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Systematic review of mycotoxins in food and feeds in Turkey

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ABSTRACT

Mycotoxins are toxic natural contaminants of food and feeds and are produced by various fungi from *Aspergillus*, *Alternaria*, *Fusarium*, and *Penicillium* genera. Molds and their toxins have attracted much attention worldwide due to the important economic losses related to their effects on human health and domestic and international trade. Although more than 400 mycotoxins have been identified, most studies have focused on aflatoxins, ochratoxin A, fusarium toxins, zearalenone, patulin, and trichothecenes owing to their relationships with food safety and economic losses. In Turkey, the dramatic variations in climatic conditions among regions have facilitated the spread of various foodborne mycotoxins. Accordingly, in this systematic review, a summary of the occurrence and contamination levels of foodborne mycotoxins in Turkey was provided. Based on the literature review, mycotoxin levels were shown to exceed the limits designated by the European Union in apple juice (35%), milk (21%), dairy products (12%), dried fruits and vegetables (11%), herbs (10%), cereal and cereal products (2%), nuts (1%), and feeds (1%). Thus, there is a need for additional studies on the mycotoxin prevalence in all types of foods and feeds throughout Turkey, and education programs on mycotoxin management are important for reducing the prevalence of mycotoxin contamination.

1. Introduction

The Mediterranean climate has made Turkey one of the world's most important agricultural producers. Indeed, in 2016, Turkey produced 18.5 million tons of milk, making Turkey the leading milk and dairy producer in the region. Dairy farms are relatively smaller in Turkey than in much of the rest of the world (Aytop, Çukadar, & Şahin, 2014; OECD, 2016). Turkey exports fresh fruits and vegetables, particularly hazelnuts, tomatoes, cherries, and apricots, to the European Union (EU) and imports cheese, wine, and fish products (www.ab.gov.tr, 2014). The United States of America (USA) exports several agricultural products to Turkey, including cotton, tree nuts, distillers' grains, and soybeans, but imports processed fruits and vegetables, snack foods, coarse grains, and fruit and vegetable juices (USTR, 2018).

The occurrence of mycotoxins is an important problem that is monitored closely in Turkey. The as low as reasonably achievable (ALARA) principle and maximum residue limit (MRL) implementations are reflected in Turkish regulations as well. Common mechanisms of exposure to mycotoxins include digestion of contaminated products, skin contact, and inhalation of mycotoxins. Studies of mycotoxin occurrence are essential for controlling the risks to both humans and animals.

In this systematic review, I provide comprehensive data on the diversity of agricultural products, mycotoxin occurrence, and regulations. The mycotoxin contamination levels in foods and feeds sold in Turkey are discussed, with the aim of providing a simple, searchable dataset for further studies.

2. Materials and methods

A systematic search was conducted in major databases, including PubMed, EBSCO, ScienceDirect, and Web of Science. Dergipark (Turkish and/or English) and Google Scholar were also used. The relevance of the references was determined by evaluating the title, keywords, abstract, and full text of papers. Reference lists of included articles were searched by hand to identify other suitable studies. Furthermore, scientific reports were retrieved from governmental organizations, such as the Organisation for Economic Co-operation and Development (OECD), Joint FAO/WHO Expert Committee on Food Additives (JECFA), and EU. Studies were excluded if the research was not conducted in Turkey, products were not bought in Turkey, and mycotoxin occurrence was not clearly described. Reviews, theses, and posters abstracts from workshops or congresses were also excluded. Animal studies, new mycotoxin research methods, and studies that investigated the effects of other mycotoxins were also excluded. Mycotoxin analyses performed on food groups and feeds in Turkey are presented in Table 1.

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Table 1
Mycotoxin analyses performed in food and feeds.

Products	AFB_1	AFB_2	AFG_1	AFG_2	AFM1	AFT	FB	OTA	ZEA	DON	T-2	HT-2	PAT
Infant formulas and baby foods	X				X			X					X
Dairy products					X								
Cereal and cereal products	X	X	X	X		X		X					
Feeds	X	X	X	X		X	X	X	X	X	X	X	
Dried fruits and vegetables	X					X		X					
Herbs	X	X	X	X		X		X					
Nuts	X					X							

3. Occurrence and Health Impacts of Major Foodborne Mycotoxins

Mycotoxins are chemically and thermally stable, low-molecular-weight secondary metabolites produced by fungi in preharvested crops, harvested produce, or their products (Fox & Howlett, 2008). Mycotoxins can also be produced as a response to oxidative stress. During colonization and infection, fungi can be exposed to host metabolites, and reactive oxygen species can trigger response pathways in fungi that include the production of mycotoxins (Ponts, Pinson-Gadais, Verdal-Bonnin, Barreau, & Richard-Forget, 2006). Fungi belonging to the genera *Aspergillus*, *Fusarium*, and *Penicillum* (Sweeney & Dobson, 1998) have effects on mammals and crops, resulting in diseases and economic losses. There are many such compounds, but only a few are regularly found in foods and animal feedstuffs. Fungi are commonly divided into two groups: field (plant pathogenic) fungi, which invade seeds before harvesting, and storage (saprophytic) fungi, which require less moisture than field fungi and tend to invade grains and seeds during storage (Placinta, D'mello, & Macdonald, 1999; Santin, 2005). The most commonly contaminated crops include staple foods, such as maize, groundnuts, wheat, barley, oats, and sorghum (Wild & Gong, 2009).

Mycotoxicosis is the result of dietary, respiratory, and dermal exposures to toxic fungal toxins (Bennett & Klich, 2003; Sweeney, White, & Dobson, 2000). The rumen microbiota is capable of degrading mycotoxins; therefore, ruminants are less effected than humans (Zain, 2011). The most agroeconomically important types of mycotoxins that contaminate foods worldwide include aflatoxins (AFTs), ochratoxin A (OTA), zearalenone (ZEA), trichothecenes, fusarium toxins (FBs), and patulin (PAT) (Huffman, Gerber, & Du, 2010). Table 2 summarizes the organisms that produce major mycotoxins, the most commonly contaminated foods, major health effects, and chemical structures.

Mycotoxin production can be prevented by organized work between different disciplines. For example, good agricultural practice (GAP) and good manufacturing practice (GMP) are effective prevention systems. Fig. 1 illustrates the factors affecting mycotoxin accumulation in foods and feeds (Magan & Aldred, 2007; Magan, Medina, & Aldred, 2011; Sarrocco & Vannacci, 2017).

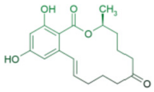
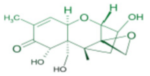
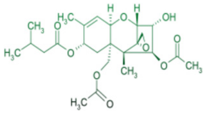
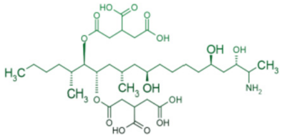
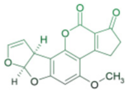
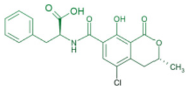
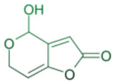
AFTs are produced by several species of soil-borne *Aspergillus* and are responsible for decomposition of plant materials. Moreover, AFTs are known for their carcinogenic properties, particularly in hepatocellular carcinoma, which is a major cause of cancer-related deaths in developing countries. The most common *Aspergillus* contaminants in agriculture are species *Aspergillus flavus* and *A. parasiticus*. Warm temperatures and humidity favor their growth, making AFT food contamination a common problem (Bbosa et al., 2013). Based on their chemical structures, AFTs belong to a group of difuranocoumarins and are divided into two subgroups: AFB_1, AFB_2, AFM_1, and AFM_2 are difuranocoumarocyclopentenones, whereas AFG_1 and AFG_2 are difuranocoumarolactones. *A. flavus* strains only produce AFB_1 and AFB_2; in addition to these toxins, *A. parasiticus* strains also produce AFG_1 and AFG_2. When cows consume contaminated feeds containing AFM_1, the main monohydroxylated derivative of AFB_1, milk products become an indirect source of AFTs (Bbosa et al., 2013). Currently, AFB_1 occurrence in foods and feeds is unavoidable, and this compound is highly stable during cooking and extrusion (Marin, Ramos, Cano-Sancho, & Sanchis, 2013). AFB_1 is considered the most toxic AFT (Gourama & Bullerman, 1995), followed by AFM_1, AFG_1, AFB_2, and AFG_2 carcinogens (Bennett & Klich, 2003). The liver is the primary target of AFB_1; because AFTs are liposoluble, they are absorbed through the gastrointestinal and respiratory tracts into the blood stream. According to the International Association for Research on Cancer (IARC) classification, AFB_1, AFB_2, AFG_1, and AFG_2 are group 1 carcinogens, whereas AFM_1 is a group 2B carcinogen. Table 3 shows the primary mechanisms of action, toxicities, EU legal limits, and IARC classifications of some food mycotoxins as potential human carcinogens (Köppen et al., 2010; Romer 2016; IARC, 1999).

