MYCOTOXINS IN FOODS, FEEDS AND THEIR COMPONENTS

MIKOTOKSINI U HRANI, KRMNIM SMJESAMA I KRMIVIMA

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SUMMARY

Mycotoxins are toxic secondary metabolites formed by toxigenic fungi present in foods, feeds and their components. Since the presence of the above mentioned microorganisms is unavoidable, mold growth is an inevitable consequence of conditions advantageous for fungi development (water content and temperature) found in case of specific food and feed technologies. Mycotoxins identified up to now (several hundred) are molecules of different chemical structures and molecular weight up to 500 Da. An attempt to explain why biosynthesis of so many toxic metabolites – are the consequence of primary metabolism – is necessary for fungi will be discussed.

Exposure of human beings and animals to the above compounds causes undesirable effects, with a broad variety of biological effects and – as a consequence – chronic diseases called mycotoxicoses. The most important genera of toxigenic and pathogenic fungi *Aspergillus, Fusarium* and *Penicillium* will be characterized, especially concerning conditions of rapid growth and development followed by biosynthesis of a variety of mycotoxins.

The above microorganisms are related – during vegetation – to plant oxidative stress induced by weather and environment conditions. The above as well as biosynthesis of the metabolites will be discussed.

Rapid development of fungi followed by toxin formation causes a reduction of crop yields, a deterioration of their quality and as a consequence results in significant economic losses, as worldwide approximately 25% of crops are affected by mycotoxins annually. Presented results will confirm that six metabolites (aflatoxins B_1, ZEA, DON, fumonisins, T-2 toxin and OTA) in diverse materials (matrices) represent a real problem throughout the world. Occurrence and concentration levels are variable for different mycotoxins and are closely related to the weather conditions and plant stress responsible for the metabolite formation, which will be highlighted. Levels of safety will be discussed with the emphasis on low doses which cause subclinical losses. Most of the diseases occur after consumption of mycotoxin-contaminated grains or their products, but other routes of exposure also exist. The diagnosis of mycotoxicoses is dependent upon adequate testing for mycotoxins, involving sampling, sample preparation and analysis. Information on mycotoxin contamination of foods, feeds and their components as well as relevant data on new sources of contamination will be given.

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Methods of decontamination are usually difficult, so prevention of mycotoxin formation is of prime concern. Results on breeding of cereal varieties resistant to pathogenic fungi and biosynthesis of toxic secondary metabolites (mycotoxins) will be presented with an emphasis on the reduction of human and animal health risk. Recent results indicating the importance of mycotoxins in Poland (compared to world data) are planned to be discussed.

Key words: mycotoxins, foods, feeds, feed components

INTRODUCTION

Mycotoxins as secondary metabolites of fungi may be formed in many agricultural crops and what is more – it happens at different stages, starting from the growth phase of a given plant, through harvest to storage. A broad spectrum of action in the case of these toxins and generally their high resistance to high temperature result in a situation when the presence of mycotoxins in food and forage is recognized as a serious threat to human and animal health.

Mycotoxins are not a new problem in foods and feeds, and some researchers suggest that they were first observed after the Flood reported in the Bible. However, a correlation of disease symptoms in humans and/or animals with the occurrence of pathogenic fungi and their metabolites was reported for the first time at the beginning of the twentieth century.

For many years studies on mycotoxins have not been successful because the metabolites are present in the matrix (usually at ppb or ppm levels) in much lower concentrations than other biologically active compounds recorded in samples. A necessary pre-condition of mycotoxin biosynthesis is the presence of toxigenic fungi in the environment. Very important factors facilitating mycotoxin formation include substrate, temperature and humidity. Under ambient temperature and high humidity, rapid growth and development of the fungus on the host tissue may easily be observed. A fungus having a new source of energy (organic matter) develops rapidly, using and transforming the host tissue into energy, simultaneously forming mycotoxins. One of the theories explaining why biosynthesis of these toxic compounds by fungi is observed is that an increasing concentration of by-products of primary metabolism (delivering energy) such as acetates, malonates and propionates — according to Le Chatelier's principle — stops reactions of primary metabolism. Since energy is necessary for the life of the fungus (to maintain metabolism), secondary metabolism with the biosynthesis of mycotoxins is initiated, originating from the above-mentioned anionic residues as the reaction substrate. That is why so many toxic metabolites may be formed by fungi, with some repeating similarities in their chemical structures, as in the case of trichothecenes group A and B, ochratoxins, and fumonisins.

