

MYCOTOXINS: A REVIEW OF TOXICOLOGY, ANALYTICAL METHODS AND HEALTH RISKS

— review —

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Abstract: The present paper focuses on the most important mycotoxins involved in human diseases and on their analysis in foodstuffs. Mycotoxins are metabolites produced by fungi causing acute and chronic adverse effects in humans and animals. The most mycotoxin exposures are chronic generating irreversible effects as cancer or immune suppression, so that mycotoxicoses are sometimes difficult to diagnose. Acute poisoning can be lethal. Some mycotoxins are genotoxic, immunotoxic, allergenic, carcinogenic, mutagenic or teratogenic.

Keywords: mycotoxin, mycotoxicosis, food contamination, fungal species, food safety

INTRODUCTION

Mycotoxin contamination of foods and feeds are among the top priorities for food and human safety. Mycotoxins are toxic agents naturally produced by several types of fungi –species of *Fusarium*, *Aspergillus*, *Penicillium*, *Cladosporium*, *Claviceps*, *Alternaria*, *Helminthosporium* (Steyn, 1971) (Urughucki et al., 1978). These toxins could contaminate a wide range of human foods and domestic animal feeds. Mycotoxin contamination was reported in cereals, legumes and oilseeds, but also in other commodities including fruits and vegetables which are rich in moisture and nutrients-two factors influencing fungi development. The presence of mycotoxins in foods and feeds not only affects economy but also represents a health hazard to

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humans and animals and constitutes a risk for international trade (Cole et al., 1981). Over 300 mycotoxins has been identified in different fungi strains some of them producing mycotoxicosis in humans (Bennett, 1987) (Fun Chu, 2004). Symptoms of mycotoxicosis depend on the type of mycotoxin, exposure duration, species, age, sex, nutritional state (nutrients deficiencies, alcohol abuse) and on the presence of other infectious diseases.

Mycotoxic contamination of crops can occur in the field, during transport and storage (Steyn, 1995). Biosynthesis of mycotoxins which are secondary metabolites is related to some internal factors e.g. genetic potential of fungi, substrate or to factors under which a crop is grown, harvested and stored e.g. oxygen (usually fungi need at least 1-2% O₂), humidity (usually fungi grow at 13-18% moisture), temperature (usually fungi grow at 20°C-30°C), physical damages by insects and other stress factors (Diekman et al., 1992) (Fink-Gremmels, 1999). However some toxigenic fungi can grow also at low temperatures near or below freezing as some species of *Fusarium* associated with alimentary toxic aleukia. Other strains are capable to grow in climate with 0.5% O₂ and 60% CO₂ (Joffe, 1986). Not all the products of fungi are toxic to animals and humans, some of them being used as antibiotics - penicillin produced by *Penicillium chrysogenum* (Diggins, 1999) (Ligon, 2004) or being first isolated as antibiotic - patulin (Ciegler, 1977) (Ciegler et al., 1971).

The most important mycotoxins of worldwide concern regarding food and human safety are produced by *Aspergillus*, *Penicillium* and *Fusarium* species. Their physical properties are presented in table 1.

Table 1. Physical properties of mycotoxins produced by *Aspergillus*, *Penicillium* and *Fusarium* species.

Mycotoxin	Main producing organism	Molecular weight	Melting point, °C
Aflatoxin B ₁	<i>Aspergillus flavus</i> , <i>Aspergillus parasiticus</i> , <i>Aspergillus nomius</i> , <i>Aspergillus niger</i>	312	268-269
Aflatoxin B ₂	<i>Aspergillus flavus</i> , <i>Aspergillus parasiticus</i> , <i>Aspergillus nomius</i> , <i>Aspergillus niger</i>	314	286-289
Aflatoxin G ₁	<i>Aspergillus flavus</i> , <i>Aspergillus parasiticus</i> , <i>Aspergillus nomius</i> , <i>Aspergillus niger</i>	328	244-246