AFTs are responsible for the suppression of humoral and cell-mediated immunity, causing susceptibility to infectious diseases (Bbosa et al., 2013). When dietary exposure to AFTs is decreased, the risk of hepatic cancer is also diminished (Chen et al., 2013). Notably, AFTs are the only mycotoxins controlled by US Food and Drug Administration (FDA) action levels; the other types of mycotoxins are subjected only to advisory levels (Alshannaq & Yu, 2017).

Fusarium verticillioides and *F. proliferatum* produce FBs (Zain, 2011). Recent studies have shown that *A. niger* can also produce some types of FBs (Huffman et al., 2010). Corn is the major commodity affected by this group of toxins; however, some reports have described the occurrence of FBs in rice and sorghum. Structurally, FBs are similar to sphingosine and sphinganine. This structural similarity is the reason for their toxicity, which is based on interference with sphingolipid metabolism (Zain, 2011). To date, 28 FBs have been isolated and classified into A, B, C, and P groups. *Penicillium fumonisins* from the B group is the most abundant. FB_1 accounts for 70% of the total FB content and is the most toxic of known FBs (Huffman et al., 2010). The target organs of FBs are the kidneys and liver. FB consumption has also been associated with oesophageal cancer in humans, and because FB_1 reduces folate uptake in different cell lines, this compound has also been shown to be involved in neural tube defects (Zain, 2011). Because of the hydrophilicity of FBs, they are not found in milk, and tiny amounts of FB_1 accumulate in edible tissues. The JECFA established the provisional maximum tolerable daily intake (PMTDI) for FBs as $2\,\mu g/kg$ body weight (bw)/day (JECFA, 2008).

OTAs are widespread in agricultural products and can also found animal-derived products (Stoev, 2013). Different fungi produce different types of ochratoxins, i.e., types A, B, and C, among which OTA is the most common and most toxic (Bayman & Baker, 2006). Although *P. verrucosum* prefers cool-temperate regions, *A. ochraceus* prefers to grow in hot climates (Scudamore, 2005), and OTA produced by *A. ochraceus* is chemically stable under acidic conditions and can tolerate normal cooking temperatures. The structure of OTA is similar to that of phenylalanine; therefore, OTA inhibits phenylalanine hydroxylase activity and protein synthesis in the kidneys and liver. OTA also hinders both RNA and DNA synthesis and is known to be immunotoxic, genotoxic, neurotoxic, and embryotoxic in mammals (Mantle, 2002). OTA is acutely nephrotoxic and hepatotoxic and has been shown to cause Balkan endemic nephropathy (Ostry, Malir, Toman, & Grosse, 2017). OTA also increases the mutagenicity of AFB_1 if both are present in the same substrate (Sedmikova, Reisnerova, Dufkova, Barta, & Jilek, 2001). JECFA established a provisional tolerable weekly intake for OTA of

Table 2
Major foodborne mycotoxins, the organisms that produce them, the foods mostly contaminated, major health effects and chemical structures.

	Some fungi source	Fungi growth	Occurrence in food	Chemical formula
$C_{18}H_{22}O_5$ **ZEA** ***Preharvest***	*F. graminearum* *F. culmorum* *F. cerealis* *F. equiseti* *F. verticillioides* *F. crookwellence*	Can be produced in relatively cool conditions compared to some other mycotoxins but it is likely that most grains mentioned above can become contaminated with zearalenone during storage and levels that were present in the grain preharvest may increase if the grain is not sufficiently dried and stored.	wheat, barley, sorghum rye	
$C_{15}H_{20}O_6$ **Trichothecene** ***Preharvest***	*F. graminearum* *F. culmorum*	Storage is not considered a problem for DON contaminated wheat and corn that has matured and been stored at moisture percentages below 14.	wheat, corn, barley	DON  T-2 toxin 
$C_{34}H_{59}NO_{15}$ **FB** ***Preharvest***	*A. alternate* *F. proliferatum* *F. verticilloides*	Drought stress followed by warm, wet weather during flowering promote production of the toxin. Quite stable and resist several decontamination and manipulation processes being able to reach final products intended for human consumption like corn flakes.	maize, corn, sorghum, asparagus, rice, milk	
$C_{17}H_{12}O_6$ **AFT** ***Postharvest***	*A. flavus* *A. parasiticus*	Grains stored under high moisture/humidity (> 14%) at warm temperatures (> 20 °C) or/and inadequately dried can potentially become contaminated	corn, cottonseed, grains, peanuts tree nuts	
$C_{20}H_{18}ClNO_6$ **OTA** ***Postharvest***	*A. ochraceus* *P. verrucosum* *A. niger* *A. carbonarius*	Grains stored under high moisture/humidity (> 14%) at warm temperatures (> 20 °C) and/or inadequately dried potentially can become contaminated. Damage to the grain by mechanical means, physical means or insects can provide a portal of entry for the fungus.	corn, beans, peanuts, oats, barley, wheat, rye, olives, beans, beer, wine, cocoa, coffee	
$C_7H_6O_4$ **PAT** ***Postharvest***	*P. patulum* *P. crustosum* *P. expansum* *A. clavatus*	Capable of causing decay in deciduous fruits and vegetables during post-harvest handling and storage. Patulin is mainly associated with damaged and rotting fruits.	Apple, pears, peaches, grapes, apricots, olives low acid fruit juices	

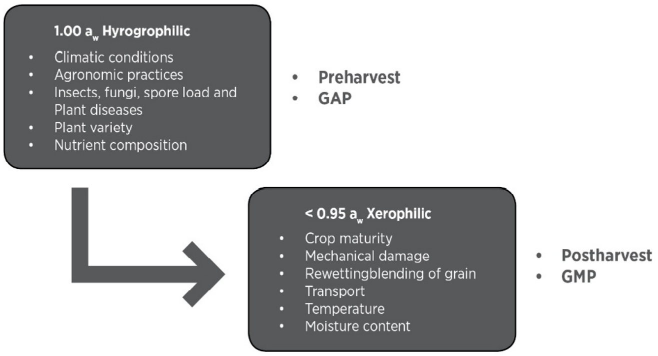


Fig. 1. The factors affecting mycotoxin accumulation in food and feeds.

112 ng/kg bw/week (JECFA, 2008).

ZEA is a secondary metabolite produced by *F. graminearum* and other *Fusarium* molds contaminating cereals (Zain, 2011). Grains infected with *Fusarium* species usually exhibit a pink colour (Richard, 2007). ZEA is an estrogenic mycotoxin because of its structural similarity to naturally occurring oestrogens (Panel, 2016). The main source of ZEA contamination in Canada and the USA is corn. Wheat, rye, and oats are also contaminated with ZEA in European countries. α-Zearalenol (ZOL) (Frazzoli, Gherardi, Saxena, Belluzzi, & Mantovani) and β-ZOL are the most important ZEA derivatives. Because of the strong affinity between α-ZOL and oestrogen receptors, the estrogenic potential of α-ZOL is higher than those of ZEA and β-ZOL. ZEA contamination typically occurs with deoxynivalenol (DON) and less often with AFTs. Moreover, ZEA is only partly removed in the presence of high temperatures (Zinedine, Soriano, Molto, & Manes, 2007). The European Food Safety Authority (EFSA) established a tolerable daily intake (TDI) for ZEA of 0.25 μg/kg bw/day (Panel, 2016).

