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**MYCOTOXINS IN MILK AND IN DAIRY PRODUCTS**DOI: <https://doi.org/10.15673/fst.v14i3.1786>**Article history**

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**Introduction. Formulation of the problem**

Production and consumption of milk and dairy products in the world varies with the region or country. Some countries try to provide the population with food without the physical possibility of monitoring it, while others exercise strict control and introduce organic manufacture process. According to clal.it, production and consumption of organic milk and dairy products is gradually increasing, and in Ukraine, too. Ukraine produces about 28 types of various dairy products, and their consumption varies by region. Thus, consumption of milk and dairy products per person in the Luhansk Region is 136.8 kg/year, while in the Ivano-Frankivsk Region, it is 273.0 kg/year [1]. There are so-called alternative dairy products: soya, rice, and

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**Abstract.** The article gives an overview of modern opinions about the ways of possible contamination of milk and dairy products by mycotoxyn. The key indicator of the presence of mycotoxins in milk and dairy products is the level to which micromycetes affect productive livestock's feed. Yet, micromycetes and mycotoxines do not always occur together: some test samples can contain certain micromycetes, but no mycotoxines. Mycotoxines are synthesised by micromycetes only under certain favourable conditions. The multi-chambered stomach ecosystem of lactating cows utilises most mycotoxins occurring in food. Only a small amount of those is excreted in milk. However, some mycotoxins can bind to milk caseins. In this case, cheese and other dairy products can contain far higher amounts of mycotoxins than at the initial stage of milk production. The paper compares the maximum permissible levels of mycotoxins in milk and in dairy products according to the regulations of Ukraine and the EU. It presents the mycotoxins isolated from secretions of mammary glands of humans and productive animals, and describes their effect on the body's physiology. It also provides a structural diagram of how mycotoxins contaminate milk and dairy products following the path "Animal feed – dairy products." We suggest four-stage assessment of the risks of mycotoxin contamination of milk and dairy products: Stage I – identifying the producer of mycotoxin (molecule, metabolites in feed, milk, and dairy products). Anamnesis; Stage II – constructing a sequence diagram. Inspecting all production stages to identify the main ways and periods of contamination, determining and describing the symptoms of contamination; Stage III – assessing how the intensity and duration of exposure to a mycotoxin and its metabolites are likely to effect on the body. Modelling the influence of mycotoxins on the body; Stage IV – assessing the risk and determining measures to eliminate or minimise it. Risk scenario forecast.

**Key words:** milk, dairy products, mycotoxins.

coconut milk, tofu cheese, soya yoghurt, and others. The wider the range of dairy products and their analogues is, the heavier the load on the system of monitoring them by safety indicators [2] (especially for possible contamination with mycotoxins). Global warming, climate change, and man-made pressures on the environment are accompanied by ecological successions. Habitats of plants and animals are changing, including those of pests, in particular micromycetes, potential mycotoxin producers, observed to be infesting farming ecosystems [3-7]. Monitoring the micromycete composition in feed for productive animals is, thus, becoming important [8, 9]. For ruminants, unlike monogastric animals, not only mycotoxins are harmful, but mould fungi as well, because both have various mechanisms of influence that reinforce each other [10].

Thus, in European countries, there is a growing risk of damage to agricultural products by micromycetes and contamination with mycotoxins [11].

**The purpose of the research** is to summarise modern data on possible contamination of milk and dairy products with mycotoxins, to study their distribution, effects on the body, and possible ways of entering food, and to suggest a methodology that allows assessing the risks if there is a possibility of mycotoxin contamination of milk and dairy products.

For this purpose, it is necessary to achieve the following **objectives**:

- to analyse the current state of the problem;
- to establish the sources of dairy products contamination and the main mycotoxins found in milk and dairy products;
- to consider potential threats to human health through consuming contaminated dairy products;
- to present the main models of assessing the risks of mycotoxin contamination of milk and dairy products.

#### Analysis of recent research and publications

**The main sources of mycotoxin contamination of milk and dairy products.** Mycotoxin contamination of dairy products can occur both through milk and through the ingredients introduced (proteins, fats of vegetable origin, cereals, nuts, spices, dried fruit, juices, etc.). Among consumers of milk and products of its

processing, children, especially infants, and the elderly are the most sensitive to mycotoxins. It is estimated that about 25% of food produced in the world is contaminated with mycotoxins [12].

Thus, 20% of infant formula in Mexico contained aflatoxin M1 (AFM1) in the concentration 40ng/l to 450ng/l, which exceeded the EU permissible limit for infant formula (25ng/l) [13].

Similarly, EU countries have repeatedly reported different levels of contamination of baby food with mycotoxins, including aflatoxin B<sub>1</sub> in Switzerland (0.18µg/kg) and in the Netherlands (0.21-0.39µg/kg) [14].

The maximum concentration limit for aflatoxin M1 (0.025µg/kg) in food raw materials for infants and older children is set by the European Commission in accordance with EU Regulation 1881/2006 [15]. In Ukraine, they are clearly spelt out in the State Hygienic Regulations and Norms [16], and harmonised with European standards as regards mycotoxin M1 (Table 1).