Aflatoxin G ₂	<i>Aspergillus flavus</i> , <i>Aspergillus parasiticus</i> , <i>Aspergillus nomius</i> , <i>Aspergillus niger</i>	330	237-240
Sterigmatocystin	<i>Aspergillus vesicolor</i>	324	246
Ochratoxin A	<i>Aspergillus ochraceus</i>	403	169
Aspergillic acid	<i>Aspergillus flavus</i>	224	93
Kojic acid	<i>Aspergillus fumigatus</i>	142	152.5
Terreic acid	<i>Aspergillus terreus</i>	154	127
Fumagillin	<i>Aspergillus fumigatus</i>	459	190-192
Citreoviridin	<i>Penicillium citreoviride</i>	434	107-110
Citrinin	<i>Penicillium citrinum</i>	250	172
Penicillic acid	<i>Penicillium puberulum</i>	170	83-87
Mycophenolic acid	<i>Penicillium brevicompactum</i>	320	138-142
Griseofulvin	<i>Penicillium janczewski</i>	353	217-224
Rubratoxin A	<i>Penicillium rubrum</i>	442	210-214
Rubratoxin B	<i>Penicillium rubrum</i>	518	168-170
Cyclopiazonic acid	<i>Penicillium cyclopium</i>	336	246
Patulin	<i>Penicillium patulum</i>	154	111
Brevianamide A	<i>Penicillium viridicatum</i>		
Deoxynivalenol	<i>Fusarium graminearum</i> , <i>Fusarium culmorum</i> , <i>Fusarium crookwellense</i>	296	131-135
T-2 toxin	<i>Fusarium poae</i> , <i>Fusarium sporotrichioides</i>	466	150-151
Fumonisin B ₁	<i>Fusarium moniliforme</i> , <i>Fusarium proliferatum</i>	721	powder
Zearalenone	<i>Fusarium graminearum</i> , <i>Fusarium culmorum</i> , <i>Fusarium crookwellense</i>	318	164

The chemical structures of mycotoxins are very complex and diverse so it doesn't exist a unique classification considering this criterium. In the attempt to classify mycotoxins diverse criteria are considered by chemists, biologists, clinicians, biochemists, as chemical structure, fungal species, affected organ or biosynthetic origins. In the present paper, we will not consider a

classification and we will list the major mycotoxins emphasizing on producing fungi, chemical structure, toxicological and health risks aspects.

The most exposure routes to mycotoxins are ingestion of contaminated foods, dermal contamination by skin contact with mold-infested substrates and respiratory contamination by inhalation of spore-borne toxins. When ingesting mycotoxin contaminated food a variety of toxic effects occur in humans and animals, including acute toxicity, carcinogenicity, mutagenicity, teratogenicity, immunosuppressive and/or estrogenic effects (D'Mello et al., 1999) (Hussein et al., 2001). As adverse effects occur at low concentrations, mycotoxins continue to be a public health concern. Research has been conducting worldwide for a better understanding of their mechanism of action, metabolism and establishments of tolerable intakes from food.

Usually legislation is regulated at national levels and refers in particular to aflatoxins. Because of an increased need for a deep understanding of the effects on human health and diseases produced by mycotoxin contaminated foods, international organizations have payed significant attention by government screening, regulation programs and establishments of specialized centers (1997: CRL for mycotoxins in animal products, at the Institute of Public Health and the Environment-The Netherlands; 1994: establishment of WHO Collaborating Center for Mycotoxins in Food, in Germany).

Literature is very abundant in articles and monographs on mycotoxins with a variable scientific quality (Betina, 1984) (Betina, 1989) (Bhatnagar et al., 1992) (Ciegler et al., 1971) (Cole et al., 1981) (Magan et al., 2004). (Sinha et al., 1998) (Smith et al., 1991) (Wogan, 1965) (Wood, 1992) (Wyllie et al., 1977) As mycotoxin is a very complex subject dealing with compounds listing, classification, fungal strains, occurrence in different foodstuffs, clinical manifestations, international regulations, etc. the present paper will attempt to avoid factual errors of earlier reviews and will focus on mycotoxins with great health risk and reviews what is known about chemical structure and biochemistry of these toxins, their producing fungal species, clinical manifestations and toxicological aspects.