Due to their low molecular weight and amphipathic nature, trichothecenes are easily absorbed across gastrointestinal membranes and are quickly distributed into various body organs and tissues (Pestka & Smolinski, 2005). The higher tolerance in ruminants than in monogastric animals is attributed to detoxification by rumen microflora prior to absorption (Wu et al., 2014). There are approximately 200 known trichothecenes that can be classified as type-A, -B, -C, or -D and are esters of sesquiterpenoid alcohols. Type A trichothecenes are the simplest group, comprising T-2 and HT-2, and are more toxic than type B analogues (e.g., nivalenol [NIV], DON, and fusarenon-X [FX]). T-2 toxin is among the most toxic trichothecenes, followed by NIV in mammals. Types C and D trichothecenes are less important (Ferrigo, Raiola, & Causin, 2016). The EFSA set a TDI for NIV of 1.2 μg/kg bw/day (EFSA, 2013). Ingestion of T-2 and HT-2 is associated with alimentary toxic aleukia, a haemorrhagic disease characterized by mouth and nose bleeding, vomiting, diarrhoea, abdominal pain, and fever. Prolonged exposure is associated with reduced weight gain, growth suppression, and severe gastrointestinal lesions. T-2 is rapidly transformed into HT-2 by deacetylation during digestion in mammals. Both HT-2 and T-2 are toxic to animals and humans, affecting the immune system and causing inhibition of protein synthesis. Chronic exposure to T-2 is also

Table 3
Foodborne mycotoxins' primary mechanism of action, toxicity, the range EU legal limits, and IARC classification.

Mycotoxin	Primary mechanism of action	Toxicity	EU limit range µg/kg		IARC carcinogen classification
			Food	Feed	
AFTs	Binds to guanine (DNA-adduct) after metabolic activation in the liver	Carcinogenic Mutagenic Teratogenic Hepatotoxic Nephrotoxic Immunosuppressive Liver disease Haemorrhage of intestinal tract and kidney	$AFB_1 + AFB_2 + AFG_1 + AFG_2$ 4 (dried fruits, cereals, nuts) 15 (groundnuts) AFM_1: 0.025 (infant milk and dietary foods) 0.05 (milk) AFB_1: 0.1 (processed cereal based foods and baby foods) 8.0 (dietary, processed cereal- based and infant foods, hazelnut)	AFB_1: 5 (compound feed) 20 (all feed materials)	Group 1 Carcinogenic Sufficient evidence AFB1, AFB2, AFG1, AFG2 AFM1 2A Probably carcinogenic to humans
OTA	Blocks protein synthesis	Kidney damage Danubian endemic familial nephropathy	0.5 (processed cereal-based and infant foods) 10 (dried vine fruits and instant coffee) 15 (SPices, including dried spices)	100 (complete feeding stuffs for poultry) 250 (cereal and products)	Group 2A Probably carcinogenic to humans None or inadequate evidence
FB	Inhibit ceramide synthase	Neural tube defect (spina bifida, anencephaly) Esophageal cancer	$FB_1 + FB_2$: 200 (processed maize-based foods and infant foods) Oat bran and flaked oats 100 (flaked oats and maize milling products	20000 (feeding stuffs for poultry, calves (< 4 months), lambs) 60000 (Maize and maize based products)	Group 2B Possibly carcinogenic to humans None or inadequate evidence
ZEA	Binds to mammalian estrogen receptor	Oestrogen like activity (infertility, vaginal prolapse, feminisation in males) Hyperestrogenism, hepatotoxic, hepatocarcinogenic	20 (processed cereal-based foods and baby foods) 50 (cereal snacks or breakfast excluding maize based ones) 75 (cereals for direct human consumption as cereal flour)	500 (feeding stuffs for calves, dairy cattle, sheep (including lamb) and goats) 3000 (Maize by-products)	Group 3 Not classifiable None or inadequate evidence
DON	Inhibition of protein synthesis	Dermatosis Constricted blood vessels Neurotoxic Immune depressant Gastrointestinal hemarrhaging	200 (processed cereal-based foods and baby foods) 500 (bakery, cereal snacks or breakfast) 750 (cereal flour, bran, pasta, germ)	2000 (feeding stuffs for calves (< 4 months), lambs) 12000 (Maize by-products)	Group 3 Not classifiable None or inadequate evidence
T-2 toxin and HT-2 toxin	DNA damage	Immun depressants mutagenic gastrointestinal haemorrhaging neurotoxic	15 (cereal based baby foods) 25 (bread, biscuits) 50 (other cereal milling products) 75 (breakfast cereals incl cereal flakes)	2000 (oat milling products (husks) 500 (Other cereal products)	Group 3 Not classifiable None or inadequate evidence
PAT	DNA and RNA synthesis inhibition	gastrointestinal symptoms, neurotoxic, immunosuppressive mutagenic	10 (apple juice, solid apple, apple puree) 50 (spirit drinks derived from apples or containing apple juice, fruit juices)		Group 3 Not classifiable None or inadequate evidence

associated with Kashin-Beck disease, a chronic degenerative osteoarthritic condition that causes short stature and may cause disability in adults (Richard, 2007; Zain, 2011). The EFSA set a TDI for T-2 + HT-2 toxins (group value) of 100 ng/kg bw/day (EFSA, 2011).

DON or vomitoxin is the most prevalent and extensively studied trichothecene. Ingested DON is rapidly absorbed and distributed, reaching maximum concentrations in various tissues after 15–30 min. In the human liver, glucoronidation is the major detoxification mechanism for biotransformation of DON, which is eventually excreted in the urine. Exposure to DON causes abdominal pain, diarrhoea, vomiting, anorexia, and fever. In mammals, chronic exposure to low doses of DON is associated with decreases in food intake, weight gain, growth, and immune system function. NIV is inefficiently absorbed from the gastrointestinal tract, whereas FX is rapidly and efficiently absorbed and is quickly converted back to NIV. Approximately 80% of ingested NIV is excreted in faeces, and the majority of FX is excreted in urine (Male et al., 2016). *Fusarium* spp. predominantly produce DON in North America but produce both DON and NIV in Japan (van der Lee, Zhang, van Diepeningen, & Waalwijk, 2015). These toxins are highly resistant to thermal processes, including extrusion (at temperatures as high as 150 °C) (Bullerman & Bianchini, 2007), frying (> 200 °C), and steaming (185 °C; 6 min) (Kabak, 2009a, 2009b). The JECFA set a PTMDI for DON of 1 µg/kg bw/day (JECFA, 2001b).

PAT is a toxic lactone produced by *Aspergillus*, *Penicillium*, *Byssochlamys*, and *Paecilomyces*. PAT is heat resistant, stable under acidic conditions, and unstable in water. *P. expansum* is found in damaged apples and low-acid fruit juices, i.e., apricots, nectarines, and plums (Cavaliere et al., 2006). The absorption of PAT can cause acute (Reddy et al., 2010) and chronic symptoms due to cellular-level effects (Abrunhosa et al., 2016). PAT does not accumulate in the body, and controlled atmosphere and introduction of biological control organisms can limit PAT contamination during storage in cold rooms (Barad, Sionov, & Prusky, 2016). PAT is not carcinogenic, and the JECFA set a PMTDI for PAT of 400 ng/kg bw/day (JECFA, 1996).

Mycotoxin production can be prevented by organized efforts from different disciplines. Mycotoxin prevention should be approached as a government policy, and efforts should be made to transfer prevention systems into practice. The application of prevention systems, such as GAP and GMP, is expected to be highly effective.

4. Results

4.1. Mycotoxins in infant formulas and baby foods

For infants, mother's milk or formula is the main food source. As the nutritional needs of infants increase by 4–6 months of age, infants also consume solid or pureed foods. Infant cereal products are digestible and provide iron and other essential minerals necessary for infant growth.

Table 4
Presence of mycotoxins in infant formulas and baby foods.