Mycotoxins by their physicochemical properties are lipophilic substances, so their content can be quite high in different oils. Thus, palm and coconut oil used to produce dairy products (cheese, processed cheese, butter, margarine, and other spreads, sour cream, ice cream) and baby food (breast milk substitutes, infant formulas, milk porridge) can contain mycotoxins in various quantities [17].

**Table 1 – Maximum allowable concentrations (MAC) of aflatoxins in milk and dairy products according to the regulations of Ukraine and the EU [15,16]**

No. in the table in the appendix to the document	Food products	Maximum levels of aflatoxins, µg/kg		
		M1	B1	Together B1, B2, G1, G2
State Hygienic Regulations and Norms. "Regulation on the maximum levels of certain contaminants in foodstuffs." Order of the Ministry of Education and Science No. 368 of 13.05.2013, Annex, section 2. Mycotoxins				
2.1.13	Unprocessed milk, heat-treated milk, milk for the manufacture of dairy foods, dairy products, condensed milk, milk powder and powdered milk products, cheeses and cheese products, butter (from cow's milk)	0.05	0.1	n/n
2.1.16	Baby food for infants and older children <sup>1</sup>	0.025	0.1	n/n
2.1.17	Special medical purpose foods intended for babies	0.025	0.1	n/n
Commission Regulation (EU) No. 165/2010 of 26 February 2010 amending Regulation (EC) No. 1881/2006 Setting maximum levels for certain contaminants in foodstuffs as regards aflatoxins				
2.1.13	Unprocessed milk <sup>2</sup> , heat-treated milk, milk for the manufacture of dairy foods, dairy products	0.050	n/n	n/n
2.1.16	Dry baby food for infants and older children, including milk and dairy products <sup>3,4</sup>	0.025	n/n	n/n
2.1.17	Special medical purpose foods intended for babies <sup>4,5</sup>	0.025	0.1	n/n

<sup>1</sup>Maximum levels apply to ready-to-eat products sold as such or reconstituted according to the manufacturer's instructions.

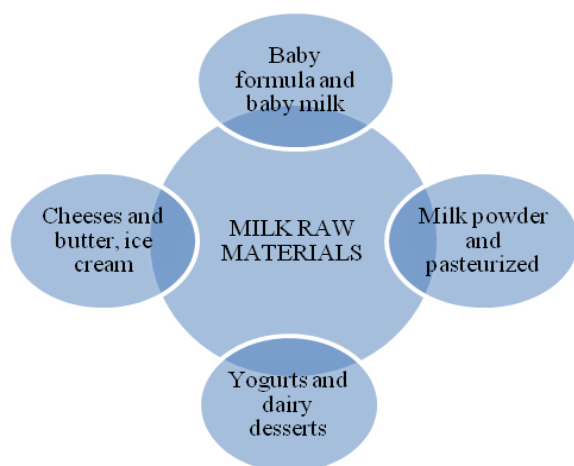
<sup>2</sup>Foodstuffs listed in this category are defined in accordance with Regulation (EC) No. 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin (OJ L 226, 25.6.2004, p. 22).

<sup>3</sup>Foodstuffs listed in this category are defined in accordance with Regulation (EU) No. 609/2013 of the European Parliament and of the Council of 12 June 2013 on food intended for infants and young children, food for special medical purposes, and total diet replacement for weight control and repealing Council Directive 92/52/EEC, Commission Directives 96/8/EC, 1999/21/EC, 2006/125/EC, and 2006/141/EC, Directive 2009/39/EC of the European Parliament and of the Council and Commission Regulations (EC) No. 41/2009 and (EC) No. 953/2009 (OJ L 181, 29.6.2013, p. 35).

<sup>4</sup>Maximum levels apply to ready-to-eat products (sold as such or reconstituted according to the manufacturer's instructions).

<sup>5</sup>Maximum levels apply to ready-to-eat dairy products sold as such or after reconstitution according to the manufacturer's instructions. In the case of products other than milk and milk products, the maximum levels apply to the content in the dry matter. The dry matter content is determined according to Regulation (EC) No. 401/2006.

Fig. 1 shows the main types of dairy products in which mycotoxin contamination was found. Studies in Western Asia have shown that aflatoxin M1 contamination of milk and dairy products was: in pasteurised milk – 95% (40.6–84ng/l); in breast milk – 59% (3.3–7.7ng/l); in dairy products – 72% (63.7–100.9ng/kg). In total, 25% of milk and 18% of dairy products contained aflatoxin M1 in concentrations exceeding its permitted level in accordance with EU standards (50ng/l) [18].



**Fig. 1. Detection of mycotoxins in milk and dairy products**

In milk-containing products, besides proteins and/or fats of non-dairy origin, one can detect mycotoxins that are alien to milk. For example, addition of spice to foods can be accompanied by mycotoxin contamination. Thus, AFB<sub>2</sub>, AFG<sub>1</sub>, AFG<sub>2</sub>, T<sub>2</sub>, and HT<sub>2</sub> were detected in samples of coriander, laurel, mint, rosemary, and verbena from Italy and Tunisia. Mixed contamination with fungal toxins was detected in some samples of rosemary and verbena [19].

Therefore, ensuring the mycotoxin safety of milk requires, above all, a comprehensive approach. Regardless of the mammal species, their milk contains a limited amount of mycotoxins, primarily aflatoxin M<sub>1</sub>, of course. However, there are a number of others, too: deoxynivalenol; ochratoxin; zearalenone; gliotoxin; T<sub>2</sub> toxin; fumonisins. Thus, there is a problem of timely and comprehensive determination of possible mycotoxin contamination of raw milk and dairy products. A possible solution to this problem is the QuEChERS method. So, methods of determining mycotoxins in dairy products should be constantly improved [20,21].

It should be noted that the struggle of agroecosystem organisms for life and food makes people use various agrochemicals and pesticides as traditional methods of, respectively, increasing crop yields and protecting them from pests. It is known that when industrial technologies are used to produce agricultural food and animal feed, the milk of various

species of productive animals and human breast milk contain not only xenobiotics, toxicants, pesticides, and antibiotics, but mycotoxins as well, and their content tends to increase. The problem of mycotoxicosis is exacerbated by the rapid adaptation of toxicogenic fungi to new production technologies and modern pesticides, which is accompanied by a several hundred-fold increase in their production of mycotoxins [22-25].

In particular, although the increasing use of fungicides reduces the level of micromycetes in plants, it boosts the synthesis of mycotoxins, due to stress on fungi under the action of fungicides [10].

The problem of contamination of plant feed with mycotoxins concerns a wide range of enterprises in both the feed and the food industries. The safety requirements for crop and livestock products, including grain, milk, and meat, are becoming stricter with years, which calls for better control of mycotoxins in food.

Micromycetes have a genetic mycotoxin-synthesising potential, but do not always direct their energy and plastic reserves to their formation. Like any synthesis, the process of synthesising mycotoxins by micromycetes requires expending their chemical energy and providing the biochemical mechanism with an adequate amount of substrate. However, under certain conditions, this system begins generating toxic molecules. These conditions include stress-inducing changes in the environment (humidity, temperature), the presence and availability of the substrate, competitive relationships with other microorganisms, etc. It is believed that cattle are less likely to have mycotoxicosis than poultry or pigs, as their diet consists mainly of straw, hay, and silage rather than of grain. They can be inhabited by various species of mould fungi and contaminated with their metabolites, thus becoming a powerful source of mycotoxins. Micromycetes are common in soil, they inhabit plants during the growing season, and non-compliance with agronomic techniques, unbalanced application of agrochemicals, violations of plant protection technologies lead to the mass manifestation of plant diseases [26]. The main pathogens causing plant diseases belong to the group of field fungi (*Puccinia* Pers., *Tilletia* Tul. & C. Tul., *Blumeria* Golovin ex Speer, *Septoria* Sacc., *Fusarium* Link, *Pyrenophora* Fr., *Botrytis* P. Micheli ex Haller). In farming ecosystems, though, some other species of fungi can develop that form mould during storage of plant products or feed preparation and are potential toxin producers (*Aspergillus* P. Micheli ex Haller, *Fusarium*, *Penicillium* Link, *Trichothecium* Link) [27-29].

The high micromycete population in fodder remains an important problem for livestock in Ukraine. In 2018-2019, studies of cattle feed found that 73.6% of samples were contaminated with microscopic fungi above the maximum allowable level (MAL). This indicates that the situation with the feed quality was not any better than it was in 2014–2017, when the level

of fungal population in substandard feed ranged 51–88%. The research results showed that the micromycete contamination in certain feed types was: in compound feeds – 23.4%, in monofodder and silage – 18.7, in straw – 10.9, in hay – 7.8%. The microbiota of the feed species studied was represented by fungi of the family *Mucoraceae* (25.6%) and species of the genera *Aspergillus* (24.7%), *Penicillium* (9.5%), *Fusarium* (3.3%), and other genera (36.9%). However, the study of feed samples for the content of mycotoxins detected zearalenone only in one sample, in the amount 0.88mg/kg, which is by 76% exceeds the MAL. The content of other mycotoxins, in particular aflatoxin B1, sterigmatocystin, patulin, and zearalenone, was beyond the method detection limits and did not exceed the MAL [30,8].

Any quantity detected of any mycotoxin indicates the product's poor quality. Besides, it means that the product can contain other toxins or toxic metabolites of their incomplete synthesis [10].

Different parts of the same batch of a product can have quite different concentrations of secondary fungal metabolites. This, in turn, can affect the results of laboratory tests, so quality sampling is of key importance.

Usually, every fungal species can produce several mycotoxins simultaneously. Given the synergism of mycotoxins, food for monogastric animals can be toxic even if the content of each mycotoxin taken separately does not exceed its maximum allowable level. The cumulative properties of toxin molecules matter, too: if mycotoxins are present in the diet at concentrations below the method's detection limit, there is a false impression of their absence and, consequently, of the safety of the food components. However, after consuming these products for several days, the dose of toxins received by the body can reach a critical level due to the cumulative effect.

One of the important biological features of fungi is their close connection and adaptation in their development to a particular substrate, and especially to plants. The quantities and composition of mycotoxins produced by certain micromycete species under different conditions of plant growth and crop formation still remain unpredictable [31].

Animals in their own way have adapted to possible contamination of plant components of their diet with secondary metabolites of micromycetes. The ecosystem of ruminant animals' forestomach makes it quite probable that mycotoxins will be neutralised by protozoa and microorganisms. The degree of mycotoxin decomposition in the rumen is not constant and depends on the physical type of food, and on the time it remains in the forestomach [10]. Thus, in the mammary gland secretion of ruminants, according to some authors, the level of mycotoxins can range from

0.3% to 6.2% of their amount received by the digestive tract of a lactating cow [32, 33].

#### **Potential health hazards due to consumption of mycotoxin-contaminated products.**

Symbiotic interactions between macroorganisms and microorganisms inhabiting the forestomach of ruminants were quite profoundly described by Professor S. Gzhytsky's school of biochemists in Lviv as early as in the last century [34]. It turns out that the ecosystem of the forestomach not only helps in digesting rough fodder, but is also responsible for an extremely high level of detoxification of mycotoxins. Monogastric animals and humans do not have this protection and are therefore more vulnerable. Thus, it was found that in 100% of Nigerian women, contamination of breast milk with AFM1 ranged 2.33-7.08ng/l, which researchers attribute to the consumption of foods based on cassava, nutmeg oil, maize, tomatoes, and dried fruits [35-37].

On the other hand, researchers note the presence of other toxins in breast milk. Thus, the average levels of AFM1 and OTA in breast milk were 3.07ng/ml and 1.38ng/ml respectively. And the concentration of ZEN and DON was higher than 0.3ng/ml in 59% of breast milk samples and exceeded 10ng/ml in 37.7% of samples, respectively. Moreover, a mother's smoking adversely affects the process of detoxification of mycotoxins in her body [38].

The *Codex Alimentarius* includes guidelines to ensure the safety and consumability of milk and dairy products to protect consumers' health and facilitate the trade in these goods. It also introduces the concept of allowable levels of contamination in milk and dairy products, which are based on relevant criteria. In particular, for aflatoxin M1 in milk, it was recommended to take 0.5mg/kg as the maximum level [39].

Mycotoxins are highly toxic, that is why their MAC in food are low. The MAC for aflatoxins in different types of nuts, cereals, figs, and milk range from 0.5 to 15µg/kg [40]. The situation with baby food control is extremely threatening, as milk, dairy products, and infant formulas, along with breast milk, are the only source of nutrients. Thus, in Zambia, in children aged 6 to 24 months, an increasing AFB1-lys level in blood results in inhibited growth and arrested development. [41]. This is explained by the risk, as high as about 1%, that the main mycotoxins can pass into the milk of ruminants [42].

Thus, recent studies make it clear that of a wide range of mycotoxins that can be present in milk and dairy products, the metabolite M1 is definitely the dominant one. Fig. 2 shows the mycotoxins excreted with milk and their biological effects on people and animals [43,44].

Aflatoxin B <sub>1</sub> , B <sub>2</sub> , G <sub>1</sub> , G <sub>2</sub> , M <sub>1</sub>	<ul style="list-style-type: none"> <li>• genotoxic carcinogenic compounds. In the liver, B1 is metabolized to M1 by cytochrome P450.</li> <li>• B1 and M1 are found in milk.</li> </ul>
Deoxynivalenol (DON)	<ul style="list-style-type: none"> <li>• Inhibition of protein synthesis and redox reactions in mitochondria</li> <li>• Contained in milk in low concentrations</li> </ul>
Ochratoxin (A, B, C)	<ul style="list-style-type: none"> <li>• Inhibits protein synthesis, carcinogen. Capable of accumulation in tissues.</li> <li>• Excreted with milk.</li> </ul>
Zearalenone	<ul style="list-style-type: none"> <li>• Binds to estrogen receptors. Mycoestrogen</li> <li>• Contained in milk in low concentrations</li> </ul>
Gliotoxin	<ul style="list-style-type: none"> <li>• Cytotoxic immunosuppressant. Used as a fungicide and antibiotic.</li> <li>• Contained in milk in low concentrations</li> </ul>
T-2 toxin	<ul style="list-style-type: none"> <li>• inhibition of protein and nucleic acid synthesis, oxidative cell damage and apoptosis. Genotoxic and cytotoxic effects.</li> <li>• contained in milk in low concentrations</li> </ul>
Fumonisin (B1, B2)	<ul style="list-style-type: none"> <li>• similar in structure to sphingolipids, embedded in biological membranes, changing their structure.</li> <li>• contained in milk in low concentrations.</li> </ul>

Fig. 2. Mycotoxins of milk and their effect on the body

There are more than 400 different mycotoxins produced by micromycetes [45]. Although they are so many, most of them have not been described at all. However, mycotoxins that affect the human body, productive animals, and agricultural plants have been identified, systematised, and studied quite thoroughly. About 20 types of aflatoxins occur in nature, but four of them – the aflatoxins B<sub>1</sub>, B<sub>2</sub>, G<sub>1</sub>, and G<sub>2</sub> – pose a special danger to humans and animals [46].