Food contamination with mycotoxins is a very complex process and sometimes more than one type of mycotoxin occur as reported co-contamination with aflatoxinB₁/fumonisinB₁ or ochratoxin A/aflatoxin B₁ (Harvey et al., 1989) (Murphy et al., 2006) (Smith et al., 1991). The co-contamination process can lead to extremely toxic interactions.

MYCOTOXINS OF HEALTH HAZARD AND FOOD PRODUCTION IMPACT

In the following section, mycotoxins with significant health and food production impact will be discussed by considering the biochemical, analytical and toxicological points of view.

Aflatoxins

Aflatoxins are metabolites produced by many strains: *Aspergillus flavus*, *Aspergillus parasiticus*, *Aspergillus nomius* and *Aspergillus niger* and less frequently by *Aspergillus bombycis*, *Aspergillus ochraceoroseus*, *Aspergillus nomius*, *Aspergillus pseudotamari* (Goto et al., 1996) (Klich et al., 2000) (Peterson et al., 2001). The biosynthetic pathway of these secondary metabolites is the polyketide route. Aflatoxins commonly contaminate cereals, peanuts, soybeans, figs, dried fruits, chili peppers, green coffee beans and sometimes milk, eggs and meat (Diener et al., 1987). Normally, aflatoxins are produced at 12°C-40°C and at pH from 3.5 to 8.0 (Bakutis et al., 2006). Storage in conditions of high humidity and temperature can increase formation of aflatoxins on commodities.

Chemically, aflatoxins are polycyclic compounds containing a coumarin nucleus fused to a bifuran and a pentanone. These compounds fluoresce strongly in UV light. Originally they were chromatographically separated in four compounds B₁, B₂, G₁ and G₂. Later the metabolic derivatives M₁ and M₂ were detected in milk. The structure of aflatoxins B₁ and M₁ are shown in figure 1.

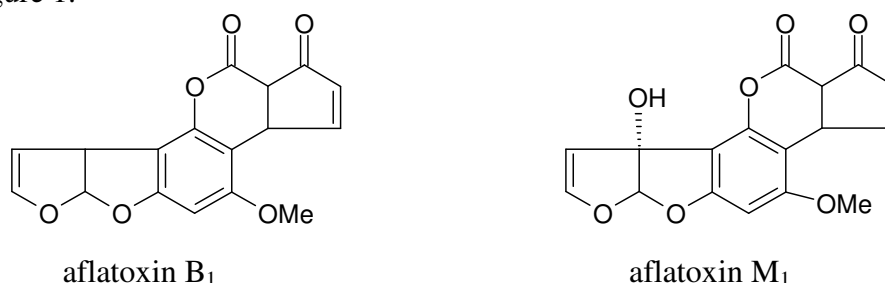


Figure 1. Chemical structure of naturally occurring aflatoxin B₁ and aflatoxin M₁.

Aflatoxins are extremely toxic for all vertebrates from fishes to humans, aflatoxin B₁ being the most naturally occurring carcinogen known (Squire,

1981), but toxicity varies strongly with animal species. For some species the hepatotoxic effect predominates while for others the hepatocarcinogen effect is predominant (Cullen et al., 1994). The hepatic lesions produced by aflatoxins consist in hemorrhagic necrosis, fatty infiltration and bile duct infiltration. The oral LD₅₀ depends on species and type of aflatoxins ranging from 0.5 mg/kg for the duckling to 10 mg/kg for the mouse. Aflatoxins are well-known carcinogen of class 2B (possibly carcinogenic to humans), mutagen and teratogen agents. The toxicity widely varies with dose, age, sex, species, route of administration, exposure to microbial agents, nutritional state and composition of the diet. It was demonstrated that aflatoxins caused cancer in experimental animals and in humans from epidemiological studies. The carcinogenicity of aflatoxins B₁ is due to metabolic activation by cellular enzymes to the corresponding 2,3-epoxide, compound that binds covalently to DNA generating irreversible mutations (Eaton et al., 1994). Aflatoxin B₁-2,3-epoxide can bind also to proteins determining toxic effects. Aflatoxins affects primarily the liver but produces damages also to other organs (kidney, heart, spleen, pancreas).

Because of the great health risk in long-term chronic exposure to extremely low concentrations of aflatoxins (hepatitis, liver cancer, cirrhosis), strict international regulations of food and feed containing aflatoxins were established at regulatory levels (FAO 1995) (Wood, 1989). The national legislation regulates the level of aflatoxin B₁ at 5 ppb in peanuts, nuts, cereals and cereals-based commodities and the level of aflatoxin M₁ at 0.5 ppb in milk (OM 975/1998).

Ochratoxins

Ochratoxins are fungal metabolites of many species of *Aspergillus* in particular *Aspergillus ochraceus*, but also *Aspergillus alliaceus*, *Aspergillus auricomus*, *Aspergillus carbonarius*, *Aspergillus glaucus*, *Aspergillus melleus*, *Aspergillus niger* and *Penicillium* sp. (Abarca et al., 1994) (Bayman et al., 2002) (Ciegler et al., 1972). Normally, ochratoxins are produced at 12°C-37°C but some ochratoxins produced by *Penicillium viridicatum* occur at lower temperatures 4°C-31°C. These toxins consist of a group of seven compounds closely structural related. The most common metabolite and the most toxic is ochratoxin A with a chemical structure consisting of chloro-dihydroisocoumarine linked to L-phenylalanine (Kurata, 1990), as shown in figure 2.

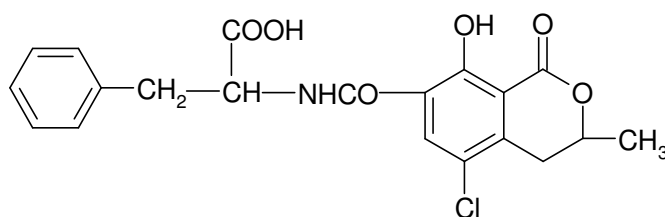


Figure 2. Chemical structure of ochratoxin A.

Ochratoxin A contaminates a wide range of commodities: cereals particularly barley but also nuts, moldy bread, porcine kidney, coffee beans, beer, wines and dried fruits.

Studies on experimental animals demonstrated the nephrotoxic effects on different species, acting at the middle and terminal segments of the proximal convoluted tubules (Scudamore, 1998). Clinical studies have shown that exposure can lead to increased urine volume, blood urea nitrogen, urinary glucose and proteinuria and low activities of enzymes in kidney. Toxin exposure could also induce renal disorders in humans. Ochratoxin A has been suggested to be responsible of Balkan Endemic Nephropathy (BEN) disease (Hult et al., 1982) which is characterized by tubular degeneration, interstitial fibrosis and hyalinization of the glomeruli. Also other factors (genetic factors, heavy metals, other infectious agents) are considered responsible for inducing BEN. Ochratoxin A is rated by the International Agency for Research on Cancer as carcinogen of class 2B (IARC 1993), mutagen and teratogen agent in experimental animals. Genotoxicity assayed by *in vitro* and *in vivo* tests is probably due to the formation of DNA adducts. It was shown that oxidative stress plays an important role in DNA adduct formation and tumor induction in the liver, kidney and testis. Some studies reported also adverse effects on the immune system. Oral LD₅₀ value varies with the species ranging from 0.2 mg/kg in dog to 46-58 mg/kg in mouse (Scudamore, 1998). Biochemically, inhibition of protein synthesis is produced by these toxins as there is a good structure similarity of them to the amino acid phenylalanine. Consequently, ochratoxin A is able also to interact with enzymes that use L-Phe as substrate (Phe-tRNA synthetase, Phe hydroxylase) (Meisner et al., 1981). Another suggested mechanism of action of ochratoxins is free radical formation and induced lipid peroxidation (Rahimtula et al., 1988).

Because of human health risks of ochratoxins, daily tolerable intakes from foods have been established at European and international levels (SCF 1998, JECFA 2001). The provisional tolerable weekly intake established by JECFA in 2001 is 100 ng/kg bodyweight. The tolerable intakes are subjected to modifications as more toxicological data will be available.

Patulin

Patulin is a metabolite produced by certain species of *Penicillium* and also *Aspergillus*. First it was isolated as an antibiotic from *Penicillium patulum* strain but in 1960 was found to be toxic to animals and humans being consequently reclassified as mycotoxin (Ciegler et al., 1971). Patulin contaminates several agricultural commodities (cereals, legumes, fruits), processed products (moldy bread, bakery products, sausages, cheese, tomato paste) and domestic animal feedstuffs. Biosynthesis of patulin is produced at 20 °C-25 °C. Patulin was detected in apples and apple juices, fruits frequently consumed by humans, determining particular safety issues in these products. In most countries, maximum level of patulin in apple juice is regulated in the range of 25-50 µg/kg juice (Doores, 1983).

Chemically, patulin is a β -unsaturated lactone optically inactive (see structure in figure 3).

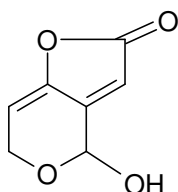


Figure 3. Chemical structure of patulin.

The toxicity of patulin is linked to gastrointestinal disorders. Patulin is considered a possibly carcinogenic agent (IARC 1986). It was found neurotoxic probably due to the inhibition of acetylcholinesterase and NAK-ATPase in the cerebral hemisphere, cerebellum and medulla oblongata. Research studies realized by *in vitro* and *in vivo* tests showed genotoxic and immunotoxic effects of patulin (Magan et al., 2004). Biochemically, patulin reacts with sulfhydryl groups of proteins, inhibiting protein synthesis with consequent decrease of glycogen in liver, kidney and intestinal tissues and also inhibiting enzymes activity (ATPase, alkaline phosphatase, aldolase,

hexokinase). LD₅₀ values vary with animal species ranging from 9 to 55 mg/kg.

The provisional maximum tolerable daily intake of patulin, set by JECFA (1996) and SCF (2000) is 0.4 µg/kg bodyweight.

Fumonisin

Fumonisin are toxins primarily produced by *Fusarium moniliforme* and *Fusarium proliferatum* and *Fusarium nygamai*, as well as *Alternaria alternata* f. sp. *Lycopersici* (Rheeder et al., 2002). Contaminate mostly corn and corn-based human foods and animal feeds. Fumonisin are the most recently characterized mycotoxins, so far being identified 12 fumonisins of related groups A, B, C and P. Several other fumonisin derivatives were detected in corn, as a result of thermal processing.

Chemically, fumonisins are polar compounds with acyclic structures, being diester compounds with different polyhydric alcohols and tricarboxylic acids. The most common and toxic is fumonisin B₁ (macrofusin), with the chemical structure given in figure 4.

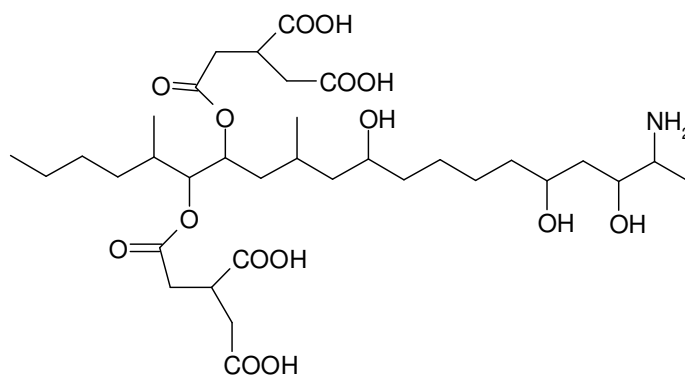


Figure 4. Chemical structure of fumonisin B₁.

Exposure of animal to feeds contaminated with fumonisins leads to equine leucoencephalomalacia (ELEM) (Marasas et al., 1988), porcine pulmonary edema (PPE) and hydrothorax (Harrison et al., 1990), chicken spiking disease (Ledoux et al., 1992). Nervous system, liver and kidney are primarily affected. In experimental animals fumonisins were found hepatotoxic and hepatocarcinogenic agent. Fumonisin are considered risk factors for human health. Epidemiological studies in areas of the world where corn is an essential component of the diet suggested fumonisin-induced human

esophageal and/or liver cancer (Sydenham et al., 1991). Fumonisin is classified as potential carcinogenic agents of class 2B (IARC 1993).

Biochemically, fumonisins act by inhibition of sphingosine N-acetyl transferase, enzyme involved in the *de novo* sphingosine biosynthesis (Merrill et al., 2001). Consequently a cascade of biochemical reactions take place leading to the decrease of cellular sphingolipids and finally to the cell death.

Concentrations of fumonisins in human foods and animal feeds are regulated at European and international level. In human foods the U.S. FDA established level is of 2-4 ppm.

Zearalenone

Zearalenone also known as F-2 toxin is produced by *Fusarium* spp.: *Fusarium tricinctum*, *Fusarium gibbosum*, *Fusarium roseum*. Contaminates cereal crops (corn, barley, wheat, and oats) worldwide but was also detected in milk.

Chemically, zearalenone is a phenolic resorcylic acid lactone as shown in figure 5.

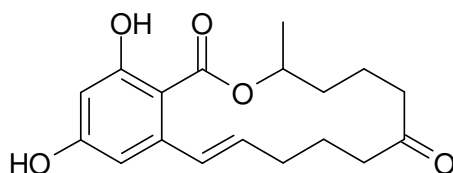


Figure 5. Chemical structure of zearalenone.

Zearalenone and its derivatives produce estrogenic effects in animals: atrophy of seminal vesicles and testes, prostate metaplasia, osteoporosis, vagina hyperkeratosis, endometrial hyperplasia (Kurtz et al., 1978). Biochemically, zearalenone binds to cytosolic estrogens receptor of uterine tissue inducing mRNA synthesis. The zearalenone derivative, zearalenol has an anabolic action by increasing growth hormone and insulin levels. Zearalenone is a potential carcinogenic and teratogenic agent in experimental animals (Pfohl-Leszkowicz et al., 1995), but much evidence is needed to consider this mycotoxin as potential human carcinogen.

Trichothecenes

Trichothecenes are toxins produced by several fungal species as *Fusarium*, *Trichothecium*, *Cephalosporium*, *Trichoderma* (Cole et al., 1981). These toxins contaminate foods and feeds, in particular cereals. From more than 80 trichothecene compounds identified, only a few are toxic to animals and humans. The most common ones that pose a human health risk are T-2 toxin, nivalenol and deoxynivalenol.

Chemically, trichothecenes are sesquiterpenic compounds classified as related groups A (T-2 toxin), B (nivalenol, deoxynivalenol), C (crotocin) and D (with macrocyclic rings) as shown in figure 6.

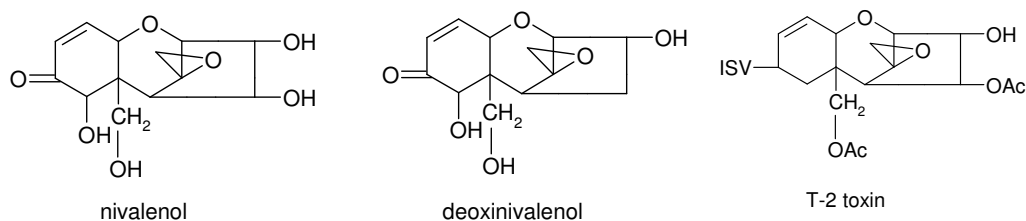


Figure 6. Chemical structures of important trichothecenes from groups A and B.

Trichothecenes are known to induce cytotoxic and immunosuppressive effects affecting primarily bone marrow, spleen and thymus (Scudamore, 1998). T-2 toxin is more toxic than nivalenol and deoxynivalenol having oral LD₅₀ value of 5.2 mg/kg in rat and mouse. T-2 toxin causes gastrointestinal, neurological and dermatological symptoms. Also, it was found responsible of alimentary toxic aleukia disease (ATA) (Beardall et al., 1994). Biochemically, T-2 toxin inhibits protein and DNA synthesis (Stafford et al., 1973) but was not found mutagenic or carcinogenic. More biochemical studies are needed to elucidate the mechanism of action of trichothecenes. However trichothecenes remain of public health concern because of their strongly immunotoxic effects. The Canadian Health Protection Branch established the tolerable daily intakes for adults at 3 µg/kg bodyweight for deoxynivalenol.

ANALYTICAL METHODS

Mycotoxin analysis represents an important tool in controlling fungal contamination of foods and feeds. Numerous chemical and biological

methods have been developed since 1970 for mycotoxin identification and quantification. The methods of analysis are standardized by specific organizations (FDA, USDA, EPA, AOAC). Analytical methodology must permit to determine low concentration of mycotoxins, at least down to regulatory limits.

One important step in mycotoxin analysis regards proper sampling procedures (Whitaker, 2001), which are stipulated by legislation (*Codex Alimentarius*). In many cases, mycotoxins are not homogeneously distributed in commodities so sample must be representative. Sample extraction and preparation are crucial procedures for obtaining reliable analytical results as samples are often varied and very complex matrices. Sometimes mycotoxins must be resolved from cross-reacting or interfering species (proteins) present in the test samples. Analytical procedures include further steps of extraction, purification and determination. Mycotoxin extracts are purified by chromatography (immunoaffinity, HPLC), centrifugation techniques or by passing on prepacked cartridges.

Classical analytical methods for mycotoxin determination include chromatographic techniques (TLC, HPLC, gas-chromatography) (Lin et al., 1998) (Jaimez et al., 2000) (Akyiama et al., 1996) (Onji et al., 2002) and mass spectrometry (Tanaka et al., 2002). TLC methods are widely used in many laboratories as they are costless, rapid and simple techniques, being used for qualitative and quantitative purposes with approximate detection limits of 0.01 ppm. Detection can be done by fluorodensitometry or visual analytical procedures. For complex extracts bidimensional TLC are preferred. HPLC become a very popular chromatographic technique and is often used for aflatoxin analysis with UV fluorescence detection, with limit detection below ng/g product. Gas-chromatography has limited application in mycotoxin analysis as it requires volatilization. Approximate detection limit of 0.0001 ppm can be detected by gas-chromatography coupled to mass spectrometry (GC-MS).

New screening tests for rapid analysis of mycotoxins in foodstuffs are described in literature. These techniques include:

1. Immunological techniques. Immunoassays are highly sensitive, rapid and specific analytical techniques useful for monitoring foods and feeds for mycotoxin contamination. Immunological techniques are binding assays based on monoclonal and polyclonal antibodies (as binding proteins) produced against toxins (as antigens). These techniques can be performed as immunoaffinity column-based analyses (IAC) (Pittet et al., 1996) or enzyme-

linked immunosorbent assay (ELISA) (Aldao et al., 1995). There are numerous commercial tests for rapid analysis of mycotoxins in particular aflatoxins but also fumonisins, ochratoxin, zearalenone, etc.

2. *Biosensors* are used as an alternative rapid screening method that implies measuring the refractive index changes during the interaction of an mycotoxin-conjugate immobilized to the sensor surface with the excess mycotoxin antibody (Mascini, 2001) (Mascini et al., 2001) (Strachan et al., 1997). Other useful biosensors for aflatoxins and fumonisins (evanescent wave fibre optic) are based on optical principles.

3. *Capillary electrophoresis* with fluorescence detection (Maragos et al., 1996). The method is used to detect mycotoxins at trace levels by laser-induced fluorescence.

4. *Chemiluminescence and bioluminescence assays* (Sarter et al., 2004). Luminescence techniques are sensitive, rapid and reliable detection methods used in mycotoxin testing. The chemiluminescent method is based on a luminescent reaction and detection of antigen-antibody binding at the final stage of an immunoenzymatic assay. Detection of the fungi present in a test sample is realized by bioluminescence technique based on the reaction between microbial ATP and luciferase to produce luminescence.

CONCLUSIONS

Mycotoxins are toxic agents produced by toxigenic fungi. They are commonly formed in field crops and can contaminate a large number of commodities in particular cereals, nuts, dried fruits and spices. Mycotoxin contamination of foodstuffs and feedstuffs continues to represent an economic and health risk. The present article reviews biochemical, toxicological and analytical data of main mycotoxins currently considered of importance for human and animal safety. Concern about safety of foods has given rise to an increased development of new analytical methods for mycotoxin and their metabolites determination at low detection limits. International and european legislation regulates the maximum permitted limits of mycotoxins in foods and feeds. Food industry has implemented HACCP systems to help mycotoxin control in the whole agrifood chain.

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