Product/Mycotoxin	No of samples	Positive samples No (%)	Range/mean (μg/kg)	Method	> EU Legal limit No (%)	Reference
Milk based/AFB_1	29	27 (93)	1.10-6.04/0.73 ± 1.11	ELISA	n.a.	(Baydar, Erkekoglu, Sipahi, & Sahin, 2007)
AFB1/Cereal based/AFB_1	25	22 (88)	1.10-6.04/0.80 ± 0.44		n.a.	(Baydar et al., 2007)
Milk + cereal based/AFB_1	9	6 (67)	1.10-6.04/1.93 ± 2.08		n.a.	(Baydar et al., 2007)
Total AFB_1	**63**	**55 (83)**				(Baydar et al., 2007)
Milk based/AFM_1	29	13 (45)	0.06–0.32/0.06 ± 0.03		–	(Baydar et al., 2007)
Cereal based/AFM_1	25	6 (24)	0.06–0.32/0.06 ± 0.03		–	(Baydar et al., 2007)
Milk + cereal based AFM_1	9	4 (44)	0.06–0.32/0.18 ± 0.09		–	(Baydar et al., 2007)
Infant formula/AFM_1	6	1 (17)	0.016/0.016	HPLC	–	(Kabak, 2012a)
Follow on formula/AFM_1	36	2 (6)	0.02-.020/0.02 ± 0.003		–	(Kabak, 2012a)
Toddler formula/AFM_1	20	2 (10)	0.07-0.022/0.020 ± 0.004		–	(Kabak, 2012a)
Infant formula/AFM_1	34	1 (3)	0.0061/0.0061	ELISA	–	(Er, Demirhan, & Yentur, 2014)
Follow on milk/AFM_1	50	31 (62)	0.006-.02/0.009 ± 0.0006		–	(Er et al., 2014)
Infant formula/AFM_1	33	–	–	ELISA	–	(Kocasari, 2014)
Total/AFM_1	**242**	**60 (23)**				
Milk based/OTA	29	7 (24)	0.27-4.50/0.50 ± 0.33		n.a.	(Baydar et al., 2007)
Cereal based/OTA	25	14 (56)	0.27-4.50/1.82 ± 1.54		n.a.	(Baydar et al., 2007)
Milk + cereal based/OTA	9	4 (44)	0.27-4.50/2.38 ± 1.22		n.a.	(Baydar et al., 2007)
Cereal based/OTA	24	4 (17)	0.12-0.374/0.22 ± 0.114	HPLC-FD	–	(Kabak, 2009a, 2009b)
Cereal based/OTA	21	4 (20)	0.08-0.20/0.14	HPLC	–	(Ozden, Akdeniz, & Alpertunga, 2012)
Infant formula/OTA	6	–	–	HPLC	–	(Kabak, 2012a)
Follow on formula/OTA	36	2 (6)	0.017-0.029/0.02 ± 0.08		–	(Kabak, 2012a)
Toddler formula/OTA	20	10 (50)	0.27-4.50/0.119 ± 0.051		–	(Kabak, 2012a)
Infant formula/OTA	50	8 (16)	0.032-0.096/.043 ± 0.8	ELISA	–	(Hampikyan, Bingol, Colak, Cetin, & Bingol, 2015)
Follow on formulae/OTA	50	10 (20)	0.027-0.187/0.089 ± 0.5		–	(Hampikyan et al., 2015)
Cereal based/OTA	50	34 (68)	0.042-0.380/0.16 ± 0.7		–	(Hampikyan et al., 2015)
Infant formula/OTA	50	8 (16)	0.026-0.089/0.037 ± 0.6	HPLC	–	(Hampikyan et al., 2015)
Follow on formulae/OTA	50	10 (20)	0.022-0.178/0.082 ± 0.4		–	(Hampikyan et al., 2015)
Cereal based/OTA	50	34 (68)	0.034-0.374/0.02 ± 0.3		–	(Hampikyan et al., 2015)
Total/OTA	**407**	**103 (30)**				
Apple juice/PAT	215	215 (100)	n.a./7 -376	HPLC	93 (44)	(Gökmen & Acar, 1998)
Apple juice/PAT	62	n.a.	31 ± 23/ < 5-119	LC	8 (17)	(Gökmen & Acar, 2000)
Apple juice/PAT	46	27 (60)	139.9 ± 114.6/19.1–732.8	HPLC	20 (44)	(Yurdun, Omurtag, & Ersoy, 2001)
Total/PAT	**323**	**242 (80)**			**121 (35)**	
TOTAL $AFB_1 + AFM_1 + OTA + PAT$	**1035**	**460 (54)**			**121 (35)**	

n.a. not available.

Infants have a higher metabolic rate, lower body weight and detoxification capacity, and high intake of food and water per kg bw. Accordingly, infants are more vulnerable to mycotoxins than adults. Although the FDA has not set limits for mycotoxins in baby foods (FDA, 2016), limits for mycotoxin levels in baby cereals have been established in many countries, including countries in the EU. However, there are no regulations for NIV (EC Regulation, 2006, pp. 5–24).

From 1035 baby foods analysed, 54% (460) were found to be contaminated with AFB_1, AFM_1, OTA, and PAT (Table 4). The most frequently found mycotoxin was AFB_1 (83%), followed by PAT (80%). Nevertheless, baby food contamination by AFB_1 is unavoidable because of the nature of baby food ingredients, i.e., milk powder, vegetables, vegetable oils, nuts, fruits, and cereals. Notably, when OTA and AFB_1 occur in the same substrate, OTA can increase the mutagenicity of AFB_1 (Sedmikova et al., 2001). The incidence AFM_1 in baby foods marketed in Turkey does not seem to be a serious health risk for children because none of the tested samples contained this compound at levels above the EU-established limit. Surveillance of baby foods must be continuous and extensive in order to decrease likely health risks because the quality of ingredients in the formula can be changed year by year depending on the harvest conditions.

The reactions of infants and young children to drugs and toxins differ from those of adults, and in most cases, infants and children are more susceptible to adverse effects. Furthermore, infants and young children eat and drink more relative to their size than adults. Importantly, synergistic toxic effects can be observed when more than one mycotoxin occurs in infant formula, follow on formula, toddler formula, or milk-based, cereal-based, and milk- and cereal-based baby foods.

Most mycotoxins are toxic even at very low concentrations and are chemically stable; thus, these toxins tend to persist in foods, even after cooking at very high temperatures. Indeed, mycotoxins are particularly difficult to remove from foods, and the best way for mycotoxin control is prevention.

Apple juice is the juice of choice for infants. In some studies, the levels and incidence of PAT in apple juice samples (17.2–44%) have been shown to be well above the limit set by the EU. Thus, the quality of the apples employed for production of apple juice is not sufficient, particularly for consumption by infants and young children, and higher processing standards should be implemented.

4.2. Mycotoxins in dairy products

The choice of milk products differs depending on eating habits, available milk processing technologies, market demand, and social and cultural surroundings. Liquid milk is the most commonly consumed dairy product throughout the developing world. Although the demand for liquid milk is high in city centres, fermented milk is preferred in rural areas. In general, approximately 3–4% of dietary energy comes from milk in Africa and Asia, compared with 9% in Europe, Oceania, and the Americas (OECD, 2017).

AFTs are the most important mycotoxins found in dairy products. AFT levels in milk differ according to the season, animal breed, and milking time (Anfossi, Baggiani, Giovannoli, & Giraudi, 2011). AFM_1 in dairy is reported mostly in developing countries (Ismail et al., 2016). The concentration of AFM_1 has been reported to be higher both in winter and in the morning as compared with that in summer season and in the evening. Favourable temperature and moisture may increase AFM_1 levels in winter, whereas animals participate in open grazing in the summer (Frazzoli, Gherardi, Saxena, Belluzzi, & Mantovani, 2017). AFTs are a problem for both importing and exporting countries. Strict rules for AFM_1 contamination in milk have been published by the EU (Ismail et al., 2016). AFB_1 in feed is converted by ruminants, yielding AFM_1 in milk (Asselt, Fels-Klerx, Marvin, Veen, & Groot, 2017); transfer factors range from 0.015 to 0.024 (MacLachlan, 2011). A direct correlation has been found between AFB_1 amount in feeds and AFM_1 levels in milk (Streit et al., 2012). Importantly, developed countries have set limits for AFM_1, and developing countries mostly apply the legal limits set by the EU or other international agencies (Ismail et al., 2016). In dairy products, AFM_1 content has been shown to be only slightly affected by storage, pasteurization, and ultrahigh temperature treatments because mycotoxins are typically heat resistant (Flores-Flores, Lizarraga, López de Cerain, & González-Peñas, 2015). Although AFM_1 is frequently detected, the levels are mostly below the monitoring limits defined by each country. However, if high consumption over the long term is combined with high exposure, mycotoxin contamination may become a serious public health problem (Campagnollo et al., 2016).

