environment and under the influence of UV rays. Mycotoxins belong to various chemical groups, including coumarin derivatives (aflatoxins, ochratoxins), polycyclic lactones (zearalenone, patulin), trichothecene derivatives (T-2 toxin, DON, NIV, satratoxin) and many other groups. Currently, the problem of mycotoxins, although not yet fully understood, is a very important issue mainly related to food safety. It should be noted that literature data indicate the possibility of the occurrence of fungal toxins in the living environment of the Etruscan population or in Athens as early as the 5th century BC. It was also hypothesized that toxins produced by strains belonging to the genus Fusarium spp. could have caused the extinction of the Etruscans. It was proven that mycotoxins were the cause of death of researchers and archaeologists, which was interpreted as the so-called curse of the tombs: Tutankhamun or Casimir Jagiellon, king of Poland [12]. The main cause was toxins produced by the species Aspergillus flavus. Repeated, long-term inhalation of mycotoxins in tombs caused cancer, strokes, strokes, and heart attacks in scientists. Mycotoxins likely played a role in diseases that plagued subsequent generations, especially during the middle Ages and colonial times. In the middle Ages, there were epidemics of fatal poisoning after consuming bread baked from flour containing ergotalkaloids - Claviceps purpurea. Ergot poisoning is also mentioned in the Old Testament. Ergotalkaloids caused Saint's disease Antoni, manifested by itching of the skin, burning ears, disturbances of consciousness, necrosis of limbs, miscarriages, and hallucinations. Symptoms of mycotoxicosis most often occurred during wars or famine, when food was difficult to access and poorly stored. Even today, mycotoxins cause many human and animal diseases. It is worth mentioning that during the Vietnam War in 1975–1981, fusarium mycotoxins - trichothecenes were used as biological weapons. They caused the death of approximately 6.5 thousand people. Mycotoxins were sprayed as dust and aerosols over the jungle using bombs carried by helicopters and planes. The bombings were called "yellow rain". In the Iraqi biological program, according to data from 1997, aflatoxins were collected and used as biological weapons. Mycotoxins were administered by inhalation at a high dose that caused death within 12 hours. Mycotoxin poisonings have also been reported in various countries around the world, mainly from food products containing grain contaminated with molds.

One of the greatest mycotoxin threats to humans is contaminated food. These compounds may enter the food chain of humans and animals directly and indirectly: indirectly by consuming the meat and milk of animals fed with contaminated products or directly by consuming plant products infected with mold fungi. Particularly dangerous and hazardous to humans and animals are mycotoxins produced by molds of the genus Fusarium sp., such as zearalenone, fumonisins, moniliformin, and numerous trichothecenes. Zearalenone (ZEA, ZON, F-2 toxin) are estrogenic compounds, mainly contaminants formed during the growth of cereals, which have estrogenic effects that are particularly dangerous for pigs. ZAE has also been shown to have the potential to stimulate the growth of human breast cancer cells. Fumonisins are also cancer-promoting metabolites. Moniliformin (MON) is also highly toxic to both

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humans and animals [13,14]. Trichothecenes are recognized as gastrointestinal toxins, dermatotoxins, immunotoxins, hematotoxins, and gene toxins [15-17]. In view of such a dangerous and dangerous phenomenon as the ubiquitous presence of mycotoxins in cereals (wheat, corn, rice) all over the world, especially when environmental conditions are unfavorable during the growing season, controls on these products should be increased before they are used as raw materials for the preparation of food and feed. The problem is not easy because due to the complexity of the chemical structure of mycotoxins, to detect them, which occur in small amounts (micrograms), and especially masked mycotoxins, modern analytical equipment is needed, such as liquid chromatography with mass spectrometry, gas chromatography (GC-MS), thin-layer chromatography (TLC) and ELISA enzyme-linked immunosorbent assays. Masked mycotoxins pose a major analytical challenge. These are mycotoxins that are transformed through complex enzymatic reactions into compounds that are not toxic to the plant.

## Masked mycotoxins

The presence of masked mycotoxins in food and feed is as harmful to animals as "ordinary" mycotoxins. Plants recognize mycotoxins and then glycosylate them or conjugate them with a sulfur molecule, which effectively neutralizes the poison. Mycotoxins transformed in this way were called "masked mycotoxins" (Figure 1) [12,15,18,19].

They are compounds that do not harm the plant in which they occur. However, these processes do not protect animals and people from poisoning. Masked mycotoxins are a new serious problem that appeared relatively recently, therefore they are not covered by current food safety regulations [20].

To protect against the harmful effects of mycotoxins, numerous methods of their elimination and detoxification are used. This is supported by many regulations, directives, and acts that regulate and control food and feed trade around the world. In particular, you should pay attention to environmental factors during the growing season (precipitation, temperature, humidity) and use fungicides if necessary. The conditions of transport, storage, and storage of grain are also important (currently in Europe we have a surplus of 30 million tons of wheat in warehouses). Effective post-harvest management of stored products, primarily wheat, barley, maize, coffee, cocoa, beans, rice, edible nuts, etc., requires clear criteria for monitoring and effective implementation in relation to abiotic and biotic factors, hygiene and monitoring to ensure that mycotoxin contamination and allowing stored products to pass through the food chain for processing. Let's appeal and spread knowledge about mycotoxins because they pose a constant threat to the health of people and farm animals.

## Conclusion

The problem of mycotoxins in food and feed is an issue

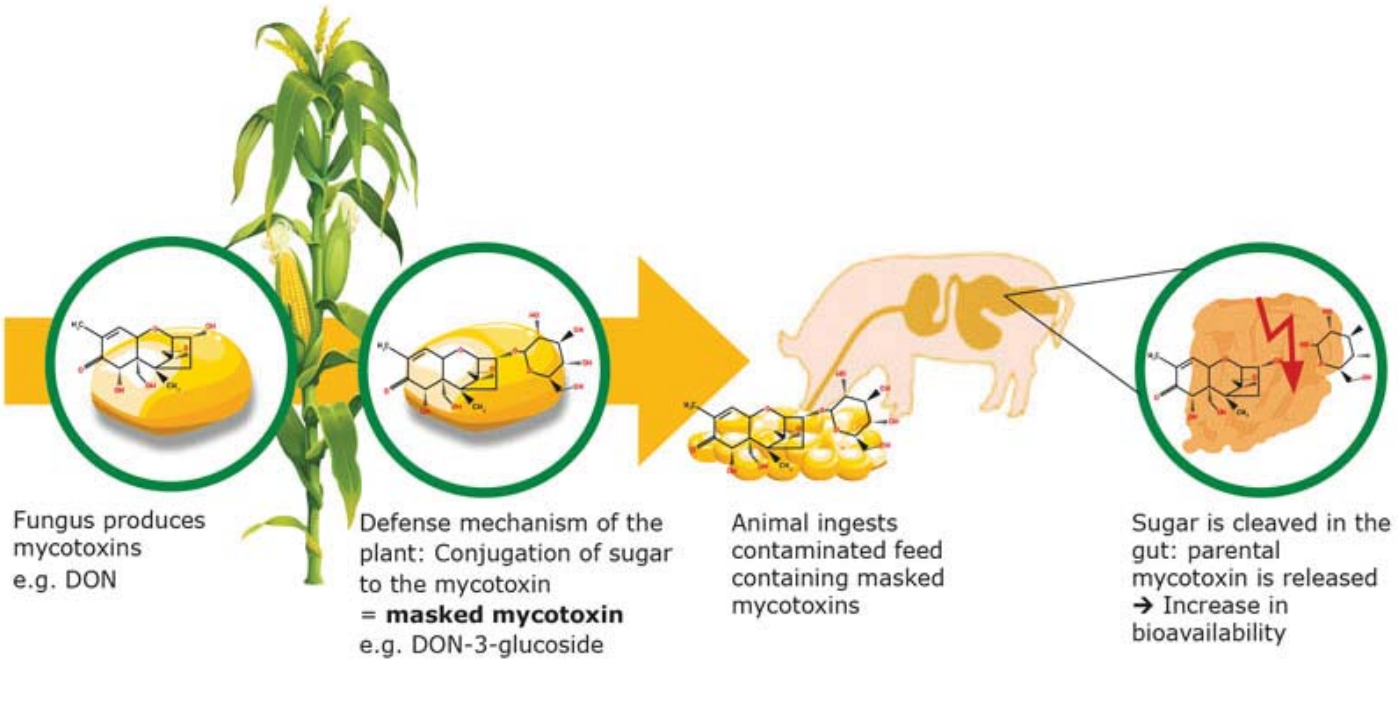


**Figure 1:** The fate of mycotoxins from production through the creation of masked mycotoxins to return to the original mycotoxin form. Source: Biomin 2021

of increasing interest among the general public. New information about their harmful impact on human and animal health, and in particular their ability to cause cancer, is a social issue. There are concerns about raw materials used for food production coming from various countries, where hygienic and climatic conditions favor the formation of mycotoxins. Due to the widespread threat of mycotoxins, food control institutions should be alerted to control the import of raw materials, their transport and storage, as well as the final product.

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