



Mycotoxins and antidotes of herbal, binding and enzymatic nature

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Abstract

Mycotoxins represent a potential risk to humans and animals. Under certain ecosystems; such as high humidity and temperature, and poor storage conditions, the mycotoxins are released and leaked into the agricultural produce, mainly crops such as legumes, rice, etc. Mycotoxins can be detected in the food by using several techniques including chromatography, Enzyme-linked immunosorbent assay (ELISA), biosensors and other advanced methods. However, it appears that analyzing the entire market's products is not possible, particularly in the developing countries. Therefore, the availability of suitable mycotoxin antidotes is necessary for health of both humans and animals due to their economic impact. This article aimed to provide a brief overview of the existing antimycotoxin drugs, chemicals, enzymes and medicinal plants; such as the mycotoxin antidotes. These antidotes range from binders, such as aluminosilicates and activated charcoal, to herbal compounds that are diverse. For instance, extracts of several plants such as *Camellia sinensis* leaves, *Carum carve* seeds, garlic, and many others, are frequently used to mitigate the mycotoxicosis in humans and animals. Besides, clinicians support the diagnosed patients with vitamins, minerals and fluids. It is worth mentioning that these antidotes remain unable to specifically target and degrade the mycotoxin, *per se*; however, they are being considered as symptomatic treatments. There is a continued need for a specific antidote. Recently, enzymes were examined for their ability to destroy the mycotoxins during food processing. Prospective research is needed to adapt the enzymes or combine them with other medicines, so that they can specifically work as mycotoxin antidotes for the humans and animals.

Keywords: Mycotoxins, Antidotes, Herbals, Enzymes



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1. Introduction

Mycotoxins are defined as subordinate metabolites produced by many fungal species such as *Aspergillii* (Onyeke, 2020). Mycotoxins are non-essential to the fungi, but potentially hazardous to the humans and animals when ingested with foodstuff (De Ruyck *et al.*, 2015). Food can be contaminated at all stages of the food chain starting from planting to harvest, including storage, shipment, processing and whole or retail sale (Onyeke, 2020). Several agricultural products are prone to be contaminated with mycotoxins encompassing, including legumes; nuts, spices, fish, milk, maize, sorghum and rice (Sun *et al.*, 2017), in addition to their by-products, such as peanut butter; pap, porridge, biscuits, bread, chips, flakes, malt, muesli, noodles, popcorn, semolina, tortilla and others (Weidenbörner, 2017). Indeed, mycotoxins are one of the major problems that directly threaten the herbivores.

Mycotoxins are rapidly produced under certain conditions. A previous study conducted by Adeyeye and Yildiz, (2016) reported that many factors such as high humidity and high temperatures; are the primary stimuli for production of the mycotoxins and contamination of the agricultural commodities. Smith *et al.*, (2016) added that drought; short autumn, overwintering, flooding and delayed harvests are predisposing factors for generating the mycotoxins. Zhang *et al.*, (2018) recently documented that the most commonly occurring mycotoxins in phytomedicines include; Aflatoxin, Ochratoxin, Trichothecenes, Zearaleones, Fumonisin, Alternaria toxins and Penicillic acid. The process of mycotoxins invasion of the herbal products, affecting factors and consequences after ingestion by the humans or animals, are demonstrated in Fig. (1).

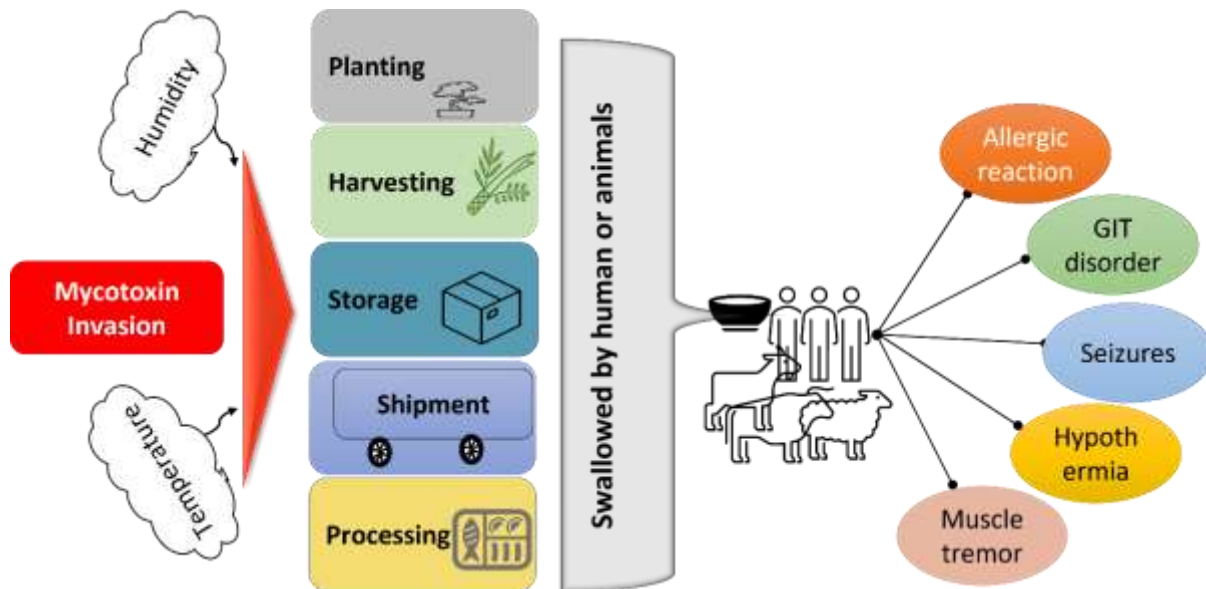


Fig.1: Factors affecting mycotoxins invasion and disorders following ingestion

Mycotoxins are of public health concern because they inflict on humans and animals, as a result of consuming the contaminated herbal products. Mycotoxins can be carcinogenic ([Liu and Wu, 2010](#); [Marchese et al., 2018](#)), immune inhibitors ([Benkerroum, 2020](#)) and organo-toxic ([Khaleghipour et al., 2020](#)). Aflatoxins are responsible for liver inflammation, which may develop into cancer in severe cases ([Marchese et al., 2018](#)). Moreover, mycotoxins cause massive economic damages to the food industry; due to losses of the agricultural harvest and subsequent loss in the trade revenues locally and internationally, in addition to healthcare costs for the

humans and animals ([Zain, 2011](#); [Ji et al., 2016](#)). The human and animal bodies metabolize the mycotoxins, such as Aflatoxin; a prototype and most prevalent mycotoxin, into Aflatoxin B₁ (AFB₁) and Aflatoxin M₁ (AFM₁), as shown in Fig. (2). According to the International Agency for Research on Cancer ([Marchese et al., 2018](#)), these mycotoxins are carcinogenic. The objectives of this study were to provide a brief overview of the currently available physical; chemical and enzymatic antidotes to the fungal mycotoxins, and to emphasize the potentials of enzymes to develop as specialized antidotes in the future.

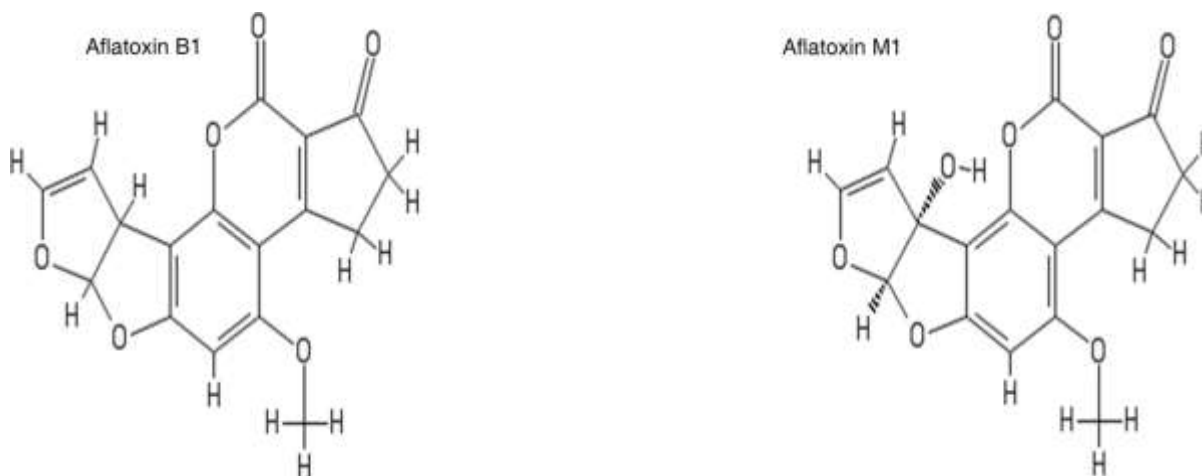


Fig. 2: Chemical structure of AFB₁ and AFM₁

2. Analytical techniques

Detection of mycotoxins in the food and feedstuff is of great importance for the decision-makers. Numerous techniques were utilized for inspecting the suspected food products and animal feedstuff. The analytical techniques include; chromatography ([Jerome Jeyakumar et al., 2018](#)), such as Thin-layer chromatography, Liquid chromatography-tandem mass spectrometry and ELISA ([Urusov et al., 2015](#)), the

Lateral Flow Immunoassay and Cytometry ([Zhang et al., 2018](#)), which are rapid and sensitive techniques. More recently, DNA-based biosensors, electrochemical and carbon nanotubes; were developed for investigating the mycotoxins in foodstuff, which are cheap, portable and highly sensitive techniques ([Younis et al., 2020](#)). The most common methods used for detection of mycotoxins in the food products are shown in Fig. (3).

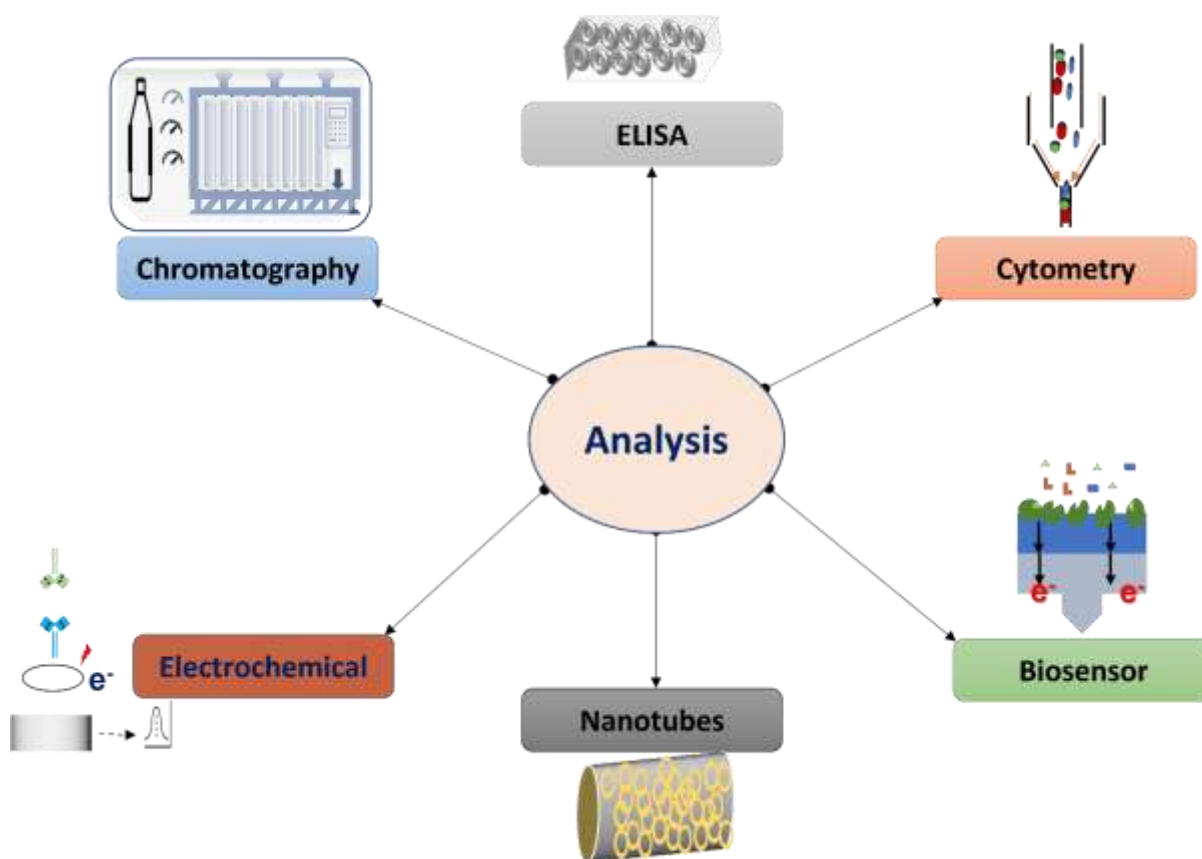


Fig. 3: Analytical methods used for detecting the mycotoxins in food products

3. Management and control

If the mycotoxins are left undetected and then ingested by humans or animals, they cause severe health and economic droppings. Accordingly, management of the food chain to avoid any contamination with the mycotoxins is necessary. These include, but are not limited to; good agricultural practices, preparing a suitable environment for storage and sale, cleaning and washing of seeds, and employing HACCP (Hazard Analysis Critical Control Points) for mycotoxins control ([Pineiro *et al.*, 1995](#); [Hell and Mutegi, 2011](#)). Moreover, cooking of food at high temperatures might decrease the levels of mycotoxins by up to 80 % ([Chilaka *et al.*, 2017](#)). Nevertheless, mycotoxins can reach the human or

animal body; in such cases medical treatment is necessary to alleviate the symptoms of toxicity and save the lives. This report provides insight into the available mycotoxins antidotes of different origins; including chemical and/or herbal-based antidotes.

4. Antidotes to mycotoxins

The toxin is defined as a metabolic product that is produced by living microorganisms, which is harmful to the body and tissues when ingested by any route, while an antidote refers to any substance that is taken to reverse the effects of a toxin ([Chacko and Peter, 2019](#)). Hence, this review discusses the substances given to humans or animals to counteract the effects of mycotoxins. This review classifies the treatment of mycotoxins into supportive therapies and antidote

administration, which depend on the type of the fungal toxin ([Rea et al., 2009](#)). Since all toxins are taken by the mouth in contaminated foodstuffs, thus health care providers can expect acute gastrointestinal disorders, including; liver and kidney injury, and other signs; such as skin lesions and allergic reactions ([Rea et al., 2009](#)). In this study, the mycotoxin antidotes and supportive treatments have been categorized into; 1) Charcoal absorbents\ binders; 2) Hydrated sodium calcium aluminosilicate (HSCAS), phyllosilicate clay and\ or anticaking agents; 3) Herbal compounds; 4) Supportive treatment; and 5) others.

4.1. Mycotoxin absorbents\ binders

Mycotoxin absorbents, such as charcoal, are used frequently for the decontamination of animal feed. These compounds bind to the mycotoxins and reduce their absorption by the gastrointestinal tract (GIT), which is later eliminated with the faeces or urine ([Abdallah et al., 2015](#)). Mycotoxin binders may be inorganic, such as activated charcoal, or organic, as the alfalfa fiber ([Abdallah et al., 2015](#); [Yalcin et al., 2018](#)). Activated charcoal is a notably known absorbent since the ancient times, and is manufactured by pyrolysis of the organic substances, which is porous, insoluble and interestingly has a wide range of surface-to-mass ratios ([Huwig et al., 2001](#)). In water medium, charcoal absorbs the mycotoxins, such as aflatoxins ([Hatch et al., 1982](#)). Table (1) lists the most commonly documented mycotoxin binders.

4.2. HSCAS aluminosilicate, phyllosilicate clay and anticaking agents

Aluminosilicates are clay minerals composed of aluminates; silicates, oxygen and cations, in addition to kaolin, alkali metals and alkaline earth metal ions. Aluminosilicates have certain properties that enable them to absorb the mycotoxins, such as being negatively charged; porous, have high surface area and cation exchangeability. Aluminosilicates, such as; bentonite, zeolite, montmorillonite and HSCAS, absorb the mycotoxins into their interspaces, outside and into their edges ([Elliott et al., 2020](#)). Aluminium

silicate (Al_2SiO_5) is the main component of the anhydrous aluminosilicates found in nature, such as andalusite, kyanite and sillimanite ([Hoshino et al., 2016](#)).

4.3. Herbal compounds

Traditional medicine is old as human life, it contributes to the treatment of ailments; including poisoning. Scientists are continuously investigating the herbal compounds and medicinal plants, for treatment of the mycotoxin's poisoning and for alleviating the symptoms of mycotoxicosis in humans and animals. For instance, *Camellia sinensis* leaves were investigated for their therapeutic effects against aflatoxicosis ([Ameen Abdulmajeed, 2011](#)). Table (2) enlists the herbal extracts and compounds that have mycotoxins antidotal effects.

4.4. Supportive treatment

Treatment of mycotoxins with a single compound seems not possible, as most of the documented studies of [Bennett and Klich, \(2003\)](#); [Rea et al., \(2009\)](#) indicate the inclusion of supportive treatment, such as; vitamins supplementation, hydration therapy, antibiotics and others, in order to mitigate the clinical signs induced by the mycotoxins and to speed up the recovery. Table (3) displays the different supportive treatments used to enhance the effects of the mycotoxin antidotes. The numerous effects of mycotoxin antidotes in the biological systems including reducing the liver enzymes; oedema, fungal mycelial growth, increasing the antioxidants, mitigating the blood homeostasis, DNA repair and unbinding the mycotoxin from the cell receptors are summarized in Fig. (4).

4.5. Other compounds helpful in alleviating the mycotoxicosis

Some compounds that are used as mycotoxin antidotes other than those categorized above, are presented in Table (4).

Table 1: Mycotoxin binder antidotes used against ingested mycotoxins in the animal bodies

Antidote	Mycotoxin	Mode of action	References
Activated charcoal Biochar	Aflatoxin (AF) Numerous mycotoxins	Reduces conversion of AF ₁ to AFM ₁ Biochar selectively absorbs poisons, including mycotoxins. Besides, it is an electron mediator in redox reactions, to donate electrons during microbial decomposition.	(Klöpffel et al., 2014 ; Schmidt et al., 2019)
Hydrated Sodium Calcium Aluminosilicate (HSCAS)	Zearalenone (ZNE) in mice, and piglets	HSCA at a dose of 400 mg\ kg reduces the patho-biochemical alterations provoked by ZNE; as it enhances the blood immunity, liver and kidney function and architecture. HSCAS acts as an absorbent.	(Colvin et al., 1989 ; Abbès et al., 2006)
HSCAS	Trichothecenes (T-2) toxin in poultry	HSCAS diminishes T-2 toxicity through improving the growth performance; liver and kidney biochemical indicators, lipoprotein profile and electrolytes homeostasis.	(Wei et al., 2019)
Bentonite	Ochratoxin A in broilers	About 3.7 – 7.5 g\ kg of bentonite significantly reduces the Ochratoxin–induced immunotoxicity, by reducing the lymphoproliferative response, and by improving the histology of the bursa of Fabricius.	(Bhatti et al., 2017)
Magnetic carbon nanocomposite	Aflatoxicosis in chicken	Approximately, 3 % of magnetic carbon nanocomposite in feed effectively absorbs AFB ₁ in GIT of poultry, and subsequently reduces the liver injury and toxicity symptoms in the treated groups, compared to the control intoxicated group.	(Zafar et al., 2017)

Table 2: Herbal preparations with mycotoxin's antidotal activities

Herbal compound	Mycotoxin	Mode of action	References
<i>Camellia sinensis</i> leaves, <i>Carum carvi</i> seeds, <i>Alpinia galangal</i> rhizomes, <i>Boswellia serrata</i> resins <i>Cenchrus ciliaris</i> bark	Aflatoxin (AF) B ₁ toxicity in rats	These plants extract's at concentrations of; 2, 1, 1.25, and 0.5 mg/ kg; respectively, significantly reduce the oxidative stress, liver and kidney damage induced by AFB ₁ . Besides, they improve the energy metabolism by increasing the bioenergetics.	(Ameen Abdulmajeed, 2011)
Curcumin	3-nitropropionic acid (3NA) mycotoxin	Curcumin showed antioxidant effects against 3NA toxicity, and reduces the neurotoxicity.	
Garlic Cabbage Onion	AFB ₁	Garlic, cabbage and onion (each 5 g\ kg) were investigated in rats for 15 d. They significantly reduce AFB ₁ toxicity by reducing the liver transaminases, and potentiate antioxidation in the treated groups, compared to those of the AFB ₁ control group. The best result was recorded by garlic, due to its anti-inflammatory properties.	(Abdel-Wahhab and Aly, 2003)
Welsh onion extracts	<i>A. flavus</i> and <i>A. parasiticus</i>	Approximately, 10 mg\ ml of welsh onion at an <i>in-vitro</i> level is capable of inhibiting the production of aflatoxins, by reducing the mycelial growth over 2 weeks.	(Fan and Chen, 1999)
<i>Moringa oleifera</i> leaf extract	AFB ₁	<i>Moringa</i> -treated group's relieves the DNA damage; suppresses the p53 genes, reduces the liver and kidney injuries, improves the blood homeostasis, and improves the histology picture of the affected organs.	(Aboelhassan et al., 2018)
Red ginseng extract	AFB ₁ , fumonisins	Red ginseng (150 mg\ kg body weight) injected in rats for 4 weeks relieved the biochemical and histological alterations induced by the AFs.	(Abdel-Wahhab et al., 2010 ; Abd El-Hack et al., 2018)
<i>Cassia senna</i> <i>Cassia tora</i> <i>Piper argyrophyllum</i> leaves and <i>Thonninga sanguinea</i> onion	AFB ₁	They have antimutagenic effects. These herbal plants mitigate the genetic and liver toxicities induced by the AFs.	
Green tea; ginger, chamomile, cinnamon, coriander, garlic, black pepper, black seed, licorice, fenugreek seeds, basil seeds and roquette seeds.	Several mycotoxins	Inclusion of these herbal preparations in the food reduce the mycotoxicosis by improving the body weight; meat quality, growth performance and organ histology. They also enhance the activity of the amylase and biochemical parameters.	(Saeed et al., 2018)
<i>Nigella sativa</i> (black cumin) <i>Eugenia caryophyllata</i> (clove) <i>Thymus vulgaris</i> (Thyme)	Mycotoxins produced by <i>Fusarium verticilloides</i> and <i>A. flavus</i> isolates	These herbal plants inhibit the fungal growth and decrease the production of the fungal toxins	(Elsamra et al., 2012)
<i>Ocimum tenuiflorum</i> (OT) Ajowan [<i>T. ammi</i> (L.) Sprague ex Turrill]	Aflatoxin	OT suppresses the AFB ₁ production, whereas Ajowan destroys the AFG ₁	(Haque et al., 2020)

Coumarin + Vitamin E	Aflatoxicosis in Nile Tilapia	Fish diet contains coumarin and vitamin E at a rate of 5 g\ Kg and 50 mg\ kg, respectively. They improve the body weight and ameliorate the toxicity, via reducing the liver enzymes due to their anti-inflammatory effects.	(Hessein et al., 2014)
Tea tree oil (<i>Melaleuca alternifolia</i>)	Aflatoxin on silver catfish (<i>Rhamdia quelen</i>)	About 1 ml of tea tree oil in a 1 kg diet alleviates the aflatoxin-induced brain damage; including gliosis and oedema.	(De Freitas Souza et al., 2019)

Table 3: Supportive treatments used to enhance the effects of the mycotoxin antidotes in the animals

Supportive treatment	Mycotoxin	Mode of action	Reference
Vitamin A	Aflatoxicosis in mice	Approximately, 100-1000 IU of vitamin A reduces the signs of toxicity.	(Ordeanu et al., 1999 ;
Vitamin C	Aflatoxicosis in rats	About 4 % of vitamin C in the diet reduces the liver injury and improves the lipid profile in rats intoxicated with the Aflatoxin	Al-Masri, 2014)
Vitamin D	Aflatoxicosis in chickens	In fact, chickens that grow under vitamin D deficiency are more sensitive to aflatoxicosis. This is attributed to the role of thiamine in preventing the oxidation of the fatty acids; hence decreasing the infliction of the liver with the Aflatoxin	(Hamilton et al., 1974)
Selenium	Aflatoxin T ₂	Selenium relieves the toxic effect of the T ₂ toxin in the embryonic chondrocytes and also inhibits the Aflatoxin B ₁ -DNA binding and adducts	(Galvano et al., 2001)

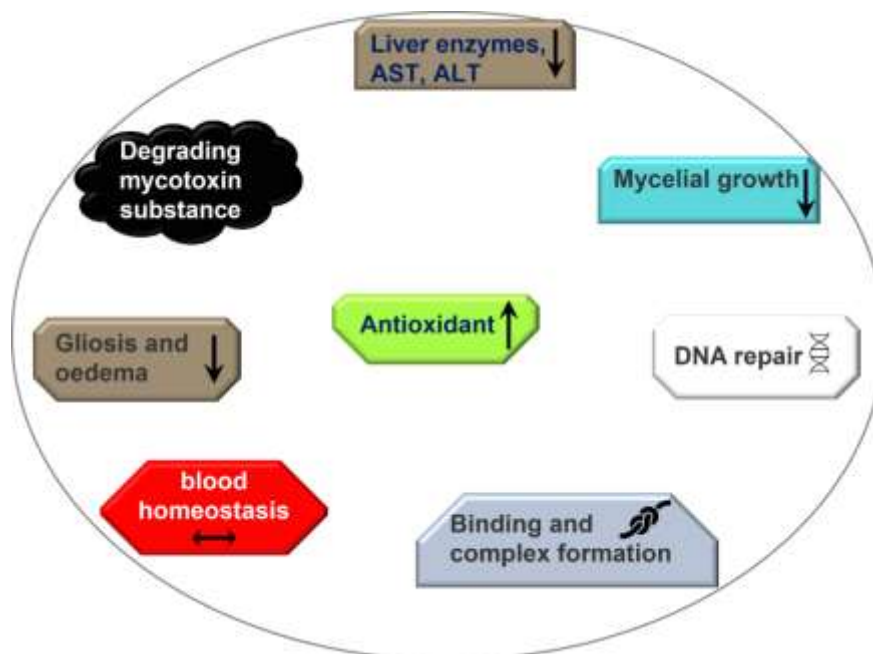


Fig. 4: Effects of mycotoxin antidotes in humans and animals bodies exposed to fungal toxins

Table 4: Other compounds used as antidotes for the treatment of mycotoxicosis

Antidote	Mycotoxin	Mode of action	References
<i>Trichosporon mycotoxinivorans</i> (TM).	Ochratoxin	TM reduces the ochratoxin levels in the liver and lowers the feed-to-tissue transfer of this mycotoxin. These effects are attributed to the ability of TM to cleave the phenylalanine moiety and hence degrade the Ochratoxin to a less toxic substance by more than 500 times.	(Schatzmayr et al., 2006 ; Bhatti et al., 2018)
L-methionine	Ochratoxin	L-methionine clearly reduced Ochratoxin-induced toxicity in lab animals when given at a dose of 43 mg\ kg. L-methionine mechanistically reduces the liver transaminases, kidney inflammatory swelling, and histology of affected organs in intoxicated animals.	(Abdel-Wahhab et al., 1999)
Hydroxytyrosol (HT)	Ochratoxin	HT alleviates Ochratoxin-induced nephrotoxicity by reducing oxidative stress on the kidney cells <i>in-vitro</i> and <i>in-vivo</i> , at a dose of 250 µg\ kg for 3 months.	(Crupi et al., 2020)
Superoxide-dismutase (SOD) and Catalase (CAT)	Ochratoxin-A	At 20 mg\ kg body weight, both SOD and CAT prevented the kidney toxicity induced by ochratoxin. The effects were attributed to their antioxidant potentials against oxidative stress induced by Ochratoxin.	(Baudrimont et al., 1994)
Red wine	Ochratoxin-A	Researchers observed a protective effect of red wine when given at 0.5 ml\ animal and mixed with Ochratoxin. Red wine is thought to produce these effects by reducing the inflammatory cytokines and inflammatory mediators.	(Gagliano et al., 2005)
Carotenoids and carotene and xanthophyll-rich food (carrots, red tomatoes, butter, cheese, paprika, palm oil, corn kernels, and red)	Aflatoxin (AFB ₁)	Carotenoids showed antioxidant and anti-mutagenic effects. Carotene-rich food mitigates the liver DNA damage due to aflatoxicosis. Besides, Carotenoids degrade the AFB ₁ to a lesser toxic substance	(Gradelet et al., 1997 ; Gradelet et al., 1998)
Bovine serum albumin (BSA)	AFB ₁	BSA showed protective effects against aflatoxicosis in one-day chicks, by improving the liver biochemical parameters and histological architecture.	(Galvano et al., 2001)
Cholestyramine* Nanoparticles	Ochratoxin	Reduced nephrotoxicity-induced by Ochratoxin	(Galvano et al., 2001)
Nano-silver (AgNPs), Zinc Oxide nanoparticles (ZnO-NPs), Selenium nanoparticles (SNP), Copper nanoparticles	aflatoxicogenic, ochratoxicogenic fungi	These compounds were investigated for their absorptive ability to the mycotoxins	(Haque et al., 2020)

(CuNPs)
nanoabsorbants
(nanogel, caly and
nanodiamond)

Monoclonal antibody	<i>Fusarium</i> mycotoxins	The mabs monoclonal antibody has a high affinity to bind to <i>Fusarium</i> mycotoxins in plants, and hence lower its availability in animal and human ingested food products	(Ling et al., 2014)
Electrolytes infusion, benzodiazepines, atropine, and pyridoxine	Mushroom toxicity (amatoxin, psilocybin, muscarine, coprine, allenic norleucine, gyromitrin, and others)	1. Electrocytes infusion 2. Benzodiazepines for hallucination 3. Atropine 0.5–1 mg IV for cholinergic toxicity 4. Pyridoxine (B6) at a dose of 25 mg\ kg IV for refractory seizures.	(Tran and Juergens, 2021)
N-acetylcysteine (NAC), silibinin, and penicillin.	Amatoxin	These drugs alleviated the amatoxicosis by reducing the inflammatory process, relaxing the blood vessels, and relieving hepatotoxicosis	
Probiotic yeast and bacteria	AFB ₁	Probiotics containing mostly some species of <i>Lactobacillus</i> and <i>Candida</i> significantly reduce the AFB ₁ by several enzymatic and absorption mechanisms	(Zolfaghari et al., 2019)

Where; *Cholestyramine is a resin found in the bile salts

5. Ergotism

Ergotism is a disease that takes place as a result of consuming rye or other grains contaminated with a fungus of the genus *Claviceps*, which is the first known mycotoxin ([Oellig and Melde, 2016](#)). Ergotism is clinically manifested in two patterns mainly; the convulsive type, where the affected patient shows spasms in the muscle, and\ or the gangrenous type, in which the patient exhibits swelling, coolness, hair loss and inflammation in the affected parts. These changes are attributed to ergot alkaloids ([Roberts et al., 2016](#)) that cause smooth muscle contraction; vasoconstriction, elevated blood pressure and body temperature, mydriasis and central nervous symptoms effects, as reported by [Craig et al., \(2015\)](#). Ergotism is a neglected disease; where the current review shortly explores the available treatments for ergotism in humans.

There are no specific antidotes for ergotism, but the following medications are suggested by [Garcia et al., \(2000\)](#):

1. Nifedipine, a Ca²⁺ channel blocker to relax the affected blood vessels;
2. Nitroprusside, used for vasodilation;
3. Prozasin HCl, to enhance the vascular elasticity;
4. Prostaglandin I₂, for pain management;
5. Prostaglandin E₂, as a vasodilator and antiplatelet agent;
6. Aspirin, as an anti-inflammatory and antiplatelet agent;
7. Human patients are advised to stop caffeine intake and smoking, to allow for blood vessels relaxation.

6. Genetically modified animals (GMA) for mycotoxicosis

In addition to the modified crops that genetically resist mycotoxins ([Assefa and Geremew, 2018](#)), scientists have also highlighted the ability to create animals' (GMA) that harbor heritable resistance to a variety of mycotoxins ([De Santis et al., 2018](#)). GMAs can possibly be made by changing several targeted genes with new technologies, such as CRISPER-Cas9 or Zinc-fingers (ZFNs), to obtain animals that withstand certain diseases ([Lillico et al., 2016](#)). This approach was proposed by a group of researchers in China; however, it raised health concerns regarding the effects of GMA on the long run; when consumed by the humans ([Haque et al., 2020](#)). This idea seems feasible if its cost is kept low, and upon confirmation that consumption of these projects remains safe for humans. On the other side, genetically-engineered humans that resist mycotoxicosis seem unpractical; if it is not a crazy idea, at least in the near future.

7. Enzymes for degrading the mycotoxins

Food technologists use numerous methods for detoxification of the food products. Addition of substances; such as sodium hydroxide, chemically hydrolyze the mycotoxins ([Li et al., 2020](#)), and feed additives such as Mycofix; biologically deactivate the mycotoxins ([Hanif et al., 2008](#)). However, these substances may reduce the food quality or deteriorate the raw materials, and thus their usage retains in food processing, but not for therapeutic purposes. Recently, enzymatic detoxification of mycotoxins stirred up numerous reports ([Ji et al., 2016](#); [Lyagin and Efremenko, 2019](#)). The main advantages of these enzymes are their specific actions, in addition to the absence of toxicity to the patients ([Lyagin and Efremenko, 2019](#)). Table (5) presents some of the enzymes that can be utilized to detoxify the mycotoxins. Several different enzymes have been studied for their mycotoxin detoxifying capabilities ([Chen et al., 2017](#)), including PGUG enzyme from *Meyerozyma guilliermondii* yeast; oxidoreductase Gox2181 enzymes from *Gluconobacter oxydans*

bacteria for patulin, organophosphorus hydrolase used for lactone hydrolysis in several mycotoxins, carboxylesterase FUMD for hydrolysis of Fumonisin and UDP-glucosyltransferase OsUGT79 that hydrolyze the Trichothecenes mycotoxins. These are simple examples of enzymes that can be used to detoxify the mycotoxins. Nevertheless, the use of these enzymes is limited to food processing, additives and in vitro work ([Xia et al., 2021](#)). The challenge is to develop enzymes or enzyme homologues that are active when ingested and/or administered to the patients.

Conclusion

Mycotoxin, as a secondary metabolite; may accumulate in the body of humans and animals, due to the ingestion of food contaminated with high doses of mycotoxins. The most widely spreading mycotoxin is the aflatoxin. Mycotoxicosis is considered of a pivotal importance because the toxicities might occur silently. Several natural products are being used for treatment and prevention of the mycotoxin toxicities; including binders such as charcoal, herbal products such as garlic and black seeds or cumin, and supportive treatments such as vitamin A, E and C. In the near future, the governmental institutions should take certain measures to lower the spreading of mycotoxins; through legislation regulation for food storage, and measurement of the mycotoxin's levels during the storage periods.

Future perspectives

Most of the antidotes alleviate the disorders caused by the mycotoxins. It will rather be better if the developed drugs work in dual functions; as antidotes and as antioxidants to achieve a quick recovery. Several enzymes are being used to modify the mycotoxins, such as Aflatoxin dialdehyde reductase; Zearalenone hydrolase, Lactonase, etc. These enzymes can be extracted and then purified to be used alone or in combination as specific (pure) antidotes, which withstand the gastric acids when ingested, and suit the clinical settings as well.

Table 5: Enzymes used for detoxification of the mycotoxins

Enzyme	Mycotoxin	Mode of action	References
Aflatoxin dialdehyde aldo-keto reductase AKR7A1	Aflatoxin	Reduces hydroxy aflatoxin B _{2a} into dihydroxyl derivatives	(Renaud et al., 2022)
Manganese peroxidase (MnP) of 40–45 kDa	Aflatoxin B ₁	This enzyme epoxidizes the AF substrate	(Martínez-Montero et al., 2021)
Oxido-reductase obtained from <i>Bacillus subtilis</i>	BacC Aflatoxin B ₁	Breakdown the lactone ring of AFB ₁	(Afsharmanesh et al., 2018)
Gliotoxin oxidoreductase (GliT)	Gliotoxin	The enzyme–substrate complex forms what is known as “Newton’s cradle”	(Dolan et al., 2017)
Zearalenone hydrolase (ZHD)	Zearalenone	ZHD disrupts the lactone ring, and attacks the carbonyl carbon in zearalenone	(Kosawang et al., 2014)
Ochratoxinase (OTase)	Ochratoxins B	This enzyme hydrolysis the ochratoxin amide bond	(Lyagin and Efremenko, 2019)

Where; Epoxidation: refers to converting the substance by oxidizing C=C bond into oxiranes

Conflict of interest

The authors declare no conflict of interests.

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None.

Ethical approval

Not applicable.

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