Table 5 shows studies of the incidence of AFM_1 in dairy products in Turkey. Notably, 49% of all of tested samples contained AFM_1, and 52% of milk samples with AFM_1 had levels varying from 0.0008 to 3.774 μg/kg. However, only 21% of samples exceeded the legal limit.

Cheese made from AFM_1-contaminated milk has more AFM_1 than the original milk. Nearly 70% of AFM_1 binds to casein, thereby increasing accumulation in curd after draining (Scaglioni, Becker-Algeri, Drunkler, & Badiale-Furlong, 2014). Iha, Barbosa, Okada, and Trucksess (2013) showed that total AFM_1 in milk was condensed by 3.2% in cheese and at pH 4.4 by 6% in yogurt. The mean amounts of AFM_1 in curd and whey were 1.9- and 0.6folds higher, respectively, than in unprocessed milk. AFM_1 levels vary from less than 0.001 μg/kg to 5.20 μg/kg in yogurt, ayran, butter, and cheese, with 12% of dairy products exceeding the legal limit based on EU regulations. Notably, for mouldy cheese, all samples had AFM_1, and the levels of this toxin exceeded the legal limit set by the EU, negatively influencing the means of samples in Turkey. Because AFTs are classified as carcinogenic and genotoxic, the ALARA method is recommended; even 1 μg/kg bw/day can cause liver cancer. As shown in Table 5, the mean concentration of AFM_1 in milk is 0.052 μg/kg. The average milk consumption in Turkey is 66 g/day. Therefore, the PDI of AFM_1 is 0.0528 ng/kg/day, assuming an adult body weight of 65 kg. The mean AFM_1 concentrations in milk in Europe is 0.023 ng/kg/day (JECFA, 2001a). Thus, the mean AFM_1 amount in Turkish milk samples is about 2 times higher than that in European milk samples.

ZEA is present in milk, albeit at lower rates than AFM_1. Unusan (2017) showed that 90.11% of milk samples were contaminated with ZEA, although the mean level was well below the recommended intake in milk and milk products. Therefore, human exposure to ZEA from milk in Turkey is not considered to be a health risk.

4.3. Mycotoxins in cereals and cereal-based foods

Since 2000, the rate of urbanization in Turkey has reached nearly 80%. However, the Turkish feed industry is among the world's top 12 producers (top 5 in Europe) (Karabina, 2017). FAO estimates have shown that 25% of harvests are contaminated with mycotoxins. The determination of mycotoxin presence in feeds, cereals, and cereal products is challenging because these compounds are generally present at very low levels, and the matrices can be highly complex. Table 6 summarizes studies on the incidence of mycotoxins. Notably, AFT and OTA are the only mycotoxins that have been studied in cereals for human consumption. These studies have shown that 49% of all cereals and cereal products are contaminated with AFTs and OTA in Turkey. AFT and OTA levels vary from limit of quantification (LOQ) to 643.5 μg/kg and LOQ to 356.8 μg/kg, respectively. However, only 1.6% of samples exceeded the legal limit.

Wheat is the main product in Turkey. The majority of wheat is used for human consumption as flour and pasta (some of which is exported) because it is regarded as a good source of vitamins, carbohydrates, and proteins; the remaining wheat is used as feed. Bread is a staple food in the general population. The WHO recommends 250 g/day intake, whereas that in Turkey is 550 g/person/day.

Barley is commonly chosen as a feed grain, particularly in ruminants. Rice is unique for making pilaf, one of the most common dishes in Turkish cuisine. Barley consumption for feed use is directly affected by price. Corn is utilized by the feed and corn starch industries, and wheat is prone to mycotoxin contamination in the field. Mold growth in corn have been shown to depend on various factors, including high daytime maximum temperatures and low moisture content of the soil. Among 20 samples that exceeded the EU limit set for mycotoxins, 16 were from corn and corn flour.

Mycotoxin contamination levels in cereals differ according to region, weather conditions, year, sowing time, and variety. Worldwide, NIV, ZEA, DON, T-2, and HT-2 are common mycotoxin contaminants in wheat. Decreases in mycotoxin concentrations are observed during cleaning, milling, fractionation, and processing (Kushiro, 2008). The end products of wheat processing are mainly used as feeds (Cheli, Pinotti, Rossi, & Dell'Orto, 2013). In a comparison of mycotoxin incidence in feedstuffs and feeds, feeds were found to have a had higher incidence rate than feedstuffs. Results regarding the occurrence of FB, ZEA, DON, HT-2, and T-2 in feeds are shown in Table 6. As little as 0.5% of feeds and layer feeds were found to exceed EU limits. Although the incidence of mycotoxins in cereals is low, the importance of such contamination must not be underestimated. It is therefore important to control and monitor mycotoxin contamination from the beginning of production through consumption.

4.4. Mycotoxins in dried fruits and vegetables

Turkey is a major producer of figs worldwide (Uzundumlu, Oksuz, & Kurtoglu, 2018). After harvesting, fresh fruits must be washed, and fruits that are unsuitable for human consumption must be removed. Dried figs are regarded as being high-risk dried fruits. In Turkey, although there are several drying methods available, traditional sun drying of fruits and vegetables is preferred (Seçkin & Taşeri, 2015). When fruits are exposed to humid environments after the drying process, the second phase of contamination may also occur.

Table 7 summarizes studies on the incidence of mycotoxins in dried fruits and vegetables. Overall, 53.8% of all products are contaminated with AFT, FB_1, and OTA. The most commonly found mycotoxins in dried fruits and vegetables are AFT and OTA. AFT and OTA are formed in dried figs when the temperature, humidity, and drought conditions are suitable during preharvest. In addition, figs contain high levels of sugars, proline, asparagine, and zinc. Low water activity and xerotolerant environments therefore promote AFT production. Additionally, sulfur dioxide fumigation prevents fungal growth in dried apricot samples.

Currently, there are no legal limits for FB_1 levels in dried fruits. Therefore, determination of FB_1 levels is necessary, although this compound is not expected to be a major hazard. Moreover, 11.4% of analysed samples contain mycotoxins at above the MRL set by the EU. Alert notifications and rejections of dried fruits due to OTA and AFTs from Turkey have occurred since 2003, as reported by the Rapid Alert System for Food and Feed (RASFF). Though OTA contamination in dried figs is not covered under this regulation, Germany has set their own limits.

There are no legal limits set in Turkey nor the EU with regard to OTA amounts in green bell peppers and dried eggplants. Accordingly, researchers have preferred to use limit values set for dried red pepper (Çağındı & Gürhayta, 2016). The incidence of OTA in dried fruits and

Table 5
Presence of AFM$_1$ in dairy products.