DISCUSSION

Global changes in climate conditions, together with an increasing exchange and trade of goods, are the factors responsible for worldwide distribution of fungi previously typical of certain zones only. In the last decade, especially after the introduction of extrusion in feed and feed component preparation (many feed producers still believe that extrusion is a panacea for all food/feed contaminants, including mycotoxins), the situation started to deteriorate. Since cereals (including maize) were introduced (to replace meat) to pelleted pet food for species belonging to *Carnivora* (cats and dogs), zearalenone has been found in pet food and in animal tissue (Goliński and Nowak 2004, Goliński et al. 2005, 2009). The reason is that cereals used in the production of such feeds, especially com, are very susceptible to infection with pathogens (*Fusarium culmorum* and *F. graminearum*), followed by *Fusarium* cob blight and zearalenone biosynthesis, which in consequence results in toxin (ZON) residues in animal tissue (Goliński et al. 2009). This leads to the conclusion that nature should not be considered as a static, but rather a dynamically changing medium - what was true 20 - 30 years ago is not necessarily true nowadays. Fungi (similarly to other living organisms), competing for energy (organic matter) under changing global climate conditions change the distribution of mycoflora in our environment. As it often happens, metabolites known for many years emerge as new problems. Thus, it is advisable to consider screening analyses of both toxigenic fungi present in agricultural products and mycotoxins contaminating foods and feeds that are of prime concern in human health protection and in the reduction of economic losses in the agricultural sector (Binder et al. 2007, Waśkiewicz et al. 2012a).

The most common toxigenic fungi found in Poland include numerous species of genera *Penicillium*, *Aspergillus* and *Fusarium* (Chełkowski et al. 2000, Goliński et al. 2002, 2010, Kiecana et al. 2002). Since *Fusarium* species have usually been associated with cereals of temperate zone, their growth and biosynthesis of mycotoxins require considerably lower temperatures than other fungal species (*e.g.* aflatoxigenic *Aspergillus* species). The profile of *Fusarium* species causing wheat head blight depends on several factors at the stage of cereals flowering, particularly the level of water (rains) and temperatures, but also on agronomic factors, such as soil cultivation, nitrogen fertilization, fungicides, crop rotation, and host genotype (Boutigny et al. 2011, Paterson and Lima 2010, Stępień and Chełkowski 2010, Talas et al. 2011). Mycotoxins enter animal organisms with contaminated feeds or their components. They may permeate to the blood, physiological fluids, tissues and organs, and as a consequence to animal-origin food, i.e. meat, milk and eggs. In this respect aflatoxins, ochratoxins, deoxynivalenol and zearalenone, found in concentrates, feeds and their components, are considered to be of major importance (Goliński et al. 2009).

Ochratoxin A

In the light of available literature ochratoxin A (OTA), under climatic conditions of Poland, may be considered a major mycotoxin found in cereal grains, food and feeds. This toxin is connected with storage and usually (although by no means always) it is absent during plant growth. Improper cereal storage, under conditions promoting the development of fungi and the production of toxic metabolites by those fungi (high temperature and humidity), as well as the application of inappropriate practices during storage of agricultural products may be the primary causes of the formation of ochratoxin A (Gilbert et al. 2001).

In European countries, especially Central and Northern Europe, ochratoxin A is the most frequently occurring mycotoxin (Niessen et al. 2005), identified in over 90% of samples of human and porcine blood, frequently in concentrations higher than 0.1 μg/kg (Petzinger and Weidenbach 2002). Among farm animals pigs are especially susceptible to ochratoxin A. The presence of OTA at a level of 200 μg/kg in feed used in the fattening of these animals is toxicologically significant and harmful to the health of these animals, especially if delivered in feed over a period of 3 - 4 months. The amounts of this toxin in food and feeds are usually relatively small; however, this compound may accumulate in human and animal organisms, constituting a serious health problem (Zheng et al. 2005). Porcine ochratoxin nephropathy in pigs is a disease typical to European countries.

The following pathological changes in kidneys are typical of ochratoxin nephropathy in pigs: enlargement, a change in colour (the so-called “pale kidneys”), very small vesicles on the surface, as well as cysts and fibroses in the cortical part. A reduced capacity of filtration and secretion of *p*-amino-hippuric acid and of the urine concentration is observed, as well as the presence of proteins and glucose in urine, with progressing necrosis of renal tubules and, at an advanced stage – sclerosis and atrophy of renal glomerules (Dragacci et al. 1999).

In birds ochratoxin A is metabolized much faster, since their enzymatic system (mainly in the digestive tract) causes not only a shorter degradation of OTA, but also its faster (4 days) half-life in the organism. Intoxication with ochratoxin A in poultry usually causes disorders in the secretory function of kidneys and changes in internal organs are similar to those in pigs.

Numerous studies have shown that this toxin exhibits cancerogenic, nephrotoxic, teratogenic, immunotoxic and probably neurotoxic action (Dortant et al. 2001, Jorgensen 2005).

Zearalenone

Another major toxin found under climatic conditions of Poland is zearalenone (ZON), detected in cereals already at the stage of plant growth and development, as a product of metabolism of fungi from the *Fusarium* genus (Bennett and Klich 2003, Goliński et al. 2009, 2010, Zinedine et al. 2007).

ZON is phytoestrogen exhibiting, due to the presence of a phenolic ring in its chemical structure, the affinity and activity to both estrogen receptors: ERα and ERβ, found in mammalian tissues (Shier et al. 2001). ZON causes several functional changes in the reproductive system, similar to those caused by natural estrogens (Góra et al. 2004).

Additionally, the introduction of ready-to-eat dry and moist dog and cat food has caused considerable demand for this type of product on the part of consumers. Poor storage conditions of dry food may result in a deterioration of its nutritive value as well as development of bacterial and fungal flora even within its shelf life (Goliński and Nowak 2004). Both regular and therapeutic ready-to-eat balanced dog and cat food contain as much as 80% of plant-origin components (cereals, vegetables, pulses). Thus, they may constitute a potential source of disadvantageous substances, including zearalenone (Skorska-Wyszyńska et al. 2004), while the manufacturing process may not be completely effective in preventing the development of toxigenic fungi (Popiel et al. 2004). It seems that a long-lasting exposure to low, threshold, values, i.e. those encountered most frequently in the case of human consumption or animal feeding, poses an especially high risk of poisoning (McEvoy et al. 2001, Gajęcka et al. 2004).

Symptoms of hyperestrogenism observable in those animals include swelling and enlargement of the vulva, balding and excessive pigmentation of skin in the perineum, sides and the belly, secondary seborrhea and ceruminal otitis externa (Tomaszewski et al. 1998). In turn, changes detected during clinical examinations may be divided into three categories: (i) disturbed sexual cycle, including sterility, (ii) disturbances in the physiology of pregnancy and parturition, including miscarriages, (iii) lesions within female reproductive organs and the mammary glands. Goliński and Nowak (2004) suggest that recently introduced, new formulations of pelleted feeds for dogs and cats, with increased cereal contents replacing meat, constitute a real possibility and danger of ZON consumption by these animals. Since ovarian cysts were detected intra-operatively, which is recognized as the first stage of the endometrial pyometra complex found in about 30% of females, the authors assumed that ZON present in the dog diet might possibly cause pathological changes mentioned above.

Studies conducted so far indicate prompt ZON absorption from the digestive tract, since as early as 30 minutes after intake zearalenone and its metabolites, α- or β-zearalenol as well as α- and β-zearalanol have been detected in blood (Berek et al. 2001, Góra et al. 2004, Zwierzchowski et al. 2005).

Until now few papers on the natural occurrence of ZON in animal tissue have been published. Curtui et al. (2001) examined ZON concentration in the blood serum, kidneys, liver and muscles of swine. ZON was detected only in serum samples with the highest concentration of 0.96 ng mL^{-1}.

Studies concerning ZON incidence in tissues and blood of domestic animals were conducted in Poland in 2005. ZON was detected in pathologically changed tissues of reproductive organs and blood of pets (dogs, cats) at a level of 0.5-2.8 ng g^{-1} and 0.5-2.9 ng mL^{-1}, respectively (Goliński et al. 2005). These studies showed a high prevalence of this toxin (in 65% of tissues and 90% of blood samples). Additionally, it was observed that in 55% of cases this toxin was present both in the blood and the tissues of examined animals. Further studies conducted in Poland concerned changes in ovaries of bitches (Skorska-Wyszyńska et al. 2004). Animals were given ZON at a dose of 200.0 μg/kg b.w. for a week and lesions detected during histopathological examinations in ovaries consisted of numerous congestions in the medullary part and damage to the *membrana granulosa* of ovarian follicles.

Zearalenone and its derivatives have been observed in many important crops such as maize, wheat, sorghum, barley, oats, sesame seed, as well as hay and maize silage (D'Mello et al. 1999). Several studies carried out in Europe and a number of transcontinental countries have reported a high incidence of ZON in cereals and feeds (De Saeger et al. 2003; Scudamore and Patel 2000). Many factors such as temperature, duration of growth, substrate and strain of fungal species influence the amounts of accumulated ZON in crops (Goliński et al. 2010, Waśkiewicz et al. 2008, Zinedine et al. 2007). In the last few years in the Central Europe climatic zone, as studies show, mycotoxins produced by fungi of the *Fusarium* genus, especially zearalenone, play a dominant role in food/feed deterioration (Conkovâ et al. 2003). The highest amounts of zearalenone formed by *Fusarium* were observed at a temperature below 25°C, at a high amplitude of daily temperature and at 16% humidity (Zwierzchowski et al. 2005).

Available data in Europe indicate that wheat and maize are cereals with a high incidence and high levels of contamination with ZON; however, both oat and barley have also been found to be contaminated occasionally with this toxin. Concerning recent data on human exposure to ZON in Europe, the occurrence of the toxin was reported in 32% of mixed cereal samples (n = 4,918) from nine European countries. The distribution showed that much of this contamination was in maize kernels and wheat grain. A high incidence of ZON was found in samples of oat from Finland (47% of samples containing >0.2 mg/kg with the highest level of 1.3 mg/kg being reported) and a high incidence of ZON was reported in wheat from France (16% of samples above 0.2 mg ZON per kg, the highest being 1.8). Raw maize was the food commodity with the highest levels of ZON (14% of maize with levels >0.2 mg/kg, the highest level of 6.5 mg/kg), reported in a sample of maize from Italy (SCOOP 2003).

Data from both Americas indicate that the highest contamination of cereals with ZON was observed in the USA and Argentina (Cavaglieri et al. 2005). Among Asiatic countries, high ZON concentrations in barley (11.0-15.0 mg/kg) were observed only in Japan (Yoshizawa 1997); however, in other countries the highest level of cereal contamination with the toxin did not exceed 1.4 mg/kg in wheat (Li et al. 2002; Park et al. 2005). Even though most African countries have a climate characterized by high humidity and high temperature, which favour the growth of moulds, little information is available on the occurrence of *Fusarium* toxins, particularly ZON, in foods and feeds. High contaminations of the raw material are a constant problem. Legal regulations have not been prepared in the field of food exhibition and retailing, and mycotoxin problems have already been associated with some food contamination in certain areas in Africa (Zinedine et al. 2007).

Due to the common occurrence of ZON in agricultural areas it is assumed that it may penetrate into the surface and ground waters which significantly increases the health hazard both for humans and animals. The occurrence of - mainly - ZON in the aquatic environment has received little attention so far (Gromadzka et al. 2009, Hartmann et al. 2008, Waśkiewicz et al. 2012b), but the levels of ZON in environmental samples were found in the range of 0.3 to 65.2 ng/L and were the highest in autumn. It indicates washing – probably with rain water – of the metabolites from the cereals and post harvest debries to the aquatic environment.

Because of the significant health hazard of *Fusarium* mycotoxins both to humans and to animals, several countries have introduced legal regulations specifying maximum acceptable levels of ZON and DON in maize and small-grain cereals (Shepard 2008).

Moniliformin

According to the literature (Goliński et al. 1996a, 1996b, 1999, Kiecana et al. 2002), *F. avenaceum* is a frequent pathogen of oats. Isolates of *F. avenaceum* vary in virulence and temperature optima. Additionally, the mycotoxic potential, understood as the ability of different *F. avenaceum* species to produce moniliformin (MON), is not uniform. This toxin is produced by several *Fusarium* species and is frequently found in maize kernels (Goliński et al. 1996b, Leoni and Soares 2003, Pineda-Valdes et al. 2002).

Under different climatic conditions both *F. avenaceum* and other *Fusarium* spp. may have a different potential to produce the toxin in the field (Gutema et al. 2000). Kernels of inoculated oat panicles exhibited typical symptoms of scab, and were smaller, shriveled and discoloured when compared to the control (non-inoculated) ones. Reduction of yield and 1000 kernel weight (TKW) associated with MON accumulation was also observed (Goliński et al. 2010).

The chemical analysis of kernels produced by 10 cultivars and 4 lines inoculated with *F. avenaceum* revealed the presence of MON at concentrations ranging from 0.06 mg/kg (line CDH 1236) up to 0.34 mg/kg (cv. Sławko), with an average value of 0.13 mg/kg. The only exceptions were cvs German and Komes, as well as lines CHD 1171 and STH 2594, where the toxin was not detected. Conclusions from this study indicate that inoculation of oat panicles with *F. avenaceum* resulted in kernels which were smaller and exhibited typical scab symptoms, associated with a reduction in yield. Susceptibility of oats to scab after inoculation with the fungus was genotype-dependent. Cultivars Sławko, Dukat, Borys and Komes showed the lowest reduction in yield and were the most resistant to the disease.

In maize especially high contamination levels of MON have been reported. More than 300.000 µg/kg was found in hand-selected, visibly infected kernels from Poland, and up to 25.000 µg/kg in hand-selected kernels from South Africa. In all those cases the high contamination could be related to *F. subglutinans*. When visibly *F. avenaceum* infected kernels of small-grain cereals were investigated for their moniliformin contamination, maximum concentrations were about 1/10 of the concentrations in maize. The highest concentration of moniliformin in small-grain cereals was 38.300 µg/kg in a hand-selected oat sample from Poland (Lew et al. 1993, Sharman et al. 1991).

Deoxynivalenol

Within the trichothecene group, deoxynivalenol (DON) is associated with growth inhibition. DON is a product of metabolism of particularly *F. graminearum* and *F. culmorum*. This toxin is promptly metabolized to its acetyl derivatives: 3- and 15-Ac-DON. The presence of DON was detected in such cereals as wheat, oat, barley, rye, rice, maize, as well as cereal-based products, e.g. flour, bread or muesli (Goliński et al. 2009, 2010).

The concentration of deoxynivalenol and its derivatives, including nivalenol (NIV), in cereals amounted on average to 3.1 mg/kg (0.7-9.0 mg/kg) and proved to be lower than in winter wheat, which was on average 6.7 mg/kg (1.6-38.5 mg/kg) (Góral et al. 1995). Deoxynivalenol, similarly as other trichothecenes, has a significant effect on biochemical processes, among others blocking protein biosynthesis at the stage of elongation of the polypeptide chain. It is assumed that DON does not exhibit cancerogenic properties, although it is characterized by high toxicity. The most frequently observed DON toxicosis symptoms in animals include vomiting and body weight loss with successive numerous physiological changes in internal organs (Wiśniewska et al. 2002). The highest susceptibility to the consumed toxin is found in pigs, despite the reported potent detoxication by intestinal microflora. Intake of feed containing deoxynivalenol may also have a significant effect on reproduction of animals, causing in most cases fetal toxicosis (Boenisch and Schafer 2011).

Fumonisins

Fusarium verticillioides and *F. proliferatum*, well known as fumonisin producers, are worldwide cereal pathogens, effecting seedling disease, root rot, stalk rot, and ear or kernel rot. These fungi attack plants and their residue (debries) in almost all fields of temperature climate zone (Blandino, et al. 2009, Waśkiewicz, et al. 2010). In the last decade, significant efforts were undertaken to enable the determination of fumonisins in corn-based food and feeds, milk, beer, biological fluids, and *Fusarium* cultures (Arino et al. 2007, Waśkiewicz et al. 2012c).

When discussing toxins found under the climatic conditions of Poland we also need to mention fumonisins, which are detected almost anywhere where maize is grown. High -energy maize kernels are primary components of the diet for monogastric animals. Horses are particularly susceptible to the action of fumonisin causing equine leucoencephalomalacia - ELEM (Voss et al. 2007). Pigs are less susceptible to the toxic action of fumonisins, as in feeds contaminated with those toxins, causing porcine pulmonary edema - PPE (Haschek et al. 2001), their concentrations tend to be much higher than in forage for horses. Moreover, fumonisins exhibit toxicity poultry, causing e.g. diarrhea and body weight loss.

In contrast to other mycotoxins, fumonisins as the only toxins are incompletely degraded in the stomach of ruminants (Gurung et al. 1999). Studies have shown that FB_1 is excreted from animal organisms mainly in the unmetabolized form (Caloni et al. 2002). Toxicosis symptoms have been discussed in cows, sheep and goats consuming feeds contaminated with this toxin (Baker and Rottinghaus 1999).

The presence of analyzed toxins in agricultural products is related to a significant health risk for animals as well as humans. In spite of extensive knowledge on the toxicity of mycotoxins further studies are required in order to develop effective methods of their detoxication, as well as fast identification in plant and animal materials.

Within the European Union (EU), the Commission Regulation has recently established regulatory limits of fumonisins in foodstuffs, based on the sum of FB_1 and FB_2 (EC, 2007); with a maximum level of 1000 ng/g for corn used for direct human consumption, with the exception of corn-based breakfast cereals and snack foods (800 ng/g) and processed corn-based foods and baby foods for infants and young children (200 ng/g) (Li et al. 2010).

CONCLUSIONS

- Mycotoxins are toxic secondary metabolites formed by toxigenic fungi present in foods, feeds and their components. Since the presence of the above mentioned microorganisms is unavoidable, mold growth is an inevitable consequence of conditions advantageous for fungi development (water content and temperature).
- Exposure of human beings and animals to the above compounds causes undesirable effects, with a broad variety of biological effects and – as a consequence – chronic diseases called mycotoxicoses.
- Under the European climate conditions the most important genera of toxigenic and pathogenic fungi are *Aspergillus, Fusarium* and *Penicillium.* The above microorganisms are related – during vegetation – to plant oxidative stress induced by weather and environment conditions, followed by biosynthesis of mycotoxins.
- Methods of decontamination are usually difficult, so prevention of mycotoxin formation is of prime concern.

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SAŽETAK

Mikotoksini su toksični sekundarni metaboliti koje stvaraju toksigene gljivice što se nalaze u hrani, krmnim smjesama i krmivima. Budući da je postojanje ovih mikroorganizama neizbježivo, rast plijesni je neizbježna posljedica povoljnih uvjeta za razvoj gljivica (sadržaj vode i temperatura) u specifičnim tehnologijama hrane i krmiva. Dosad identificirani mikotoksini (nekoliko stotina) su molekule različitih kemijskih struktura i molekularne težine do 500 Da. U radu će se raspravljati o pokušaju objašnjenja zašto je za gljivice potrebna biosinteza tolikih toksičnih metabolita - kao posljedica primarnog metabolizma. Izlaganje ljudi i životinja navedenim komponentama uzrokuje nepoželjne učinke i mnogo različitih bioloških učinaka te kao posljedicu kronične bolesti zvane mikotoksikoze. Opisat će se najvažnije vrste toksigenih i patogenih gljivica Aspergillus, Fusarium i Penicillium, osobito uvjeti brzog rasta i razvoja te biosinteza raznih mikotoksina. Gore navedeni mikroorganizmi u vezi su za vrijeme vegetacije s oksidativnim stresom biljke izazvanim vremenskim i okolišnim uvjetima. Raspravljat će se o ovome, kao i o biosintezi metabolita. Brzi razvoj gljivica te stvaranje toksina uzrokuje smanjenje prinosa usjeva, pad njihove kvalitete, te kao posljedicu, znatne privredne gubitke budući da je širom svijeta godišnje oko 25% usjeva zahvaćeno mikotoksinima. Izneseni podaci će potvrditi da šest metabolita (aflatoksini, B1, ZEA, DON, fumonizini, toksin T-2 i OTA) u različitim materijalima (matricama) predstavljaju stvarni problem u čitavom svijetu. Pojava i razine koncentracije variraju za razne mikotoksine i usko su povezane s vremenskim uvjetima i stresom biljke, odgovornima za stvaranje metabolita. Govorit će se o razinama sigurnosti s težištem na niskim dozama, što uzrokuje subkliničke gubitke.Većina bolesti pojavljuje se nakon konzumiranja različitog zrnja ili njihovih proizvoda zaraženih mikotoksinima, ali postoje i drugi načini izlaganja. Dijagnoziranje mikotoksikoza ovisi o odgovarajućem testiranju na mikotoksine uključujući uzorkovanje, pripremu uzoraka i analizu. Govorit će se o zaraženosti hrane, krmnih smjesa i krmiva mikotoksinima te dati i odgovarajući podaci o novim izvorima zaraze. Metode dekontaminacije su obično teške pa je sprječavanje stvaranja mikotoksina od prvenstvene važnosti. Bit će predstavljeni rezultati istraživanja niza žitarica otpornih na patogene gljivice i biosinteza toksičnih sekundarnih metabolita (mikotoksina) s naglaskom na smanjenje rizika za zdravlje ljudi i životinja. Predmet rasprave bit će najnoviji rezultati što upućuju na važnost mikotoksina u Poljskoj (u usporedbi s podacima u svijetu).

Ključne riječi**:** mikotoksini, hrana, krmne smjese, krmiva