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Mycotoxin contamination of the food supply chain - Implications for One Health programme

Dragan Milicevic^{a,*}, Ksenija Nesic^b, Sandra Jaksic^c

^a*Institute of Meat Hygiene and Technology, Kacanskog 13, 11040 Belgrade, Serbia*

^b*Institute of Veterinary Medicine of Serbia, Auto put bb, 11070 Belgrade, Serbia*

^c*Scientific Veterinary Institute Novi Sad, Rumenicki put 20, 21000 Novi Sad, Serbia*

Abstract

Mycotoxins are a group of naturally occurring toxic chemical substances, produced by different fungal species, which can cause illness or even death due to their toxigenic, carcinogenic, mutagenic and teratogenic effects. Though more than 400 mycotoxins are known to have toxic effects on human when ingested along with contaminated food, mycotoxins like aflatoxins, ochratoxins, zeralenone, trichothecenes and fumonisins are the major mycotoxins influencing the public health and agriculture. Due to the global nature of the food supply and advances in analytical capabilities, mycotoxin contamination will continue to be an area of concern for regulatory agencies, the food industry, and consumers.

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1. Mycotoxins in general

Mycotoxins are natural contaminants produced by a range of fungal species. Their common occurrence in food and feed poses a threat to the health of humans and animals. This threat is caused either by the direct contamination of agricultural commodities or by a “carry-over” of mycotoxins and their metabolites into animal tissues, milk, and

* Corresponding author. Tel.: +381-11-2650-655; fax: +381-11-2651-825
E-mail address: dragan@inmesbgd.com

eggs after feeding of contaminated feedingstuffs¹. The most important agro-economic and public health classes of mycotoxins are aflatoxins (AFT), ochratoxins (OTA), zeralenone (ZEA), trichothecenes, and fumonisins (FUMs) produced by species of *Fusarium*, *Penicillium* and *Aspergillus*. If these mycotoxins occur at a considerably high level in foods, they can cause toxic effects ranging from acute to chronic (mutagenic, teratogenic, carcinogenic) manifestations in humans and animals². The economic impact of mycotoxins include loss of human and animal life, increased health care and veterinary care costs, reduced livestock production, disposal of contaminated foods and feeds, and investment in research and applications to reduce severity of the mycotoxin problem³. Due to their deleterious effects on humans and farm animals, several countries have implemented regulations prescribing mycotoxin limits in several food commodities intended for consumption. In 1993, the WHO-International Agency for Research on Cancer^{4,5} evaluated the carcinogenic potential of AFT, OTA, TCT, ZEA, and FUMs.

1.1. Factor affecting production, contamination of foods and feeds by mycotoxins

Various factors operate interdependently to affect fungal colonization and/or production of the mycotoxins. D'Mello and MacDonald⁶ categorized the factors as physical factors (moisture, relative humidity, temperature and mechanical damage), chemical factors (carbon dioxide, oxygen, composition of substrate, pesticide and fungicides), and biological factors (plant variety, stress, insects, spore load). The biological factors have been further sub-categorized into intrinsic factors, including fungal species, strain specificity, strain variation, and instability of toxicogenic properties. This is in part due to the multidisciplinary nature of mycotoxin research, which involves analytical chemistry, toxicology, taxonomic mycology, hygienic measures, microbial physiology, epidemiology, and increasingly weaponry. Some molds are capable of producing more than one mycotoxin and some mycotoxins are produced by more than one fungal species. Often more than one mycotoxin is found on a contaminated substrate. Therefore, the presence of potentially toxicogenic fungi does not imply the presence of mycotoxins and vice versa⁸.

1.2. Occurrence and significance of mycotoxins in foods and feeds

Mycotoxicoses in humans or animals are characterized as food or feed related, non-contagious, non-transferable, non-infectious, and non-traceable to microorganisms other than fungi. Clinical symptoms usually subside upon removal of contaminated food or feed. Mycotoxin contamination is encountered in various environments. For instance, mycotoxins have been frequently identified in grain products, coffee beans, spices and nuts. In agriculture, mycotoxins can be present mainly in livestock feed. A wide range of commodities can be contaminated with mycotoxins both pre- and post-harvest. Serbia is largely a developing agriculture-based economy, so therefore, surveillance for mycotoxins and mycotoxicogenic fungi is critical for maintaining high quality of feed (Table 1) and food (Table 2)^{9,10,11}.

1.2.1. Aflatoxins

AFs are difuranocoumarin derivatives produced by a polyketide pathway by many strains of *Aspergillus flavus*, *Aspergillus parasiticus* and the rare *Aspergillus nomius*, which contaminate agricultural commodities. They have toxic, carcinogenic, mutagenic and teratogenic effects in laboratory animals. The liver is the main target organ for AF toxicity and carcinogenicity. The rate of metabolism and products formed determine differences in species susceptibility to AF. In this instance, the presumed intermediate metabolite, AFTB₁ 8,9-epoxide forms an adduct with DNA and consequentially disrupts the transcriptional and translational processes. Approximately 95% of AFB₁ metabolites excreted in milk are in the form of AFM₁, though AFM₂, AFG₁ and AFB are also reported.

1.2.2. Ochratoxin

OTA is produced by fungi of the genera *Aspergillus* and *Penicillium*. The target organ for OTA is the kidneys and initial interest in this group of toxins was as a cause of porcine nephropathy. OTA has subsequently, been

associated with human disorders most noticeably Balkan Endemic Nephropathy in the former Yugoslavia, Chronic Interstitial Nephropathy and kidney tumours. Historically, consumption of pork has been a significant source of human exposure to ochratoxin A in these regions¹².

Table 1. Incidence of mycotoxins in investigated livestock feedingstuffs produced in Serbia during 2014.

Feed/ feedingstuffs	AFTB ₁		OTA		T-2/HT-2		ZEA		DON	
	N	n (%)	N	n (%)	N	n (%)	N	n (%)	N	n (%)
Poultry	189	73.0	27	29.6	38	39.5	14	28.6	32	53.1
Pigs	190	58.4	62	30.7	77	26.0	77	48.1	66	63.6
Cattle	103	59.2	4	0	5	20.0	9	77.8	5	40.0
Corn	100	37.0	39	20.5	48	18.8	52	53.9	50	76.0
Silage	14	71.4	3	0	-	-	8	100.0	12	66.7
Sunflower meal	8	15.0	1	0	-	-	2	0	5	0
Wheat	2	50.0	2	0	1	0	3	33.3	5	100.0

N - total number of analysed samples; n - percentage of positive samples.

Table 2. Occurrence of mycotoxins analysed in selected foodstuffs from Serbia.

Types of foodstuffs	AFTB ₁		AFTM ₁		DON		ZEA		FUM's		T-2		OTA	
	N	n	N	n	N	n	N	n	N	n	N	n	N	n
Milk	-	-	50	100	-	-	-	-	-	-	-	-	-	-
Cheese (white and hard type)	-	-	54	100	-	-	-	-	-	-	-	-	-	-
Wheat flour	15	0	-	-	15	86.7	15	33.3	15	0	15	26.7	15	0

N - total number of analysed samples; n - percentage of positive samples.

1.2.3. Zearalenone

ZEA is a phenolic resorcylic acid lactone with potent oestrogenic properties, produced primarily by *Fusarium*. ZEA is a non-steroidal oestrogen and its major metabolites α -zearalenol and β -zearalenol elicit significant oestrogenic activity in human and animals, corresponding to their binding affinities for hepatic, uterine, mammary and hypothalamic oestrogen receptors. Pigs are very sensitive to ZEA whereas poultry are very tolerant.

1.2.4. Fumonisins

A number of *Fusarium* species produce fumonisins, a group of some 12 compounds of which fumonisin B1 is the most studied and most toxic. The toxicity of FUMs largely reflects their ability to disrupt sphingolipid metabolism by inhibiting the enzyme ceramide synthase; an enzyme responsible for the acylation of sphinganine and sphingosine. It is now established that the FUMs cause equine leukoencephalomalacia and porcine pulmonary oedema, are carcinogenic in rats and may be a major aetiological factor in the incidence of human oesophageal cancer in southern Africa and China.

1.2.5. Trichothecenes

Several fungal genera are capable of producing TCT, however, most of them have been isolated from *Fusarium spp.* TCT comprise a vast group of over 100 fungal metabolites with the same basic structure. Examples of type A TCT include T-2 toxin (T-2) and HT-2 toxin (HT-2), and diacetoxyscirpenol (DAS). Fusarenone-X (FUX), deoxynivalenol (DON), and nivalenol (NIV) are some of the common naturally occurring type B TCT. At the

cellular level, the main toxic effect of TCT mycotoxins appears to be a primary inhibition of protein synthesis. TCT affect actively dividing cells such as those lining the gastrointestinal tract, the skin, lymphoid and erythroid cells.

2. Mycotoxin analysis

Mycotoxin analysis in food and feed is generally a multistep process comprised of sampling, sample preparation, toxin extraction from the matrix (usually with mixtures of water and polar organic solvents), extract clean-up and finally detection and quantitative determination. Proper sampling, milling and homogenisation procedures are prerequisite for obtaining reliable analytical results because of the heterogeneous distribution of mycotoxins in food commodities.

3. Mycotoxin legislation and regulations

Legislation and regulation are constantly evolving issues. Many developing countries have realised that reducing mycotoxins levels in foods will not only reduce the financial burden on health care, but also confer international trade advantages such as exports to the attractive European markets. Factors fundamental to a country's ability to protect its population from mycotoxins include the political will to address mycotoxin exposure and capability to test food for contamination, which determines whether requirements can be enforced.

4. Prevention of mycotoxins

Management practices to maximize plant performance and decrease plant stress can decrease mycotoxin contamination substantially. This includes planting adapted varieties, proper fertilization, weed control, necessary irrigation, and proper crop rotation. For post-harvest mycotoxin control, prevention of conditions that favor fungal growth and subsequent toxin production needs to be considered, *i.e.* factors such as water activity of stored products, temperature, grain condition, gas composition of the intergranular air, microbial interactions, and presence of chemical or biological preservatives.

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