Product	No of samples	Positive sample No (%)	Range/mean (μg/kg)	Method	> EU Legal limit No (%)	Reference
Milk	129	75 (58	< 0.01-≥0.5/n.a.	ELISA	61 (47)	(Unusan, 2006)
	27	11 (59)	< 0.01–0.0505/n.a.	HPLC	1 (4)	(Gürbay, Aydın, Girgin, Engin, & Şahin, 2006)
	100	67 (67)	0.01-0.63/n.a.	ELISA	31 (31)	(Tekinşen & Eken, 2008)
	50	50 (100)	0.1012 ± 53.8	ELISA	10 (20)	(Gündinç & Filazi, 2009)
	20	20 (100)	0.01-0.080/n.a.	ELISA	3 (15)	(Var & Kabak, 2009)
	137	89 (65)	0.001-0.866/n.a.	HPLC	44 (28)	(Delialioğlu, Otağ, Ocal, Aslan, & Emekda, 2010)
	36	22 (61)	n.a./0.0232 ± 0.40	ELISA	–	(Aksoy et al., 2010)
	90	90 (100)	0.005-0.080/n.a.	ELISA	63 (70)	(Buldu, Koc, & Uraz, 2011)
	50	43 (86)	0.001-0.030/n.a.	ELISA	–	(Ertas, Gonulalan, Yildirim, & Karadal, 2011)
	40	8 (20)	< 0.004–0.07/n.a.	HPLC-FLD	2 (5)	(Kabak & Ozbey, 2012)
	176	53 (30)	0.042–1.01/n.a.	HPLC-FLD	30 (17)	(Golge, 2014)
	77	61 (79)	0.005-0.410/n.a.	ELISA	4 (5)	(Bakırdere, Yaroğlu, Tırık, Demiröz, & Karaca, 2014)
	126	34 (27) n.a	< 0.008–0.032/n.a. n.a	HPLC	–	(Kara & Ince, 2014)
	124					
	38	36 (95)	0.00–0.126/0.057 ± 40.3	ELISA	21 (55)	(Temamogullari & Kanici, 2014)
	12	12 (100)	0.02–0.091/0.043 ± 23.2		3 (25)	
	90	19 (21)	0.011–0.1/0.036	HPLC-FLD	3 (3)	(Sahin, Celik, Kotay, & Kabak, 2016)
TOTAL	**1322**	**690 (52.19)**			**276 (21)**	
Dairy desserts	50	26 (52)	0.002-0.080/0.026 ± 19.6	ELISA	5(10)	(Ertas et al., 2011)
Yoghurt	80	70 (88)	0.010-0.475/n.a.	ELISA	1 (2)	(Atasever, Atasever, & Özturen, 2011)
	50	28 (56)	0.003-0.078/0.030 ± 17.3	ELISA	7(14)	(Ertas et al., 2011)
	50	10 (20)	0.040–.072/0.06 ± 12.68	ELISA	5 (10)	(Temamogullari & Kanici, 2014)
	60	2 (3.3)	0.024-0.028/n.a.	HPLC-FLD	–	(Sahin et al., 2016)
	50	50 (100)	0.012-0.69/0.07 ± 135.23	ELISA	1 (2)	(Altun, Temamogulları, Atasever, & Demirci, 2016)
Ayran	80	72 (90)	0.006-0.264/n.a.	ELISA	11 (14)	(Atasever et al., 2011)
	55	1 (2)	0.023	HPLC-FLD	–	(Sahin et al., 2016)
Butter	27	25 (93)	< 0.001–0.100/n.a.	ELISA	1 (4)	(Aycicek, Aksoy, & Saygi, 2005)
	10	3 (30)	0.040-0.070/0.057 ± 13	ELISA	2 (20)	(Var & Kabak, 2009)
	80	66 (83)	0.010-0.121/n.a.	ELISA	13 (16)	(Atasever, Atasever, Özturan, & Urcar, 2010)
	40	n.r.	–	ELISA & HPLC	–	(Aksoy, Atmaca, & Yazici, 2016)
Cream cheese	200	8 (4)	0.1-0.70/0.285 ± 0.81	ELISA	2 (1.)	(Yaroglu, Oruc, & Tayar, 2005)
Kashar cheese	200	12 (6)	0.120-0.800/0.272 ± 59	ELISA	2 (1.)	(Yaroglu et al., 2005)
	53	47 (89)	< 0.001-≥0.250/n.a.	ELISA	7 (13)	(Aycicek et al., 2005)
	36	10 (27)	0.050-0.690/0.194 ± 15	ELISA	10 (27)	(Tekinşen & Eken, 2008)
	20	10 (50)	0.040-0.388/0.119 ± 95	ELISA	1 (5)	(Var & Kabak, 2009)
	25	20 (80)	< 0.001- > 0.01/0.04 ± 10.7	ELISA	–	(Aksoy et al., 2010)
	30	12 (40)	0.060–1.15/0.25 ± 7.5	ELISA	2 (7)	(Hamparsun Hampikyan, Bingol, Cetin, & Colak, 2010)
	20	8 (8)	0.012-0.37/0.12 ± 0.112	ELISA	1 (2)	(Ertas et al., 2011)
	147	144 (98)	0.015-3.774/0.273	HPLC	16 (11)	(Gul & Dervisoglu, 2014)
Küp cheese	60	25 (42)	0.016-0.136/n.a.	HPLC-FL	12 (20)	(Koluaçık, Sivri, & Kaptan, 2015)
Mouldy cheese	100	52 (52)	0.0106-0.702/0.211	ELISA	85 (85)	(Özgören & Seçkin, 2016)
Surk cheese (spices + garlic)	120	72 (60)	0.016-1.043/n.a.	ELISA	16 (13)	(Aygun, Essiz, Durmaz, Yarsan, & Altintas, 2009)
Tulum cheese	20	11 (55)	0.057–1.36/0.38 ± 9.4	ELISA	2 (10.0)	(Hampikyan et al., 2010)
	20	16 (27)	0.013-0.378/0.098 ± 0.09	ELISA	2 (3)	(Ertas et al., 2011)
Van otlu(herb)	60	52 (87)	0.16-7.26/2.02 ± 0.4	Fluorometer	12 (20)	(Tekinşen & Tekinşen, 2005)
White cheese	200	10 (5)	0.100-0.600/0.253 ± 51	ELISA	2 (1.)	(Yaroglu et al., 2005)
	50	31 (62)	0.10-5.20/0.70 ± 0.16	Fluorometer	30 (60)	(Tekinşen & Tekinşen, 2005)
	94	86 (92)	< 0.0001-≥0.25/n.a.	ELISA	12 (13)	(Aycicek et al., 2005)
	193	16 (82)	0.052-0.86/0.234 ± 15.2	ELISA	6 (26)	(Ardic, Karakaya, Atasever, & Adiguzel, 2009)
	20	16 (80)	0.054-0.263/0.142 ± 56	ELISA	1 (5)	(Var & Kabak, 2009)
	50	14 (28)	0.020-2/n.a.	TLC	5 (10)	(Filazi, Ince, & Temamogullari, 2010)
	25	12 (48)	< 0.001- > 0.01/0.02 ± 6.53	ELISA	–	(Aksoy et al., 2010)
	30	18 (60)	0.052–2.52/0.42 ± 8.2	ELISA	4 (13)	(Hampikyan et al., 2010)
	127	36 (28)	0.071-0.77/0.072 ± 14.1	ELISA	13 (10)	(Kav, Col, & Tekinsen, 2011)
	20	14 (23)	0.016-0.15/0.072 ± 46.5	ELISA	–	(Ertas et al., 2011)
	50	10 (20)	0.040–0.13/0.10 ± 29.13	ELISA	5 (10)	(Temamogullari & Kanici, 2014)
	130	130 (100)	0.010-0.80/60.26 ± 26.46	ELISA	22 (17)	(Altun et al., 2016)
TOTAL	**2732**	**1255 (46)**			**316 (12)**	

n.a. not available.

Table 6
Presence of mycotoxins in cereal and cereal products.