Of course, for milk and dairy products, the content of aflatoxins is the most important, especially that of AB1 (chemical name (6aR,9aS)-2,3,6a,9a-Tetrahydro-4-methoxycyclopenta[c]furo- (3', 2':4,5)furo[2,3-h][1]benzopyran-1,11-dione (9CI), synonym: 6-Methoxydifurocoumarone) and AM1 (chemical name (6aR,9aR)-2,3,6a,9a-Tetrahydro-9a-hydroxy-4-methoxycyclopenta [c] furo [3',2':4,5] furo [2,3-h] [1]

benzopyran-1,11-dione (9CI), synonym: 4-Hydroxyaflatoxin B1) (Fig. 3).

The main physicochemical properties of mycotoxins of the genus *Aspergillus* are presented in Table 2. Aflatoxins are compounds of the furocoumarin group. They are of crystalline structure, pale yellow in colour, heat-resistant, with a melting point 299–244°C, very poorly soluble in water (10–30 µg/ml); highly soluble in chloroform, methanol, and dimethyl sulphoxide, non-resistant to ultraviolet light in the presence of oxygen. Aflatoxins are also destroyed when reacting with ammonia or sodium hypochlorite. The toxicity of aflatoxins may be due to their interaction with nucleophilic sites of DNA, RNA, and proteins [48].

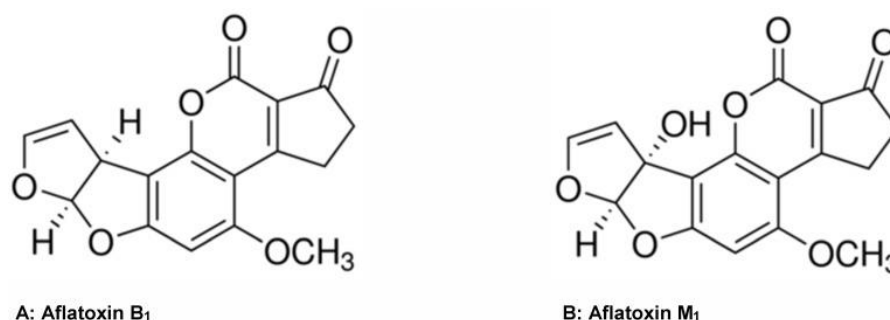


Fig. 3. Chemical structure of aflatoxin B1 and aflatoxin M1 [49]

Table 2 – Basic physicochemical properties of mycotoxins of the genus *Aspergillus* [47]

Mycotoxins	Molar mass, g/mol	t melt., °C	λ max, nm	Fluorescence, colour, nm
Aflatoxin B1	231	268-269	265.362	Blue, 425
Aflatoxin G1	328	244-246	–	Green, 450
Aflatoxin M1	328	299	265.357	Blue-purple, 425
Ochratoxin A	403	169	213.332	Green, 475
Ochratoxin B	369	221	218.318	Blue

Mammals are not sensitive to some mycotoxins. In the course of evolution, specific defence mechanisms have developed (low absorption, or no absorption in the digestive tract in the biologically active form; metabolised by digestive tract microorganisms; no target cells for mycotoxin; high level of detoxification after entering the body with no pathophysiological effects; the rate of their excretion from the body significantly exceeds their potential metabolic activity and possible intensity of deposition in tissues). This must be why only a small number of the great many mycotoxins discovered can adversely affect the physiological state of their body.

We believe (Fig. 4) that in the effect of mycotoxins on the body's physiological state, the change of

biochemical processes plays the key role. This change is accompanied by the manifestation of certain pathophysiological effects. Any toxicity of a molecule initially manifests itself in affecting the integrity of metabolic processes and physiological functions. That is, when a toxin interacts with a receptor, DNA, RNA, proteins, membranes, or metabolites, this always leads to changes in the activity of the relevant biochemical processes and is accompanied by morphological and functional transformations, adequately to the level of toxic action. A toxic effect is always based on the relevant biochemical factors and mechanisms. They can result in a range of consequences: from certain ultrastructural changes in a cell to physiological disorders and pathologies.

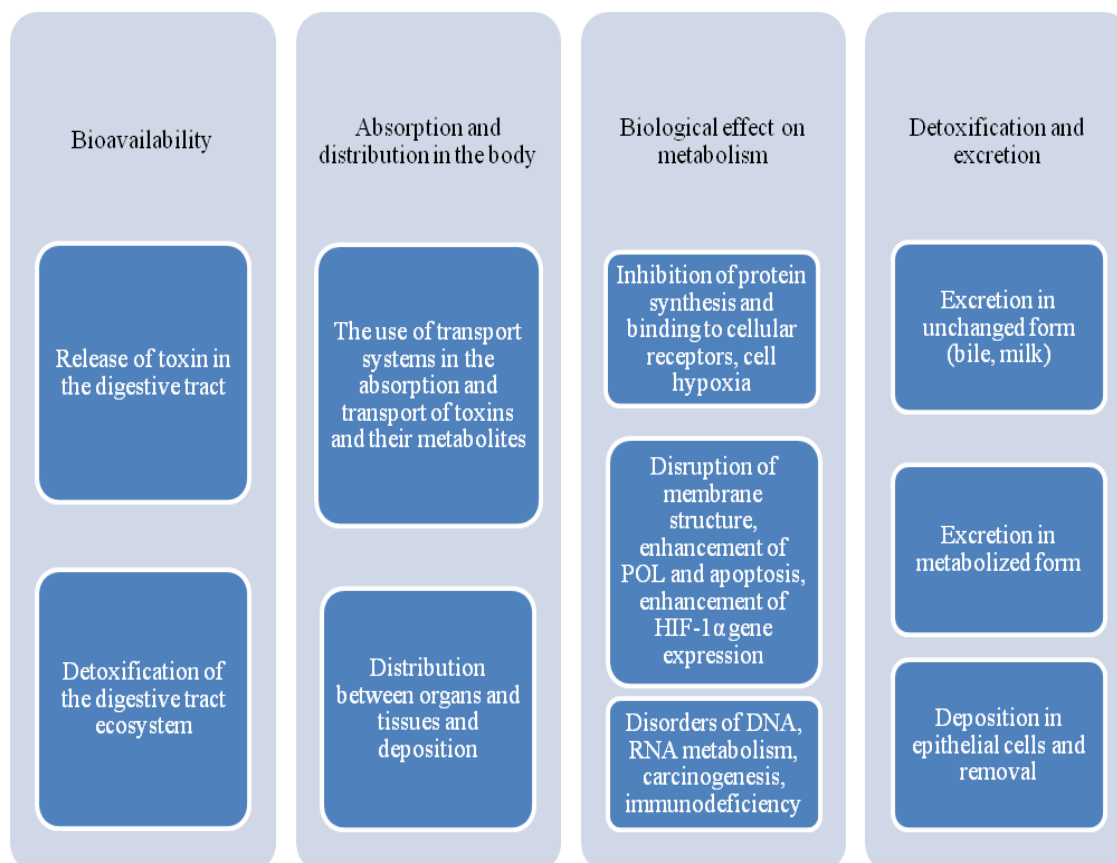


Fig. 4. The main components of the action of mycotoxins on the body

Of course, bioavailability and the intensity of absorption and excretion from the body play a role, too. Some researchers note that mycotoxin contamination of food can significantly exacerbate the course of concurrent diseases [50].

**Basic models for assessing the risks of mycotoxin contamination of milk and dairy products.** The key indicator of the presence of mycotoxins in milk and dairy products is the level to which micromycetes affect animal feed for ruminants.

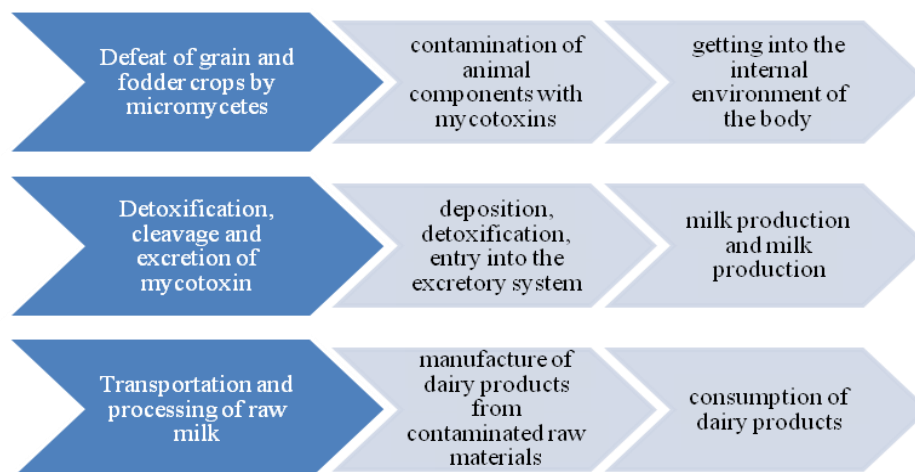


Fig. 5. Structural diagram of the path “Mycotoxins in feed - mycotoxins in dairy products”

It is absolutely impossible to determine the content of mycotoxins in all feeds by chromatography using a mass detector. It is believed that a low level of mycotoxins passing into milk guarantees its purity. Here, the main task is to identify the risks.

First, as a result of milk processing, the content of mycotoxins in the final product can change. And secondly, addition of other components to dairy products significantly increases the risk of contamination of milk with mycotoxins of non-dairy origin.

Therefore, monitoring mycotoxins will prevent them from entering the final product. But why, then, about 25% of human food today is affected by mycotoxins?

The idea that milk processing significantly reduces the content of mycotoxins is wrong. The vast majority of mycotoxins are insensitive to temperature changes. Therefore, measures to pasteurise and disinfect milk do not significantly affect their concentration [55,56].

Moreover, in the course of milk processing and removal of water from the raw materials, the content of mycotoxins can increase significantly. The solution becomes more concentrated due to the reduced amount of the solvent (water). In the Moroccan studies, AFM1 was detected in 14 of 40 samples of UHT milk (35%) with the average concentration  $14.76 \pm 10.21 \text{ ng/kg}$ , and it was detected in all 7 samples of milk powder (100%) with the average concentration  $25.50 \pm 12.06 \text{ ng/kg}$  [57].

Studies conducted on a Portuguese farm showed that all samples of animal feed contained 2 to 13 mycotoxins. Of these, ZEA was detected in 100% of samples, DON in 80%, and OTA in 50%. The results obtained indicate possible contamination of milk with several mycotoxins [51].

So, monitoring compound feeds, root crops, and rough fodder for cows is one of the main problems. Fig. 5 shows the structural diagram of how mycotoxins find their way into dairy products [51-54].

Some mycotoxins can bind to milk caseins. In this case, raw dairy products can contain much higher amounts of mycotoxins than at the initial stage of milk production [58].

Checking some cheeses that appeared in the trade networks of Alexandria, Egypt (90 varieties of cheese), showed that certain varieties were contaminated with AFM1 (26.7% to 40%) [59].

In the manufacture of cheeses, aflatoxin is not distributed evenly in whey and cheese. The largest proportion (60%) was found in the whey, while 40% of AFM1 remained in the cheese. However, the AFM1 concentration was higher in the cheese compared to its initial level in milk [60].

For cheeses, there are 4 main sources of mycotoxins:

- AFM1 coming with milk as a result of feeding contaminated feed to animals;
- synthesis of aflatoxins (B1, B2, G1, and G2) by fungi that grow on cheese (despite the low level of carbohydrates) [61];
- using AFM1-contaminated milk powder to produce cheese [62];
- introducing various spice and additives of plant origin contaminated with mycotoxins.

When risks of consuming dairy products that may potentially contain mycotoxins, antibiotics, or pesticide residues are assessed, it becomes possible to identify the main components of risks, and thus elaborate effective measures to reduce or prevent damage to the

environment, one's health, or business. On the other hand, a better understanding of the process allows taking systematic risk-reducing measures and training the staff.

In the world, there are several models for assessing the risks of mycotoxin contamination of milk and dairy products. In countries with a low level of livestock husbandry, risk assessment is based on several basic components:

- determining the level of efficiency of dairy farming (low, basic, intermediate, or standard);
- ranking the technology of obtaining dairy products by quality, safety, and hygiene;
- developing grids to differentiate the levels of efficiency of dairy products obtaining practices
- determining critical points of regulating the safety parameters of dairy products [63].

In countries with developed livestock and dairy industries, two extremely effective approaches to prevention of mycotoxin contamination of milk and dairy products can be outlined.

The first is state monitoring, identification of critical points, correction and control at various levels. In the United States, the Agricultural Research Service (at USDA) regularly monitors food and raw materials for the following mycotoxins: aflatoxins (B1, B2, G1, G2, M1), fumonisins (FB1, FB2, FB3), deoxynivalenol, patulin, ochratoxin A, and zearalenone [64].

There is also an extremely effective practice used in China. For example, in China, those involved in the melamine incident were convicted: two people were sentenced to be shot, four people to life imprisonment. Not only does the Chinese system provide product monitoring, but there are also methods of assessing a manufacturer's moral rectitude, which are based on developed criteria [65].

If there is a danger of mycotoxicosis due to consumption of dairy products of dubious quality, it is recommended to assess the risks to the environment, health, and business in stages (Fig. 6).

**Stage I** – laboratory tests of samples of feed, milk and dairy products, biological material; anamnesis (verification of previous research, adequacy of measures, previous experience, previous predictions and experts' assessments, feedback from consumers, removing false-positive and false-negative results).

**Stage II** – a full-scale study according to the sequence diagram. Survey of milk and dairy products from the feed, fields, and farms to the dairy and the sale of final products (impartiality, competence, responsibility, openness, confidentiality, response to appeals): analysis of raw materials and inspection of all stages of production and sales; manufacture inspection summary; identification, analysis, assessment, regulation, control, and documentation of risks related to production, sale, and consumption of dairy products.

**Stage III** – assessing how the intensity and duration of exposure to a mycotoxin and its metabolites are likely to effect on the body, ecosystem (biochemical analysis, pathophysiological and clinical manifestations, toxicodynamics, toxicokinetics). Biomonitoring strategies are considered.

**Stage IV** – interpretation of research results and decision-making about how big the risks are and how to correct them. Assessing risks (to the human body, ecosystems, dairy production, and the state's food security). Determining measures to eliminate risks or minimise them. Corrective action should be proportionate to the expected consequences, and ensure that the risk management system is adequate and applicable

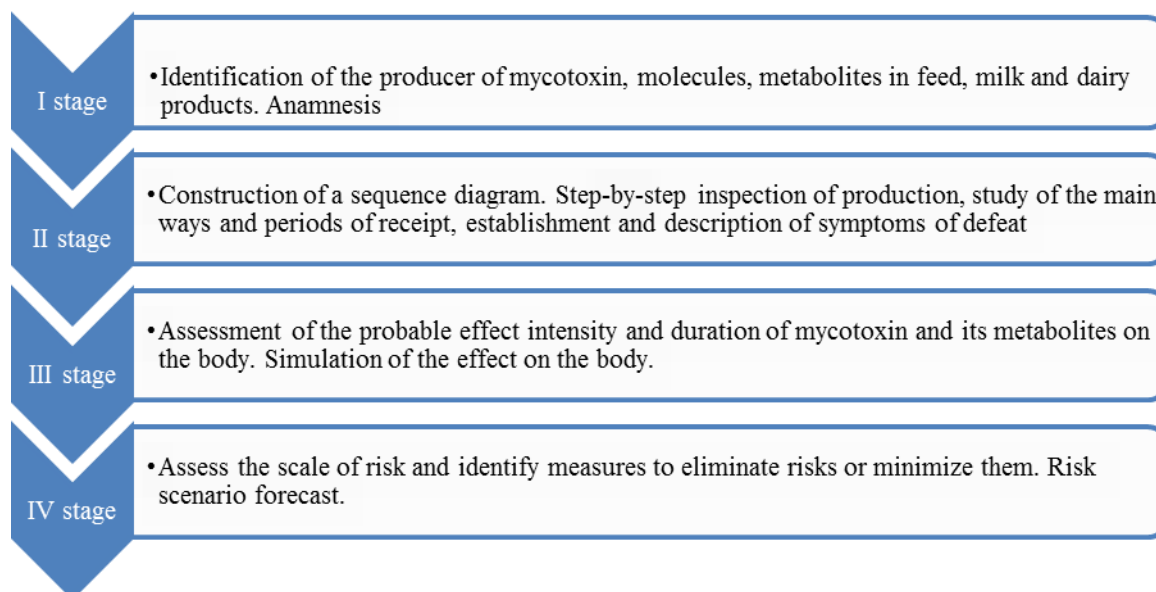


Fig. 6. Assessment of risks of mycotoxin damage to milk and dairy products

### Conclusion

Thus, the milk and dairy production technology should be constantly controlled at certain critical points for possible contamination of the product. Timely detection of mycotoxins at some key points of dairy and

baby food production makes a product's further technological use impossible, and thus prevents consumers' mycotoxicosis. The technology should be provided with standardised, scientifically based measures to control raw materials for the level of mycotoxins and prevent their entry into baby food and dairy products.

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## МІКОТОКСИНИ МОЛОКА ТА МОЛОЧНИХ ПРОДУКТІВ

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**Анотація.** У статті узагальнено сучасні погляди щодо можливої контамінації молока та молочних продуктів мікотоксинами. Ключовим у процесі виявлення мікотоксинів у молоці та молочних продуктах є рівень ураження мікроміцетами кормів для продуктивних тварин. Виявлення тих чи інших мікроміцетів не завжди супроводжується фіксацією у досліджуваному зразку наявності мікотоксину. Для синтезу мікроміцетами мікотоксинів мають створитись відповідні умови. У лактуючих корів екосистема передшлунків забезпечує утилізацію переважної більшості мікотоксинів, що потрапляють з кормом і тільки незначна їхня кількість виділяється з молоком. Окремі мікотоксини можуть зв'язуватися з казеїнами молока і в такому випадку сиромолочна продукція може містити їх значно вищу кількість ніж на початковому етапі виробництва молока. У статті зроблено порівняння гранично допустимих концентрацій мікотоксинів у молоці та молочних продуктах згідно нормативних документів України та ЄС. Наводиться перелік мікотоксинів виділених із секретів молочних залоз людини і продуктивних тварин та їхня дія на фізіологічний стан організму. Представлено структурно-логічну схему процесу контамінації мікотоксинами молока та молочних продуктів «Мікотоксини корму – молочна продукція». Пропонується оцінку ризиків за ураження мікотоксинами молока та молочних продуктів проводити в чотири етапи: I етап – ідентифікація продуцента мікотоксину, молекули, метаболітів у кормах, молоці та молочній продукції. Анамнез; II етап – побудова діаграми послідовності. Покрокове обстеження виробництва, вивчення основних шляхів та періодів надходження мікотоксинів, встановлення та опис симптоматики ураження; III етап – оцінка ймовірного впливу інтенсивності та тривалості надходження мікотоксину та його метаболітів на організм. Моделювання впливу на організм; IV етап – оцінка масштабів ризику та визначення заходів щодо усунення ризиків або їхньої мінімізації. Прогноз сценарію розвитку ризиків.

**Ключові слова:** молоко, молочні продукти, мікотоксини.

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