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MYCOTOXINS: RISKS, REGULATIONS AND EUROPEAN CO-OPERATION

ABSTRACT: Mycotoxins and mycotoxicoses have been problems of the past and the present, but scientific attention for mycotoxins did not start until the early 1960's. Nowadays, many mycotoxins are known, and their occurrence in food and animal feed may cause various adverse effects on human and animal health, including carcinogenic, hepatotoxic, immunotoxic, nephrotoxic, neurotoxic, oestrogenic and teratogenic effects. Some important mycotoxins include the aflatoxins, ochratoxin A, the fumonisins and the trichothecenes, and their significance is briefly described. To protect human and animal health, many countries have enacted specific regulations for mycotoxins in food and animal feed. Risk assessment is a major factor for scientific underpinning of regulations, but other factors such as availability of adequate sampling and analysis procedures also play an important role in the establishment of mycotoxin regulations. In addition, socio-economic factors such as cost-benefit considerations, trade issues and sufficiency of food supply are equally important in the decision-taking process to come to meaningful regulations. Nowadays, more than 100 countries have formal mycotoxin regulations for food and feed. The mycotoxin regulations are the most stringent in the EU, where various organizations and pan-European networks contribute to combat the mycotoxin problem. It is to be expected that mycotoxins will stay with us in the future and climate change might have a negative influence in this respect. Several possibilities exist to mitigate the problems caused by mycotoxins. In particular prevention of mould growth and mycotoxin formation is key to the control of mycotoxins.

KEYWORDS: aflatoxin, climate, Europe, fumonisin, mycotoxin, ochratoxin, prevention, regulation, risk, trichothecene

INTRODUCTION

Mycotoxins are secondary metabolites of fungi which are capable of producing acute toxic, carcinogenic, mutagenic, teratogenic and estrogenic effects on animals at the levels of exposure. Mycotoxins occur worldwide and they are considered significant food and feed safety issues. Mycotoxins form an important class of the natural toxins – toxic substances of natural origin. The natural toxins also include the bacterial toxins, the phycotoxins, the plant toxins and the animal toxins. Toxic symptoms resulting from the intake of mycotoxins by man and animals are known as “mycotoxicoses”.

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Mycotoxicoses have been known for a long time, and they have been described in history many times. The first recognized mycotoxicosis was probably ergotism (Tulasne, 1853), better known as “Saint Anthony’s fire” or “Holy fire”. The disease, caused by ergots alkaloids formed in the sclerotia of the fungus *Claviceps purpurea* was already described more than 1000 years ago. This disease, leading to gangrene, loss of limbs and hallucinations, often occurred in Europe in the Middle Ages. In 1890 cardiac beriberi (yellow rice disease) was described in Japan, caused by citreoviridin, a neurotoxin produced by *Penicillium citreo-viride* (Kinosita and Shikata, 1965). The ingestion of “yellow rice” by men caused vomiting, convulsions and ascending paralysis. Death could also occur within 1–3 days after the appearance of the first signs of the disease. In 1913 and again in 1944 Alimentary Toxic Aleukia broke out in Russia, due to the consumption of overwintered wheat which contained high levels of trichothecenes, produced by *Fusarium sporotrichioides* (Mayer, 1953). These toxins caused hemorrhages and malfunctioning of the human immune system, leading to many fatalities in Russian villages (Joffe, 1965). In 1952 Balkan Endemic Nephropathy was described for the first time. This disease is characterized by severe shrinkage of the kidneys, leading to human death. Ochratoxin A, produced by e.g. *Penicillium verrucosum* is, among other components, considered responsible for this serious disease.

Despite many examples of mycotoxin-caused diseases in men, mycotoxicoses remained the “neglected diseases” until the early 1960’s, when Turkey X Disease in Great Britain broke out, and within a few months more than 100,000 turkeys and other poultry suddenly died, mainly in East Anglia and southern England (Stevens et al. 1960). The problem of Turkey X Disease led to a multidisciplinary approach to investigate the cause of the disease. These efforts were fruitful and the cause of the disease was found to be due to aflatoxins, highly toxic and carcinogenic compounds, found in the Brazilian groundnut meal fed to the poultry. The aflatoxins were mainly formed by two fungi, *Aspergillus flavus* and *Aspergillus parasiticus*, and hence the name ‘aflatoxin’ – an acronym derived from the name of the first fungus. Further elucidation of the toxic factor demonstrated that the material could be separated chromatographically into four distinct spots (Nesbitt et al., 1962). Distinction of the four substances (aflatoxins B₁, B₂, G₁ and G₂) was made on the basis of their fluorescent colour with subscripts relating to the relative chromatographic mobility.

In the period following the outbreak of Turkey X disease, a wealth of information about the aflatoxins has been produced, and many other mycotoxins have also been isolated and characterized. Since the discovery of the aflatoxins, tens of thousands of publications on mycotoxins have been published, dozens of mycotoxin conferences have been held, several international organisations got involved with mycotoxins, thematic interlaboratory research and networking projects have been initiated, professional networks have been founded and mycotoxin-dedicated scientific journals were created. Moreover, the growing knowledge about the real and potential hazards of mycotoxins to human and animal health led many countries to establish legal measures to control mycotoxin contamination of foodstuffs and animal feedstuffs.

SOME IMPORTANT MYCOTOXINS AND THEIR CHARACTERISTICS

Currently hundreds of mycotoxins are known, many of these are produced by *Aspergillus*, *Penicillium* and *Fusarium* species. Some important mycotoxins formed by these genera include the aflatoxins, the ochratoxins, the fumonisins and the trichothecenes. They probably play a role in serious human and animal diseases. Without intentionally ignoring the potential significance of the many other mycotoxins that exist, only these mentioned mycotoxins will be briefly reviewed hereafter.

Aflatoxins

Aflatoxin B₁ (Figure 1) is the most notorious of the aflatoxins, feared for its high toxicity and carcinogenicity to humans and animals. Aflatoxins are found worldwide, especially in warm and humid climate zones. Aflatoxins have also recently caused fatal human intoxications. For instance, human aflatoxicosis has occurred several times in Kenya in the last decade, due to human consumption of aflatoxin-contaminated maize, leading to more than 100 fatalities in 2004, including many children. Whereas the aflatoxins were not found in Europe until the turn of the millennium, they were detected in maize in Northern Italy a decade ago, and subsequently in milk from dairy cattle fed with this maize. Since then their occurrence gradually spread over south-eastern Europe, a phenomenon which is possibly due to climate change. Also in the Balkan, where a lot of maize is produced, the occurrence of aflatoxins have become an issue of concern, including problems with exports to the EU in 2013. An important feature in dairying is the fact that aflatoxin B₁ shows a significant carry-over (up to 6%; Veldman et al., 1992) into the milk in its hydroxylated form aflatoxin M₁ (figure 1). Aflatoxin M₁ is a suspected human carcinogen and its occurrence in milk and milk products should therefore be limited as much as possible.

Ochratoxin A

Ochratoxin A, formed from isocoumarin and phenylalanine (Figure 2) is another carcinogenic mycotoxin, produced by *Aspergillus* and *Penicillium* species, *A. ochraceus* and *P. verrucosum* in particular. *Penicillium* tends to be more prevalent in cooler climates and *Aspergillus* in warmer climates. Ochratoxin A has been found in many countries. The toxin is a renal carcinogen in mice and rats and it is nephrotoxic in all animal species tested, while pigs are particularly sensitive. Ochratoxin A is also highly immunotoxic in mice. In addition, it has been associated with Balkan Endemic Nephropathy (BEN), a human kidney disease leading to shrinkage of the kidneys. It has also been related with the occurrence of urogenital tract tumors in animals and possibly in humans. Nowadays, it is believed that also other compounds may play a

role in the etiology of BEN, e.g. aristolochic acid, a toxic plant constituent (Schmeiser et al., 2012). The main route of human exposure to ochratoxin A is through consumption of vegetable products, contaminated with ochratoxin A (e.g. cereals, coffee, cocoa, beans, wine, beer, spices, dried vine fruit, liquorice), but it can also occur by transfer via animals such as pigs. Pig blood and plasma are used in the preparation of various sausages, thus meat products can become contaminated with this toxin.

Fumonisin B₁

Natural occurrence of fumonisins is specifically associated with maize, where they are produced specifically by *Fusarium verticillioides* and *F. proliferatum*. Fumonisin B₁ (Figure 3) is the most significant of the fumonisins in terms of occurrence and toxicity. Contrary to most of the other mycotoxins, the fumonisins do not have cyclic structures, but possess long aliphatic chains with two ester-linked hydrophilic side chains and a primary amine moiety. Fumonisin B₁ can induce hepatic cancer in rats and epidemiological studies suggest a possible role in human esophageal cancer in Africa and Asia. In husbandry animals, dramatic effects caused by fumonisin B₁ in the feed have been observed in horses and pigs. In horses leukoencephalomalacia (ELEM or hole-in-the-head syndrome) has been described, a neurological disorder in the brains, which may lead to death within 2-3 days. In pigs fumonisin B₁ may cause pulmonary edema, a fatal disease in which the animals' lungs are filled with fluid. Residues of fumonisins are not known to occur in animal products such as meat, milk and eggs and this is not an issue of potential concern.

Trichothecenes

Trichothecenes constitute a family of more than 100 structurally related compounds, primarily produced by *Fusarium* species. Deoxynivalenol (Figure 4) is the most commonly occurring trichothecene, detected frequently in maize, wheat and barley, in virtually all regions of the world. The toxin is particularly produced by *F. graminearum* and *F. culmorum*. Deoxynivalenol exhibits toxic effects in all animal species investigated and like most of the mycotoxins it has an adverse effect on the immune system. The susceptibility to deoxynivalenol may vary among species, and pigs are particularly sensitive, where the intake of the toxin may lead to nausea, vomiting (deoxynivalenol = vomitoxin), feed refusal, reduced feed intake and weight reduction. These phenomena may lead to significant economic damage in the feed industry. The emetic effect also occurs in humans, and vomiting is one of the earliest symptoms of trichothecene poisoning. The exposure of children to deoxynivalenol may lead to growth retardation. Carry-over of deoxynivalenol from animal feed into animal products hardly occurs. Deoxynivalenol survives some food processing, such as milling, baking and boiling.

MYCOTOXIN REGULATIONS

The first food regulation was probably promulgated approx. 3500 years ago by a king of the Hittites in what is now Turkey. That law already focused on the two goals of modern food laws: the protection of health and the prevention of fraud. In the early days of food legislation the protection of health was mostly a local affair, and municipal ordinances were promulgated for the purpose. But in the beginning of the 20th century this situation changed and national statutory food legislation was enacted, thanks to the development of auxiliary sciences such as chemistry, bacteriology and microscopy. Specific mycotoxin regulations did not appear until the late 1960s, approx. 10 years after the discovery of the aflatoxins. Around the turn of the millennium regional harmonization of mycotoxin regulations in food and feed started to take place in the EU (European Union), MERCOSUR (Mercado Comun del Sur), Australia/New Zealand, GCC (Gulf Cooperation Council), ASEAN (Association of South East Asian Nations) and COMESA (Common Market of Eastern and Southern Africa).

A most important factor for drafting meaningful mycotoxin regulations is risk assessment, which is the scientific underpinning of regulations and limits. Formal health risk assessments have been carried out by authoritative international organizations, such as JECFA (FAO/WHO Joint Expert Committee on Food Additives and Contaminants) and EFSA (European Food Safety Authority). Risk assessment involves a number of steps: hazard identification, hazard characterization, exposure assessment and risk characterization. Risk assessment is one of the pillars of the Risk Analysis Framework, the other pillars are risk management and risk communication. Whereas risk assessment is primarily the responsibility of scientific committees, risk management is primarily the responsibility of regulators and policy makers. Risk communication is the communication between risk assessors and managers, and with the public.

In addition to hazard assessment and exposure assessment other factors are also important when it comes to the establishment of mycotoxin regulations in food and feed. These include the availability of methods of sampling and analysis. The distribution of the concentration of mycotoxins in products is an important factor to be considered in establishing regulatory sampling criteria. The distribution can be very heterogeneous, as is the case with aflatoxins in peanuts and figs. The number of contaminated peanut kernels in a lot is usually very low, but the contamination level within a kernel can be very high. If insufficient care is taken for representative sampling, the mycotoxin concentration in an inspected lot may therefore be wrongly estimated. Reliable analytical methods will have to be available to allow enforcement of the regulations in daily practice. In addition to reliability, simplicity is desired, as it will influence the amount of data that will be generated and the practicality of the ultimate measures taken. Socio-economic factors play an important role, such as cost-benefit considerations and trade issues. Finally, there must be sufficiency of food supply, which can be a problem in the developing coun-

tries that may be faced with shortage of food and severe mycotoxin problems in their food and feed supply at the same time. Weighing the various factors in the decision-taking process to come to regulations is not a trivial task, and common sense is a major factor in reaching a decision. Despite the dilemmas, many countries have established formal mycotoxin regulations and limits.

Over the years there have been several international inquiries on mycotoxin regulations, from 1981 to 2012. These yielded details about tolerances, legal bases, responsible authorities and official protocols of sampling and analysis, and have resulted in various publications, e.g. by FAO (2004) and by Van Egmond et al. (2007). In 2013 there were more than 100 countries worldwide that have enacted regulations or detailed guidelines for the control of mycotoxins in food and animal feed. These regulations are related to aflatoxins (B₁, B₂, G₁, G₂), aflatoxin M₁, trichothecenes (deoxynivalenol, diacetoxyscirpenol, T-2 toxin and HT-2 toxin), fumonisins (B₁, B₂, B₃), agaric acid, ergot alkaloids, ochratoxin A, patulin, phomopsins, sterigmatocystin and zearalenone.

When reviewing the existing legislation on mycotoxins in certain parts of the world, it can be observed that mycotoxin regulations develop continuously. In Europe for instance, and particularly in the European Union, the regulatory and scientific interest in mycotoxins has undergone a development in the last 15 years from autonomous national activity towards more EU-driven activity with a structural and network character. In 2013 harmonized EU limits exist for 63 mycotoxin-food/feed combinations. In addition, harmonized guidance limits are in place for 18 mycotoxin-feed combinations, while indicative levels for 15 mycotoxin-feed combinations have been set. The direct or indirect influence or involvement of European organisations and programs in the EU mycotoxin regulatory developments is significant. They include the Rapid Alert System for Food and Feed (RASFF), the European Food Safety Authority (EFSA), the European Standardization Committee (CEN) and the EU and National Reference Laboratories for Mycotoxins (EU-RL and NRLs); see also next section “EUROPEAN CO-OPERATION”.

Regulatory limits on mycotoxins in food and feed are under constant debate among trading countries. Their enactment has increased awareness of the issues caused by mycotoxins and has led research, industry and policy makers to work on solutions to combat the problems.

EUROPEAN CO-OPERATION

Since the discovery of the aflatoxins, several international organizations got involved with mycotoxins, thematic interlaboratory research and networking projects have been initiated and professional networks have been founded. Moreover the growing knowledge about the real and potential hazard of mycotoxins to human and animal health led many countries to establish legal measures to control mycotoxins in foodstuffs and animal feedstuffs. Especially

in Europe various activities take place to combat the mycotoxin problem. Examples of European collaboration on mycotoxin issues can be found in the Rapid Alert System for Food and Feed, the European Food Safety Authority, the European Committee for Standardization and the EU- and National Reference Laboratories for Mycotoxins.

Rapid Alert System for Food and Feed

Already for several decades the European Union has a rapid alert system for the risk of contaminants in food and feed (RASFF) that are harmful to human health. The system involves a quick information exchange among the competent authorities of the Member States (including EFTA/EEA countries), the European Commission itself and the EFSA. In the case of problems in the food chain of direct risk to human health, the RASFF facilitates that necessary measures can be taken to recover the consumer safety. In 2011, the RASFF received over 600 border rejection notifications connected to risks for human health by mycotoxins. Figure 5 shows that the problems with mycotoxins were much greater than those of other food and feed menaces. Almost 90% of these mycotoxin notifications were related to aflatoxins in the product group of nuts (pistachio nuts, peanuts, hazelnuts, almonds) and nut products (peanut butter) which were imported in 2011 in the EU. The RASFF notifications provide useful data for the development of new EU regulations and safeguard measures, and thus contribute to the improvement and maintenance of European food safety.

European Food Safety Authority

The European Food Safety Authority (EFSA) is an independent body of the European Commission, established in 2002 and, among other tasks, charged with the development of risk assessments on issues of concern in the food and feed supply. EFSA publishes its advices in the form of scientific opinions, which form the main scientific basis for the preparation of EU regulations (Anonymus, 2006). Opinions about risks of mycotoxins in food and feed are adopted in EFSA's Panel on Contaminants in the Food Chain, and are based on comprehensive documents produced in dedicated working groups of European experts. Over the years EFSA has published various opinions on its website and in the EFSA Journal about mycotoxins in food and animal feed, and several more are in preparation. Published EFSA mycotoxin risk assessments include those about aflatoxins, *Alternaria* toxins, citrinin, ergot alkaloids, fumonisins, ochratoxin A, phomopsins, several trichothecenes and zearalenone. EFSA opinions are quite influential in the decision-making process by European risk managers to come to meaningful EU-harmonized mycotoxin regulations and limits.

European Committee for Standardization

The European Committee for Standardization (CEN) is the European equivalent of ISO. Among other tasks, CEN standardizes mycotoxin methods, which are selected according to a performance criteria approach. In Europe, CEN methods are getting increasingly important. Currently, 22 mycotoxin methods have been standardized by CEN, and their number will further grow in the coming years. CEN mycotoxin methods are not mandatory for official food control in the EU. However, all CEN mycotoxin methods can be used in the EU for official food control purposes because their performance characteristics fulfil the criteria, laid down in the EU directives for sampling and analysis (Commission of the European Communities, 2006a). Regulation EC no. 882/2004 (European Commission, 2006b) provides that sampling and analysis methods used in the context of official controls shall comply with relevant Community rules or if no such rules exist, with internationally recognized rules or protocols, for example those that CEN has accepted. The view of the European Commission on CEN standards is clear: *“The establishment of standardized methods of analysis is of utmost importance to guarantee a uniform application and control of the European legislation in all Member States. Standardized methods of analysis are an indispensable element in guaranteeing a high level of food safety”*.

EU- and National Reference Laboratories for Mycotoxins

The European Commission’s Joint Research Centre/Institute for Reference Materials and Measurements (Geel, Belgium) fulfills the role of EU Reference Laboratory (EU-RL) for Mycotoxins. These tasks are related to mycotoxins in vegetable products, and human exposure through this route is in fact, much more significant than the indirect exposure through carry-over of mycotoxins from feed into animal products. However, the latter route is also considered relevant (e.g. in relation to aflatoxin M₁ in dairy products) and the RIKILT Institute of Food Safety (Wageningen, the Netherlands) is formally charged with the task of EU-RL for mycotoxins in products of animal origin. The tasks, duties and requirements for EU-RLs for food and feed and for animal health have been published (Commission of the European Communities, 2006b). The EU-RL for mycotoxins has been created in order to take, among other duties, initiatives and to co-ordinate activities related to the development, improvement and application of sample preparation and methods of analysis for the official control of maximum levels for mycotoxins in food and feed. Among the tasks mentioned is the function *“to provide technical assistance to the Commission and, upon its request, to participate in international forums relating to the area of competence, concerning in particular the standardization of analytical methods and their implementation”*. So, it is evident that the link with the European Standardization Committee (CEN) is important.

In addition to these structural Europe-coordinated activities, several EU projects in the 7th Framework Programme had a strong focus on mycotoxins, such as CONffIDENCE and MycoRed. CONffIDENCE (www.confidence.eu) was a Large Collaborative Project in the Food, Agriculture and Fisheries, and Biotechnology Program, focusing on the development and validation of simple, fast, multi-analyte, multi-class detection methods. The project, which ended in late 2012, contained a Work Package Biotoxins, in which (among many other tasks) a multiplex dipstick method was successfully developed and validated, able to simultaneously detect the *Fusarium* mycotoxins deoxynivalenol, zearalenone, T-2 and HT-2 toxins, and fumonisins. MycoRed (www.mycored.eu) is another Large Collaborative Project in the same program, dedicated to the “Reduction of mycotoxins in food and feed chains”. In MycoRed the focus is on aflatoxins, ochratoxin A, trichothecenes, zearalenone and fumonisins, and a lot of research was devoted to prevention and reduction of mycotoxin formation. Within the successful project, which finishes in late 2013, various international mycotoxin workshops and conferences were also organized in Europe, Asia, Africa and Latin America. These and other EU-sponsored research and networking projects, in their own right and collectively, are very valuable to increase our knowledge, to advance the analytical state-of-the-art and to create strong networks of collaboration on mycotoxins in Europe and beyond.

CLIMATE CHANGE, PREVENTION AND CONTROL

A contemporary issue that also has a potential influence on mycotoxins is climate change. Due to this phenomenon changes, may occur in the latitudes where certain fungi are able to compete. An example is the increasing occurrence of *Fusarium graminearum*, a nivalenol producer, in certain areas in Europe. Climate change may also lead to drought and flooding, which may result in the occurrence of more mycotoxins and changed toxin profiles. For example, since about 10 years ago aflatoxins have been found in south-eastern Europa in particular in maize, and the affected areas are becoming larger. Increases of plant diseases and insect manifestations are also expected as a result of climate change, and these may have a significant effect on mycotoxins as well.

Potentially successful measures to combat and control mycotoxins include (but are not limited to) the following:

- Prevention; possibilities exist with programs to develop plants resistant to certain fungi, to improve the proper application of fungicides, and to control insects, which may act as vectors of fungal spores and may damage crops.
- Improved agricultural practices; e.g. application of irrigation of maize may assist in preventing damage from drought stress, which may lead to significantly increased aflatoxin formation.

- Biocontrol; biocompetitive exclusion is a newer technique, where non-toxicogenic fungal strains are inoculated in the field to outcompete toxicogenic strains. Successful application has been achieved in Nigeria with non-aflatoxigenic strains in maize and peanuts producing areas.
- Development of predictive models; theoretical models have been developed, e.g. at RIKILT, that forecast the occurrence of emerging mycotoxins in food and feed chains at an early stage so that timely management measures can be taken to minimize their impact on food and feed safety.
- Post-harvest; it is essential that agricultural harvest is rapidly dried and stored under cool and dry conditions to avoid fungal growth and mycotoxin production.
- Hygienic conditions at storage; not only control of water activity and temperature are important, but possibilities of (re-) infection by moulds must be excluded as good as possible.
- HACCP in production chains, novel food processing; the rigorous application of Hazard Analysis Critical Control Point procedures at diverse stages of the food and feed production and processing chain is recommended to achieve final products that fulfill to desired criteria with respect to Mycotoxin contamination. The development of novel food processing techniques that exclude the possibility of fungal re-infection can be also effective.
- Cleaning, sorting, application of decontamination systems; various physical, chemical and biological procedures have been developed to reduce or degrade mycotoxin contamination of food and animal feed. Not all of them are (economically) feasible in practice, and they should be considered with care.
- Improved methods to detect fungi; their application by phytopathologists may help others to be alarmed at an early stage that undesired fungi are developing or have developed, able to produce mycotoxins.
- Improved sampling and analytical methods for mycotoxins; errors made in sampling and in analytical methodology can be quite substantial, and provide little comfort for those who must pay for analytical measurements, or who base potentially important decisions on the data generated.
- Drafting of regulations; whilst mycotoxin regulations themselves will not directly lead to reduction of mycotoxins, they may force food and feed business operators to apply good agricultural, good manufacturing, good storage and good hygienic practices with regard to mycotoxins, eventually leading to reduced chances of undesired human exposure.
- Training, education and networking; awareness, experience, capacity-building and international collaboration are all essential elements in the combat of mycotoxins, both at local and at global level.

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Figures:

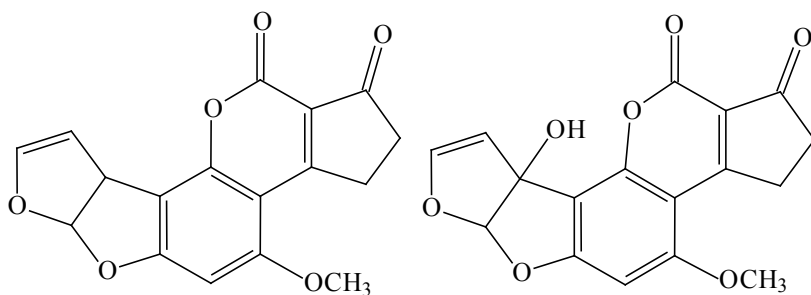


Figure 1: Chemical structures of aflatoxin B₁ (left) and aflatoxin M₁ (right)

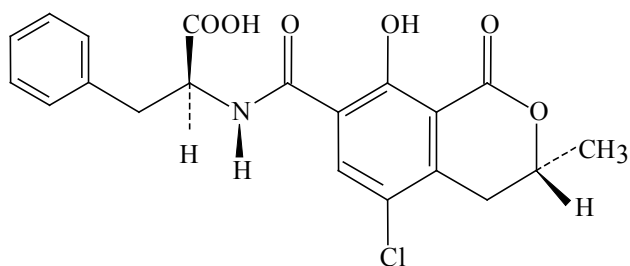


Figure 2: Chemical structure of ochratoxin A

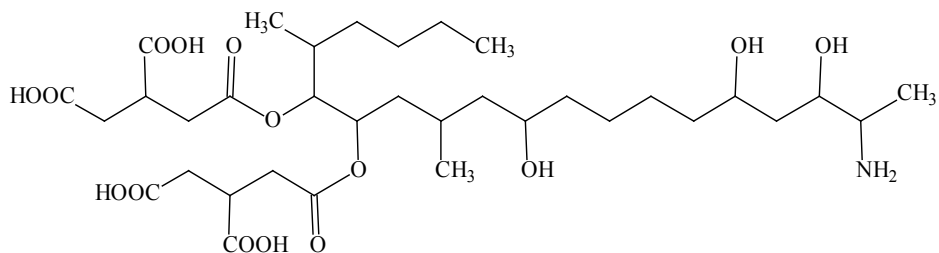


Figure 3: Chemical structure of fumonisin B₁

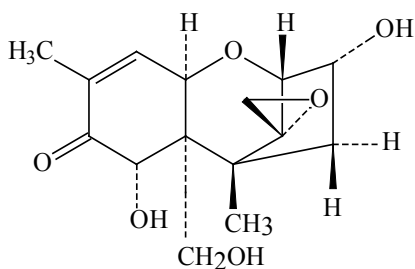


Figure 4: Chemical structure of deoxynivalenol

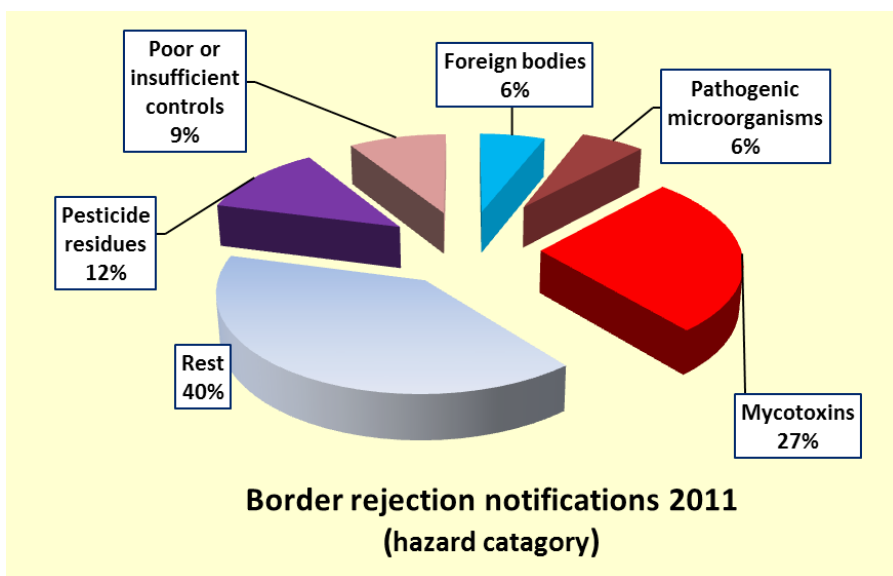


Figure 5: Rapid Alert System for Food and Feed: Border rejection notifications 2011

МИКОТОКСИНИ: РИЗИЦИ, ПРОПИСИ И ЕВРОПСКА САРАДЊА

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Пословна јединица за загађиваче и токсине

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РЕЗИМЕ: Микотоксини и микотоксикозе као и данас, и у прошлости су представљали проблем, али научног интересовања за њих није постојало све до почетка шездесетих година прошлог века. Многи микотоксини данас су познати, а њихова појава у храни за људе као и у храни за животиње може да изазове различите негативне ефекте на здравље људи и животиња, укључујући канцерогене, хепатотоксичне, имунотоксичне, нефротоксичне, неуротоксичне, естрогене и тератогене ефекте. Неки од важних микотоксина су афлатоксин, охратоксин А, фумонизин и трихотецен, а њихов значај је укратко описан. Да би заштитиле здравље људи и животиња, многе земље донеле су посебне прописе за микотоксине у храни за људе и у храни за животиње. Процена ризика главни је фактор за научну потврду прописима, али и други фактори као што су доступност адекватног узорковања и анализа процедура који такође играју важну улогу у формирању прописа у вези са микотоксинима. Поред тога, социо-економски фактори, као што су трошкови, трговина и довољна снабдевеност храном, подједнако су важни у процесу доношења одлука да би се донели важни прописи. Данас више од 100 земаља има формалне прописе у вези са микотоксинима у храни за људе и храни за животиње. Прописи у вези са микотоксинима најстрожији су у ЕУ, где различите организације и пан-европске мреже доприносе борби против проблема

микотоксина. Треба очекивати да ће микотоксина бити и у будућности, а климатске промене могу да имају утицај у том погледу. Постоји неколико могућности за ублажавање проблема изазваних микотоксинима. Спречавање појаве плесни и формирања микотоксина кључно је за контролу микотоксина.

КЉУЧНЕ РЕЧИ: афлатоксин, клима, Европа, фумонизин, микотоксин, охратоксин, превенција, пропис, ризик, трихотецен