Product	No of samples	Positive samples No(%)	Range/mean (μg/kg)	Method	> EU Legal limit No(%)	Reference
Lentil/AFB$_1$	20	20 (100)	0.575-1.743/n.a.	HPLC	–	(Baydan et al., 2016)
Rice/AFB$_1$	18	18 (100)	0.700-1.621/n.a.	HPLC	–	(Baydan et al., 2016)
Lentil/AFB$_2$	20	20 (100)	0.532-1.161/n.a.	HPLC	–	(Baydan et al., 2016)
Rice/AFB$_2$	18	18 (100)	0.604-1.829/n.a.	HPLC	–	(Baydan et al., 2016)
Lentil/AFG$_1$	20	20 (100)	0.428-1.297/n.a.	HPLC	–	(Baydan et al., 2016)
Rice/AFG$_1$	18	18 (100)	0.501-1.651/n.a.	HPLC	–	(Baydan et al., 2016)
Lentil/AFG$_2$	20	20 (100)	0.426-1.292/n.a.	HPLC	–	(Baydan et al., 2016)
Rice/AFG$_2$	18	18 (100)	0.538-0.630/n.a.	HPLC	–	(Baydan et al., 2016)
Total/AFB1 + AFB2 + AFG1 + AFG2	**152**	**152 (100)**			-	
Corn/AFT	52	37 (71)	1.5–133/n.a.	ELISA	2 (4)	(Nizamlýolu & Oguz, 2003)
	47	47 (100)	0–120.3/n.a.	ELISA	4 (9.)	(Giray, Atasayar, & Sahin, 2009)
	19	19 (100)	0.01–32.30/n.a.	ELISA	–	(Oruc, Cengiz, & Kalkanli, 2006)
	69	11 (16)	0.379-24.54/n.a.	HPLC	1	(Şengül, Yalçın, Şengül, & Çavuşoğlu, 2016)
Wheat/AFT	41	24 (59)	10.4–643.5/n.a.	HPLC	–	(Giray, Girgin, Engin, Aydın, & Sahin, 2007)
Total/AFT	**228**	**138 (61)**			**7 (3)**	
Corn/OTA	47	47 (100)	n.d.-8.57/n.a.	ELISA	4 (9)	(Giray et al., 2009)
	19	19 (100)	0.80–356.8/n.a.	ELISA	–	(Oruc et al., 2006)
Rice/OTA	58	3 (5.2)	< LOQ-0.98/n.a.	HPLC	–	(Golge & Kabak, 2016)
Total/OTA	**124**	**69 (56)**			**4 (3)**	
Cereal based food/AFT	110	27 (25)	0.052-0.459/0.124	HPLC	–	(Kabak, 2012b)
Breakfast cereal/OTA	24	9 (38)	0.172–1.84/n.a.	HPLC	-	(Kabak, 2009a, 2009b)
	37	8 (21)	0.06-0.42/0.32	HPLC-FLD	–	(Ozden et al., 2012)
Cerealbased food/OTA	110	48 (44)	0.066-1.125/0.286	HPLC	–	(Kabak, 2012b)
White wheat bread/OTA	102	10 (9.8)	< LOQ-2.83/0.16	HPLC	–	(Golge & Kabak, 2016)
Total/OTA	**273**	**75 (25)**			-	
Corn flour/AFT	21	4 (IARC)	< LOQ-5.35/n.a.	HPLC	4 (19.)	(Algül & Kara, 2014)
	24	16 (67)	0.041-1.12/0.193	HPLC-FLD	–	(Kara, Ozbey, & Kabak, 2015)
Wheat flour/AFT	25	21 (84)	0.03–22.40/n.a.	HPLC	2 (8)	(Demirel & Sariozlu, 2014)
	60	0 (0)	0.044- < LOQ/0.001	HPLC-FLD	–	(Kara et al., 2015)
Rice flour/AFT	16	0 (0)	< LOQ	HPLC-FLD	–	(Kara et al., 2015)
Total/AFT	**146**	**41 (28)**			**6 (4)**	
Corn flour/OTA	21	1 (5)	< LOQ-25.34/n.a.	HPLC	1 (5)	(Algül & Kara, 2014)
	24	10 (42)	0.061-0.59/0.120	HPLC-FLD	–	(Kara et al., 2015)
Rice flour/OTA	16	0 (0)	0.065-0.214/0.049	HPLC-FLD	–	(Kara et al., 2015)
Wheat flour/OTA	25	21 (84)	0.80-4.76/n.a.	HPLC	2 (8)	(Demirel & Sariozlu, 2014)
	60	16 (27)	0.105-0.918/n.a.	HPLC-FLD	–	(Kara et al., 2015)
Total/OTA	**146**	**48 (33)**			**3 (2)**	
TOTAL	**1214**	**599 (49)**			**20 (2)**	
Feed/AFB$_1$	30	17 (56)	n.a./3.31 ± 0.26	HPLC	–	(Bilal, Aksakal, Sunnetci, Keser, & Eseceli, 2014)
Layer feed/AFB$_1$	73	7 (32)	0-5/n.a.	LC MS/MS	1 (4)	(Yalcin, Isik, Avci, Oguz, & Yurduseven, 2017)
Feed/AFB$_2$	30	1 (3)	n.a./0–3.31 ± 0.01	HPLC	–	(Bilal et al., 2014)
Feed/AFG$_1$	30	9 (30)	n.a./0–1.1 ± 0.30	HPLC	–	(Bilal et al., 2014)
Feed/AFG$_2$	30	1 (3)	n.a./0.67 ± 0.11	HPLC	–	(Bilal et al., 2014)
Total/AFB$_1$ + AFB$_2$ + AFG$_1$ + AFG$_2$	**193**	**35 (18)**			**1 (4)**	
Feed/AFT	180	108 (60)	3.82-16.8/10.7 ± 1.26	ELISA	8 (4.4)	(Kocasari, Mor, Oguz, & Oguz, 2013)
	76	20 (26)	0.278–8.43/2.74	HPLC-FLD		(Sahin et al., 2016)
Layer feed/AFT	26	15 (58)	1.5–133/n.a.	ELISA	2 (4)	(Nizamlýolu & Oguz, 2003)
Layer feed/AFT -2007	100	13 (13)	0.4–36.8/6.5 ± 0.2	ELISA	–	(Değirmencioğlu, Eseceli, Demir, & Şentürklü, 2012)
2008	100	15 (15)	0.5–47.0/7.3 ± 0.2		–	
Total/AFT	**482**	**171 (36)**			**10 (2)**	
Feed/FB	180	19 (11)	2.69–4.96/3.19 ± 15	ELISA	–	(Kocasari et al., 2013)
Layer feed/FB	73	60 (90)	0-20000/n.a.	LC MS/MS	–	(Yalcin et al., 2017)
Total/FB	**253**	**79 (31)**			-	
Layer feed/OTA	73	16 (47)	0-100/n.a.	LC MS/MS	–	(Yalcin et al., 2017)
Feed/OTA	180	84 (47)	1.01–15.85/4.48 ± 0.34	ELISA	No regulations	(Kocasari et al., 2013)
Total/OTA	**253**	**100 (40)**				
Feed/ZEA	180	57 (32)	2.10–29.30/7.79 ± 0.85	ELISA	–	(Kocasari et al., 2013)
	30	22 (73)	n.a./37.72 ± 13.40	HPLC	–	(Bilal et al., 2014)
Layer feed/ZEA	73	11 (38)	0-250/n.a.	LC MS/MS	–	(Yalcin et al., 2017)
Total/ZEA	**283**	**90 (32)**			–	
Feed/DON	30	13 (43)	n.a./0–486 ± 62.85	HPLC	–	(Bilal et al., 2014)
	180	87 (48)	18.50–500/60 ± 7.0	ELISA	–	(Kocasari et al., 2013)
Layer feed/DON	73	1 (10)	0-5000/n.a.	LC MS/MS	–	(Yalcin et al., 2017)
Total/DON	**283**	**101 (36)**			–	
Feed/T-2	180	85 (47)	3.85–52.4/8.9 ± 0.9	ELISA	–	(Kocasari et al., 2013)
Layer feed/T-2	73	0	0	LC MS/MS	–	(Yalcin et al., 2017)
Total/T-2	**253**	**85 (36)**			-	
Layer feed/HT-2	73	3	0-30/n.a.	LC MS/MS	–	(Yalcin et al., 2017)
TOTAL	**2073**	**664 (32)**			**11 (1.)**	

n.a. not available.

Table 7
Presence of mycotoxins in dried fruits and vegetables.

Product/Mycotoxin	No of samples	Positive Samples No (%)	Range/mean (μg/kg)	Method	> EU Legal limit	Reference
Figs/AFB$_1$	98	7 (72)	0.23–4.28/n.a.		n.a.	(Bircan, 2009)
Figs/FB$_1$	71	51 (72)	n.d.–3.649/0.369	LC	n.a.	(Karbancıoglu-Güler & Heperkan, 2009)
	4	56 (80)	n.d.–0.276/0.223			
Dried eggplant/AFT	50	50 (100)	0.82-2.58/1.35 ± 0.35	HPLC	–	(Çağındı & Gürhayta, 2016)
Green bell pepper/AFT	50	50 (100)	0.81-2.42/1.51 ± 0.57	HPLC	–	(Çağındı & Gürhayta, 2016)
Figs/AFT	17	5 (29)	4.1–33.9/13.9	TLC		(Erdoğan, Gürses, & Sert, 2010)
	130	16 (12)	0.1–28.2/0.53	HPLC-FD	3 (2)	(Kabak, 2016)
	45	23 (51)	0.16-5.20/n.a.	HPLC	–	(Yılmaz, 2017)
Grapes/AFT	25	16 (64)	0.02–20.7/n.a.	HPLC	–	(Yılmaz, 2017)
Total/AFT	**317**	**160 (51)**			**3 (2)**	
Apricots/OTA	20	1 (5)	0–0.97 n.a.		–	(Bircan, 2009)
Eggplant/OTA	50	50 (100)	8.88-21.35/17.67 ± 2.95	HPLC	40 (80)	(Çağındı & Gürhayta, 2016)
Figs/OTA	98	18 (18)	0.87–24.37/n.a.	HPLC	3 (3.06)	(Bircan, 2009)
Grapes/OTA	264	153 (58)	< 0.026–10 n.a.	IAC	26 (10)	(Meyvaci et al., 2005)
	53	28 (53)	0.51–58.04 n.a.		2 (3.77)	(Bircan, 2009)
	50	8(16)	0.19–2.59/1.15	HPLC-FD	–	(Akdeniz, Ozden, & Alpertunga, 2013)
Greenbell pepper/OTA	50	50 (100)	15.38-24.70/20.53 ± 2.1	HPLC	50 (100)	(Çağındı & Gürhayta, 2016)
Grape juice/OTA	10	2 (20)	0.90–1.90/1.40	HPLC	–	(Akdeniz et al., 2013)
Total/OTA	**595**	**310 (52)**			**121 (20)**	
TOTAL	**1085**	**584 (54)**			**124 (11)**	

n.a. not available.

vegetables is higher than that of other mycotoxins. This can be explained by contamination by the relevant fungi at postharvest.

4.5. Mycotoxins in herbs

Turkey is the third largest producer of red chili pepper worldwide. Nearly 80% of this spice is produced in the southeast region of the country. Red chili pepper is consumed as a fresh paste or sauce in traditional Turkish dishes. Weather and climate factors not only affect the quantity of fungi but also the types of AFTs produced. The inadequate preharvest and postharvest conditions, i.e., inadequate cleaning processes, drying, and storing, are expected to increase the risk of fungal contamination and therefore affect mycotoxin production. Table 8 reviews studies on the incidence of mycotoxins in dried herbs. Notably, 85.9% and 75.71% of all products are contaminated by AFB$_1$ and AFT, respectively. Chili sold in Turkey has been shown to contain AFB$_1$ and AFT at high amounts, with 11.7% and 16.41% of samples, respectively, exceeding the limits set by the EU. The presence of high amounts of AFB$_1$ and AFT is related to contact with soil during drying, unfavourable harvesting, production and storage conditions, and relative humidity. Between 2002 and 2012, of the 188 notifications for AFT, 17.1% for paprika were from Turkey. Moreover, several mycotoxins are present in chili. Therefore, the combined effects of different types of mycotoxins can cause increased risks to both animal and human health than the ingestion of one type of mycotoxin alone (Speijers & Speijers, 2004).

Mesir paste, also known as meshir macun or putty, contains 41 types of spices, plant extracts, honey, and sugar. This product is in UNESCO's Representative List of Intangible Cultural Heritage of Humanity (Giritlioglu, Avcikurt, & Savas, 2010) and is exported to European countries. There are no regulations in the EU regarding AFT and AFB$_1$ levels in mesir paste; thus, AFT contains in some types of spices may contaminate mesir paste. Çağındı (2017) showed that 9.5% of samples were above the limit set by the EU for AFT, but none exceeded the limit for AFB$_1$.

4.6. Mycotoxins in nuts

Hazelnuts are mainly grown on the Black Sea coast, which has a climate with a relatively high humidity, and Turkey produces 75% of all hazelnuts sold worldwide. Groundnuts are mostly cultivated in the Mediterranean region, which is known for its dry, hot summers and rainy, warm winters, increasing the risk of AFT contamination during harvest and drying. Improper handling and storage conditions also promote AFT contamination after dehulling. In Turkey, nuts may be a dietary source of various mycotoxins since they are consumed as snacks and as raw materials in breakfast cereals and deserts (Table 9). Turkish delight and Walnut sujuk are traditional Turkish deserts made from various nuts, and most of these products are made locally either by small-scale producers or family-run businesses. EU regulations clearly state that limits apply to specific ingredients, rather than finished product itself (EC Regulation, 2006, pp. 5–24).

Nut mycotoxin analysis is rather challenging, because of the complexity of the matrix, i.e., the high lipid content. Despite this, nut consumption is known to be an important contributor to mycotoxin exposure, particularly AFT (Van de Perre, Jacxsens, Lachat, El Tahan, & De Meulenaer, 2015). Only 16 of 3442 (0.5%) and 44 of 4196 (1.05%) samples and were found to be contaminated with AFB$_1$ and AFT, respectively, at greater than the legal limits. The RASFF received a total of 489 notifications regarding the occurrence of mycotoxins; of these, only 58 notifications were from hazelnuts and pistachios from Turkey in 2016.

5. Discussion

The contamination of foods and feeds with mycotoxin-producing *Aspergillus*, *Alternaria*, *Fusarium*, and *Penicillium* is a common problem affecting human and animal health worldwide. The relationship between geographical region and mycotoxin occurrence in food and feeds is summarized in Fig. 2. Cereal and cereal products, dried fruits and vegetables, and herbs are the main sources of AFT and OTA intake in humans in Turkey (Table 10), where a subtropical climate and widespread agricultural practice support fungal growth, leading to the formation of mycotoxins. However, it is also important to note that changes in climate and agricultural practices may decrease fungicide use.

AFM$_1$ in dairy products; AFT and OTA in cereals, dried fruits, and dried vegetables; AFB$_1$ and AFT in feeds and nuts; and AFB$_1$, AFT, and OTA in herbs were found to be above the EU limits in Turkey (Table 10). Smith, Madec, Coton, and Hymery (2016) also showed that for European samples, most reported (24%) mycotoxin mixtures were AFT + OTA. The combined effects of mycotoxins have worried policymakers because the combined effects can be higher than the individual effects of each mycotoxin. Often, individual levels of

Table 8
Presence of mycotoxins in herbs.

Product/Mycotoxin	No of samples	Positive Samples No(%)	Range/mean (μg/kg)	Method	> EU Legal limit	Reference
Isot/AFB_1	75	72 (96)	0.11–24.7/1.9	ELISA	11 (15)	(Ardic, Karakaya, Atasever, & Durmaz, 2008)
Red chilli powder/AFB_1	30	30 (100)	1.25-15.99/4	TLC	-	(Taydaş & Aşkın, 1995)
Red chilli powder AFB_1	100	68 (68)	0.025–40.9/3.9	ELISA	-	(Aydin, Erkan, Başkaya, & Ciftcioglu, 2007)
Fall:	60	60 (100)	n.a.	HPLC	8 (13)	(Set & Erkmen, 2010)
Winter:	60	60 (100)	n.a.	HPLC	12 (20)	(Set & Erkmen, 2010)
	182	150 (82)	0.24–165/8.89	HPLC-FD	10 (6)	(Golge, Hepsag, & Kabak, 2013)
Spring:	60	60 (100)	> 1–33.5	HPLC	23 (38)	(Ebru Set & Erkmen, 2014)
Summer:	60	60 (100)	> 1-90	HPLC	35 (58)	(Ebru Set & Erkmen, 2014)
Red chilli flake/AFB_1	31	28 (90)	n.d-28.5/8.43	TLC	-	(Taydaş & Aşkın, 1995)
	40	40 (100)	1.1–44/8.66	TLC	-	(Ağaoğlu, 1999)
	82	69 (84)	5.1–20.19/n.a.	ELISA	6 (7)	(Ergün, Özkan, & Abbasoğlu, 2016)
Red pepper/AFB_1	36	17 (65)	0.6–56	HPLC-FD	-	(Omurtag, Atak, Keskin, & Ersoy, 2002)
	50	50 (100)	1.48–70.05	ELISA	-	(Kanbur, Liman, Eraslan, & Altinordulu, 2006)
	30	6 (20)	2.9–11.2	ELISA	-	(Colak, Bingol, Hampikyan, & Nazli, 2006)
Total/AFB_1	**896**	**770 (86)**			**105 (12)**	
Red chilli powder/AFB_2	182	84 (46)	0.15-11.3/0.88	HPLC-FD	–	(Golge et al., 2013)
Red chilli powder/AFG_1	182	32 (18)	0.15-3.88/0.77	HPLC-FD	–	(Golge et al., 2013)
Red chilli powder/AFG_2	182	–	–	HPLC-FD	–	(Golge et al., 2013)
Total/$AFB_2 + AFG_1 + AFG_2$	**364**	**32 (IARC)**			-	
Black pepper powder/AFT	15	4 (27)	0.3–2.3	HPLC-FD	0	(Bircan, 2005)
	23	7 (30.4)	0.13-0.46	HPLC-FD	–	(Ozbey & