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Review

A Review of Mycotoxin Types, Occurrence, Toxicity, Detection Methods and Control

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Abstract. Mycotoxins are health hazardous natural toxin produced by various fungal species due to favourable environmental conditions for fungal growth. These are carcinogenic, hepatotoxic and immuno-suppressive substances usually found in food and feed items. Mycotoxins are broadly divided into two major groups on the basis of mycotoxin producing fungi i.e., those fungi which invade in pre-harvest conditions and those which are produced in post-harvest conditions called storage fungi. The conditions which promote mycotoxin growth are high temperatures, moisture levels, poor hygienic conditions and contamination during storage and transportation. Aflatoxins, ochratoxins, citrinin, trichothecene, fumonisins, patulin and zearalenone are prominent mycotoxins in food and feed commodities. This review renders the comprehensive data regarding occurrence of main mycotoxins, their analysis and health hazardous effects on human health alongwith some detoxification protocols.

Keywords: mycotoxin, detoxification, health hazard, metabolites

Introduction

Mycotoxins, the secondary metabolites formed by various Aspergillus fungal species *Penecillium*, *Fusarium* and *Trichoderma* are health hazardous poisons frequently present in food and feed (Tola and Kebede, 2016). These may be present as toxic compounds in feed and food like cereals, legumes, oilseeds and milk, vegetables, fruits having high levels of moisture and nutrients (Gizachew *et al*., 2016; Marin *et al*., 2013). Mycotoxins are one of the main public health concerns due to severe toxicity. All over the world work has been conducted on mycotoxins to evaluate its presence in different food entities and its severity (Berthiller *et al*., 2018; Yu *et al*., 2004). Toxic effects of mycotoxins on mammalian cell (Zain, 2011; Creppy, 2002) are given in Table 1.

Mycotoxins persuade and endanger economy, international trade as well as develop the irreversible health effects in living beings (WHO, 2006). Biosynthesis of mycotoxins defined that these are secondary metabolites concerned with internal factors like genetic potential of fungi and substrate and external factors like moisture and temperature conditions in which crop is grown, harvested and stored (James, 2005).

Mycotoxin contamination is inevitable and at times capricious, which makes it an inimitable dispute to food safety. The favourable conditions for mycotoxins growth are started with poor hygienic circumstances at the time of haulage and storage, moisture, heavy rains and high temperatures (FAO, 1995).

Generally, mycotoxins cause severe circumstances by intake of unhygienic foods, inhalation of spore-borne toxins and by dermal contact with mold infected substrates. Effects by mycotoxins are carcinogenic, cytotoxic, teratogenic, estrogenic, immunosuppressant and neurotoxic (Benkerroum, 2016). This review paper briefly entails mycotoxins information including their structures, major types of mycotoxins, health hazardous effects, their analysis and different ways to control mycotoxin contamination. Most of the diseases related to mycotoxins are because of accumulating contaminated food (Alrabadi *et al*., 2018).

Chemical structure of mycotoxins. Mycotoxins are poisonous compounds having low molecular weight formed by fungal species which contaminate food and

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feed. These are diminutive and quite stable molecules which are very complicated to get rid of or eliminate (Milani, 2013; Steyn, 1995). Mycotoxins constitute chemically heterogeneous and toxigenically assembly that are grouped together. Several mycotoxins exhibit overlapping toxicities to humans, animals and plants (Bennett, 1987). The structures of major mycotoxins are given in Fig. 1.

Various types of mycotoxins. *Aflatoxin*. These are poisonous class of mycotoxins formed by poisonous molds, particularly *Aspergillus parasiticus* and *Aspergillus flavus*, which may contaminate food and feed badly. Aflatoxins are liver killers (Goto *et al*., 1996) and may greatly effect immune system by suppressing system activity (Peterson *et al*., 2001; Klich *et al*., 2000). Aflatoxin B1, G1, B2 and G2 are the four main types while aflatoxin M1 is hydroxylated form of B1 which is found in milk and dairy products. B and G stands for blue and green fluorescence character of aflatoxin under UV light, respectively while 1 and 2 refer to position of these aflatoxins on thin layer chromatography. Aflatoxin B2 and G2 are less toxic as compared to B1 and G1 and aflatoxin B2 is less toxic than G1 (Sanchis *et al*., 1994). The fungi species: (*Aspergillus flavus* and *Aspergillus parasiticus*) show suitable growth at warm conditions (Chase and Overton, 2012). Optimum environment for aflatoxin growth is 33 °C and 0.99 aw (water activity). Aflatoxin growth in food and feed was observed in stressful growing stage, e.g. drought growth conditions. Under harsh situations fungi (molds), spores survive and start decaying vegetation under microbiological actions and under suitable environment attacks on hay and grain especially when moisture content is higher in humid soil (Ominski *et al*., 1994). Aflatoxins have adverse carcinogenic, toxic, teratogenic and mutagenic effects and also may cause liver and organ cancer in humans. Direct exposure to aflatoxin may occur frequently by ingestion of food and also by other means like dermal contact and inhalation (Mizrak *et al*., 2009).

Aflatoxins impart their noxious effects on humans and animals health and the severity level of their lethal effects is directly related to nature of aflatoxin, age of consuming body, exposure time and food status of a person. The plants, grains, cereals, spices, nuts and oilseeds that commonly favour the growth of aflatoxin and consequent fungal toxin production are the vital causes of exposure to aflatoxin. The examples are maize, wheat, rice, oilseeds, sunflower, peanut, cotton, almond, pistachio, walnut, coconut and spices like black pepper, red chilli, turmeric and coriander (Van Egmond, 2002). The other commodities which may have aflatoxin contamination are plants parts like vegetables and fruits and also in meat, animal tissues and animal products (Milicevic *et al*., 2010).

Different countries have adapted different permissible limits of aflatoxins in feed and food entities. The allowable level of aflatoxin in various food entities (Tritscher *et al*., 2013) in different countries is given in Table 2.

Table 1. Mycotoxins and their toxic effects

Mycotoxins	Producing organism	Chemical structure	Effect on mammalian cells
Aflatoxins (B1, G1, M1, B2, G2, M2)	*Aspergillus*	Difuranocoumarin derivatives	Carcinogenic
Ochratoxins	*Aspergillus penecillium*	Dihydroisocoumarin derivatives linked to phenylalanine	Carcinogenic nephrotoxic hepatotoxic teratogenic
Citrinin	*Penecillium*	Benzopyran derivative	Nephrotoxic
Trichothecenes or Deoxynivalenol	*Fusarium trichoderma*	Sesquiterpenoid Compounds	Cytotoxic immunosuppressive
Fumonisin	*Fusarium alternaria*	Isoflavanoid compounds	Hepatotoxic carcinogenic
Patulin	*Aspergillus penecillium*	Unsaturated heterocyclic lactones	Carcinogenic immunotoxic genotoxic
Zearalenone	*Fusarium*	Phenol resorcyclic acid lactone	Esterogenic activity potential carcinogenic and hepatotoxic

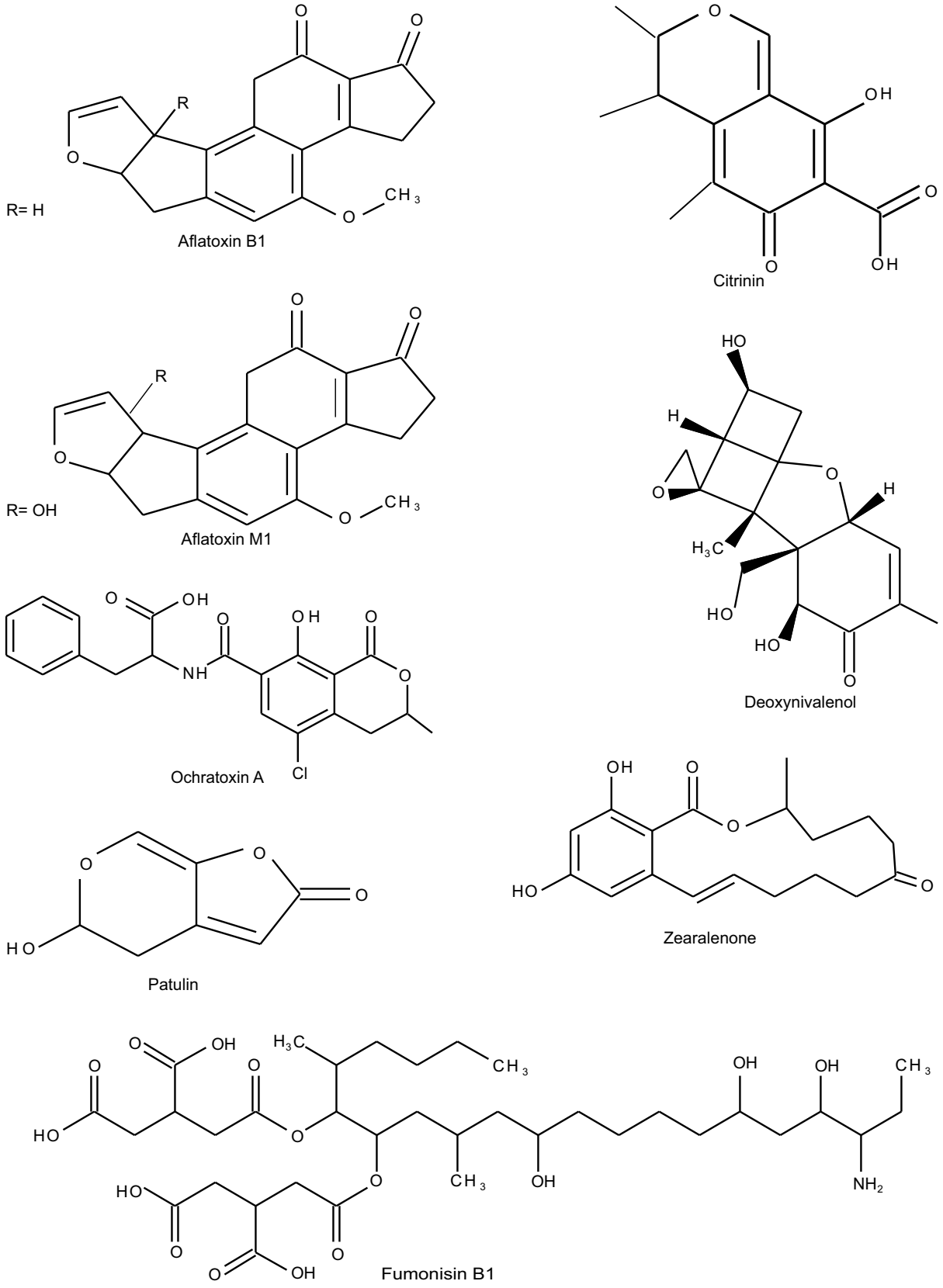

Fig. 1. Chemical structure of Mycotoxins.

Table 2. Permissible limits for aflatoxins

Aflatoxins	Maximum permissible limit (µg/kg)	Product	Country
Total aflatoxins (B1+B2+G1+G2)	10	Groundnuts	China, Egypt, Japan, Thailand, Turkey
Total aflatoxins	15	Groundnuts	Australia, Indonesia, Malaysia, Taiwan
Total aflatoxins	4 (Direct consumption) 15 (Additional processing)	Groundnuts	European Union
Aflatoxin B_1	2		
Total aflatoxins	20	Groundnuts	Kenya
Aflatoxin B_1	5	Groundnuts	Russia
Total aflatoxins	15	Nuts and subsequent products	Canada
Total aflatoxins	20	Nuts and Products	Philippines
Total aflatoxins	5	Nuts	Singapore
Total aflatoxins	30	All food products	India
Total aflatoxins	20	All foods except milk	USA
Total aflatoxins	10	Food entities	Vietnam

(Tritscher *et al*., 2013).

Ochratoxins. The fungal metabolites formed by species *Aspergillus ochraceous* and *Aspergillus penecilliumare* are termed as Ochratoxins (Zahra *et al*., 2016; Bayman *et al*., 2002). Ochratoxin A is common and pertinent toxin of this group. Ochratoxins A, B and C are structurally related and are equally harmful. Ochratoxin A pollutes agricultural products and due to its growth in food, represents a serious danger equally to human and animal health globally (Jordan and Pattison, 1996). Optimum conditions for ochratoxin growth are at 25-30 °C and 0.98 aw (water activity). Among three Ochratoxins A is most common and toxic compound found in cereals, barley, nuts, dried fruits, porcine kidney, beer, coffee beans, wines and moldy bread (JECFA, 2001). Ochratoxins are alleged to be involved in the tumors of urinary organs and etiology of human nephropathies (Kuiper-Goodman *et al*., 2010). According to the European Commission 2002, ochratoxin infectivity was set at 3 µg/kg in cereals consequent products. In dry grapes the contamination limit fixes to a limit of 10 µg/kg (El Khoury and Atoui, 2010). This difference in commendations shows differences in risk managing procedures, ensuing different permitted limits functional to diverse food products and to the same goods in various regions (Walker, 2002).

Citrinin. The secondary toxic metabolites of benzopyran created by numerous *Aspergillus* and *Penicillium* species particularly by *P. citrinum* are termed as Citrinin mycotoxin. It is usually formed subsequent to harvest and can be found mostly in stock up grains and cereals chiefly rice, barley and wheat and also found in other plant parts like fruits, vegetables and beans. It may also contaminate herbs, juices, spices and dairy products (Abou-Zeid, 2012). Citrinin is nephrotoxic mycotoxin (Ali *et al*., 2018) which can co-occur in food entities, resulting in internal revelation. Depending on species nature, Citrinin may form at 20-30 °C and 0.75-0.85 aw (water activity). Due to this toxin food poisoning reaches its peak especially in countries with a hot and humid weather (Sinha and Prasad, 1996; Frank, 1992). This toxin may affect kidneys and can cause severe renal failure (Degen *et al*., 2018). Physiological research also identified various unsympathetic effects on gastrointestinal tract and liver as well (Krejci *et al*., 1996).

Trichothecenes. Trichothecenes are globally dispersed and generally formed by *Fusarium* species in extreme environments (Nelson *et al*., 1994). The trichothecenes are categorized in two different groups i.e. nonmacrocyclic or macrocyclic compounds. There are two subdivisions of non-macrocyclic trichothecene compounds i.e., type A and type B. The type A includes NEO (neosolaniol), HT-2 toxin, T-2 toxin and DAS (diacetoxyscirpenol). The type B trichothecenes include DON (deoxynivalenol), NIV (nivalenol), 3-AcDON (3-acetyldeoxynivalenol) and 15-AcDON (15-acetyldeoxynivalenol) (Hedayati *et al*., 2007).

Tricothecenes may cause depression of the immune response, vomiting, blood and reproductive disorders,

growth retardation, dermatitis and oral lesions (Rocha *et al*., 2005; CAST, 2003). Optimum conditions (Ramirez *et al*., 2006) for trichothecenes growth are at 26-30 °C and 0.995 aw (water activity). The permissible limit of DON in Canadian soft wheat is set at 2 ppm and 1 ppm for infant food. DON allowable limit (Pestka and Smolinski, 2005) in United States, Russia, China, Hungary and Switzerland is set at 1 ppm while in Austria, Germany and Netherlands it is 0.5 ppm.

***Fumonisins*.** Fumonisins are the mycotoxins produced by *Fusarium verticillioides*, *F. oxysporum*, *F. globosum*, *F. proliferatum* and several other *Fusarium* spp. (Scott, 2012). Its types are Fumonisins B1, Fumonisins B2 and Fumonisins B3. Fumonisins received special attention in 1988 (Marasas *et al*., 1988) when experiments were conducted in horse and found fumonisins cancer causing activity and the initiation of leukoencephalomalacia.

Fumonisins are mainly found in corn and in corn-based animal feeds. Fumonisin B1 (FB1) is the most frequent and is most meticulously studied. FB1 causes diseases like porcine pulmonary edema (PPE) and equine leukoencephalomalacia (ELEM). FB1 is harmful for the liver in all species and the kidney in some farm animals, causing apoptosis chased by mitosis in the affected tissues (Voss *et al*., 2007).

Fumonisins may found in different food entities like barley, wheat, millet, oat and maize and concerned products (Aoyama *et al*., 2010). The optimum growth parameters for Fumonisins are: temperatures 15-30 °C and 0.9-0995 aw (water activity). The permissible limits of fumonisins in maize products are 2 or 4 mg/kg for popcorn grain (USFDA, 2001).

***Patulin*.** Patulin is also a toxic type of mycotoxin formed by different fungal species like *Penicillium patulum* now called *Penicillium griseofulvum*. Its chemical formula is 4-hydroxy-4H-furo[3,2c]pyran-2(6H)-one. Patulin is harmful for plants and animals, excluding its therapeutic use as an antibiotic (Bennet and Klich, 2003). Patulin is stable in apple and grape juices and also in dry cereals but it may decompose in wet cereals (Moss and Long, 2002; Trucksess and Tang, 2001; Armentia *et al*., 2000). Optimal growth of patulin was observed at 25 °C. Patulin has been confirmed to be extremely poisonous. It is teratogenic, genotoxic and probably immune-toxic to animals. Uptill now the harmfulness of patulin in humans has not been verified and demonstrated decisively but to limit its concentration in food commodities is taken as a preventive measure (Cunha *et al*., 2014).

European Guideline 1425/3003 has set a permissible level of patulin i.e. 50 µg/L for fruit juices and derivative products. The permissible limit of patulin is 25 µg/L for apple products while it is 10 µg/L for foods and juices prepared for young infants (Chalmers *et al*., 2004) while according to USFDA allowable limit for patulin is 50 µg/L (Puel *et al*., 2010).

***Zearalenone*.** Zearalenone is mainly formed from *Fusarium graminearum* and *F. culmorum* fungal species in different cereals including wheat, maize, oats, rye and barley. Zearalenone has been demonstrated to induce infertility, mammary hypertrophy and vulva oedma in various animal females (Zinedine *et al*., 2007).

Zearalenone may accumulate in different cereals depending upon many factors like temperature, substrate, strain of fungal species and duration of *Fusarium* growth. It may contaminate both food and feed stuffs (De-Saeger *et al*., 2003). The favourable temperature and water activity for patulin augmentation was observed at 25 °C and 0.95 aw, respectively.

Zearalenone has categorized as a class 2A carcinogen by International Agency for Research on Cancer (IARC, 1993). In 2011, the harmfulness of Zearalenone by the EFSA (European Food Safety Authority) has now been clarified and set a TDI (tolerable daily intake) of 0.25 µg/kg body weight (EFSA, 2011).

Determination of mycotoxins. Mycotoxin examination gives a picture of harmful fungal infectivity of foods and feeds. There are various chemical and biological ways known since 1970 for detection and quantification. Different organizations like FDA, EPA and AOAC has standardized the process of mycotoxin analysis. Systematic methods have now been developed even to determine low quantity of mycotoxins in food and feed commodities. Proper sampling procedure by fixed legislation (Codex Alimentarius) is essential step in mycotoxin analysis. Mycotoxins are not homogenous in food and feed samples. So, sample extraction and preparation is critical process to achieve good analytical results. Mycotoxins analysis include 3 main steps i.e. extraction, purification and evaluation (Trucksess and Pohland, 2001).

Mycotoxins are purified by different chromatographic and centrifugation methods and also by passing through prepacked cartridges. TLC (thin layer chromatography),

HPLC (high performance liquid chromatography) with Diode Array detector and Fluorescence detector, GC (gas chromatography) with Mass Spectrometer, LC (liquid chromatography) with Mass Spectrometer and ELISA (enzyme linked immune-sorbent assay) are the popular techniques for the analysis of mycotoxins in diverse food and feed commodities (Onji *et al*., 2002; Jaimez *et al*., 2000; Lin *et al*., 1998).

Mycotoxins control. Mycotoxin contamination may harm humans and animals health so its control is obligatory. Preventive measures should be adapted which include preharvest control, post-harvest control while corrective measures include removing mycotoxins from food and feed stuffs.

Pre-harvest control. Suitable cultivation techniques can reduce mycotoxins. For instance, exclusion of farming waste is helpful in mitigating the contagion of the plants and crops by fungal attack. Fungicides used in field crops may reduce and lower the mycotoxin contamination. Software appliances are accessible to help out farmers predicted mycotoxin threat throughout the year which work according to climatic parameters. Various microorganisms as bio-control agents are proposed to reduce aflatoxin infectivity in pre-harvest; for instance, non-aflatoxigenic strains of the same varieties might be bio-competitive agents (Jard *et al*., 2011). Resistance propagation is conventionally applied to improve the confrontation of the host plants to fungal attack and infectivity (Anthony *et al*., 2012). To lowering fumonisin in maize and deoxynivalenol in wheat, bio-competitive exclusion shows capable results (Cleveland *et al*., 2003). By using genetic engineering the plant genes become less at risk level to fungal infection.

Postharvest control. The contamination of mycotoxin by *Aspergillus*, *Alternaria*, *Fusarium* and *Penecillium* species is inevitable in different environmental circumstances. Storage and sorting are the main post harvest control parameters. Best storage conditions are necessary to lessen the mycotoxin in food and feed stuffs. Water activity, the presence of chemical preservatives, gas composition, temperature and microbial contacts of the stored products are factors which may affect mycotoxin growth. An integrated control of these factors might give great effective control. No single method used against wide range of mycotoxins which may present with co-contamination. Many strategies are introduced for decontamination of mycotoxins. Infected grains do not have the same colour or density as protected grains. Thus, the contaminated grains must be separated according to density or appearance (Kabak, 2009; Afolabi *et al*., 2006).

Eliminating mycotoxins from food and feed. The main purpose of detoxification is to inactivate or remove mycotoxins. The nutritional value and deliciousness of foodstuff should be maintained. Several ways and methods have been investigated for lessening mycotoxin infectivity in feed and food stuffs. These methods are categorized as physical, chemical and biological methods (Varga and Tóth, 2005).

Physical methods. The effective control of mycotoxin contamination can be reduced by various physical methods like colour-wise sorting, mechanical separation, removal of the fines and density segregation. Washing of grains by simply water or sodium carbonate solution is used to reduce the concentrations of Zearalenone, Deoxynivalenol and Fumonisins in maize and cereal grains. Gamma radiations were used to control ochratoxin in feeds (Stepanik *et al*., 2007).

Chemical methods. Aflatoxin contamination is inevitable and capricious which makes it distinctive challenge to both food and feed safety as it directly or indirectly agonies animals and human beings. Although there are many chemicals but it is found that 0.5% hydrochloric acid is the pre-eminent chemical for decontamination of aflatoxin B1 in fish feed and poultry samples (Nisa *et al*., 2012a; 2012b). 0.3 and 0.4% NaOCl, 0.5% HCl, 0.3% HCl, 0.1% HCl, 10% citric acid, 30% citric acid, 50% calcium hydroxide, 96% ethanol and 99% acetone were used for detoxification. The aflatoxins were reduced to 55.1% in super sella rice, 90.9% in super basmati rice, 28.08% in brown rice and 80.0% in white rice samples. Aflatoxins were detoxified in dal chana, dal mash, dal masoor, haldi and kalongi upto 70.5, 83.0, 46.2, 82.09 and 36.9%, respectively. Reduction of aflatoxins was carried out 39.7, 7.1, 39.5, 82.0 and 62.0% in red chilli, makhana, corn flakes, kheer mix and pistachio. The aflatoxins level was reduced in maize grain, damaged wheat, peanut, figs and dates upto 31.3, 64.3, 63.6, 42.7 and 19.8%, respectively (Nisa *et al*., 2013). Ammoniation is an efficient method used for several years and is mainly used to decrease the level of aflatoxins in feed but it may affect food quality. Similarly, alkalization, acidification and thermal treatment may reduce mycotoxin levels in food and feed samples (Bretz *et al*., 2006). Deamination i.e., addition of $NaNO_2$ reduce aflatoxin B1 by deaminating and so decrease its toxicity (Lemke *et al*., 2001).

Table 3. Overview of studies in some countries regarding different mycotoxins analysis

Mycotoxin	Food commodity	Countries	Sampling year	No. of samples	Mycotoxin contaminated positive samples (%)	References
Aflatoxin B1	Rice	Turkey	2009	100	35.00	Buyukunal *et al*., 2010
Ochratoxins					38.00	
Aflatoxin B1	Animal feed	Kenya	2015	74	56.00	Makau *et al*., 2016
Deoxynivalenol				43	63.00	
Aflatoxin M1	Milk			68	48.50	
Aflatoxin M1	Milk	Iran	2011	42	1.60	Ali *et al*., 2012
Aflatoxins B1,	Peanut	Brazil	2011-2012	240	35.00	Jager *et al*., 2013
B2, G1, G2	Corn				42.00	
	Bean				75.00	
Aflatoxin M1	Milk				41.00	
	Cheese				33.00	
	Yougurt				0.00	
Aflatoxin M1	Buffalo Milk	Pakistan	2013	50	84.00	Sajid *et al*., 2015
	Cow Milk				72.00	
Zearalenone	Wheat	Egypt	2013	60	40.00	El-Desouky and Naguib,
	Corn				20.00	
	Barley				26.00	
Trichothecene	Wheat	Czech Republic	1999-2005	191	92.00	Hajslova *et al*., 2007
	Barley		2005	24	100.00	
	Rye		2001	15	100.00	
Citrinin	Barley	Egypt	1994-1995	274	55.90	Abd Alla, 1996
	Rice				39.40	
Patulin	Apple Juices	Turkey	2001	45	44.00	Yurdun *et al*., 2001
Patulin	Apple products	South Africa	1996 to 1998	60	16.00	Leggott and Shephard, 2001
Aflatoxins	Dried chilli	Thailand	2004	33	43.50	Kladpan *et al*., 2006
Fumonisin B2	Coffee bean	Thailand	2007	12	58.30	Noonim *et al*., 2009
Aflatoxin	Maize products	Brazil	2002-2003	121	1.70	Sekiyama *et al*., 2005
Ochratoxin					0.80	
Zearalenone					0.80	
Zearalenone	Cereals	Timis county, Romania	2008-2010	125	29.60	Galbenu *et al*., 2011
Deoxynivalenol	Noodle	Thailand	2007	30	6.67	Poapolathep *et al*., 2008
	Bread			30	16.70	
	Cereals			30	33.30	
Deoxynivalenol	Rice	South America	2009	100	38.00	Abbas and Shier, 2009
Zearalenone					65.00	
Aflatoxins	Corn	China	2007	283	70.30	Liu, 2007
	Peanuts				23.10	
Aflatoxin B1	Cereals and	Yangtze Delta	2010	76	14.50	Li *et al*., 2014
Ochratoxin	oil products	region of China			14.50	
Deoxynivalenol					15.80	
Zearalenone					27.60	
Aflatoxin B1	Maize	India	2010-2012	150	18.70	Mudili *et al*., 2014
Ochratoxin					13.30	
Fumonisin B1					38.70	
Deoxynivalenol					15.30	
T-2 Toxin					7.33	
Fumonisins	Maize products	Coimbra, Portugal	2005	67	22.40	Silva *et al*., 2007
Fumonisins	Rice	Canada	2008	99	15.20	Sarathchandra and Muralimanohar, 2013
Aflatoxin B1	Feed stuff	Tamil Nadu	2010	441	52.60	
Ochratoxin					23.13	
Citrinin					50.11	
T-2 Toxin					3.63	
Zearalenone					19.50	
Aflatoxin	Brown Rice	Pakistan	2006-2010	1029	22.42	Nisa *et al*., 2015
	White Rice			1561	33.13	
	Sella Rice			13	24.27	
	Parboiled Rice			52	26.92	
	Broken Rice			33	39.39	
Aflatoxin	Brown Rice	Pakistan	2015	50	92.00	Nisa *et al*., 2016
Aflatoxin	Chilli	Pakistan	2012	183	26.23	Nisa *et al*., 2012
Aflatoxin	Brown rice	Pakistan	2016	90	56.0	Zahra *et al*., 2017
	White rice			60	67.0	
Aflatoxin	Pepper	Mexico	2017	54	95.0	Garduño-García et al., 2017
Fumonisins	Garlic	Italy	2017	56	5.36	Tonti *et al*., 2017

Table 4. Pros and cons of aflatoxin detection tools

Technique	Pros	Cons.	References
TLC	• Easy and reliable semi-quantitative way • Involves no sophisticated equipment	• Obsolete method • Need HPLC analysis for quantification results • Samples destruction during preparation	Rahmani *et al*., 2009
HPLC	• Reliable and sensitive quantitative method	• Very expensive to analyze number of samples • Samples destruction during preparation	Shephard *et al*., 2012; Pascale and Visconti, 2008
GC	• Good sensitivity • Simultaneous analysis of mycotoxins • Provides confirmation (MS detector)	• Amplified trichothecene responses (up to 120%), • Calibration curves non-linearity • High deviation in terms of reproducibility and repeatability	Petterson and Langseth, 2002
LC/MS	• Instantaneous analysis of different mycotoxins • Detection limit is low • No derivatization required	• exceptionally costly equipment requiring devoted operator to infer results • sensitivity depends on ionization • need internal standards	Li et al., 2013; Krska *et al*., 2008
ELISA	• Rapid, specific and quite easy to exercise • concurrent analysis of numerous samples • semi-quantitative (screening) or quantitative analysis possible • partial use of organic solvents • economical equipment • low limit of detection	• Probability of false positives/ negatives • constricted detection range	Lippolis and Maragos, 2014; Lattanzio *et al*., 2011

***Biological methods*.** Bio-transformation by adsorbing, binding or detoxifying can reduce mycotoxins. Hydrated sodium calcium alumino silicates (HSCAS) may reduce aflatoxin B1. HSCAS is very important to prevent aflatoxicosis in a diversity of animals. Activated carbon has ability to adsorb Fumonisins B1 and Ochratoxin A in aqueous solutions. Yeast dried cell mass and wall substance of lactobacillus have ability to merge with mycotoxins. Fungal conidia may bind mycotoxins effectively, especially Zearalenone and Ochratoxins (Jard *et al*., 2009). Probiotic microorganisms (*Saccharomyces cerevisiae* and *Lactobacillus delbrueckii*) were investigated to reduce mycotoxins as biological control agents and found the use of probiotics as an alternative treatment to prevent aflatoxin production in food entities (Silva *et al*., 2015).

Conclusion

Mycotoxicoses may cause severe and deadly diseases. Presence of diverse mycotoxins in food and feed samples may harm to human as well as animal health and also can damage country's economy to great extent. The stringent control of foodstuff quality, in both developing and industrialized regions is very much necessary to avoid cruel and painful circumstances. Sometimes mycotoxin contamination is inevitable and cause huge economic losses. Preventive and corrective measures have great importance regarding the safety of food and feed. There should be strong applicability of rules and regulations in every country to allow the occurrence of permitted limits of these harmful mycotoxins in food and feed stuffs to make food and feed safe. Useful systems like HACCP (Hazard analysis and critical control points) may control the mycotoxins in entire agricultural food chain effectively.

Conflict of Interest. The authors declare no conflict of interest.

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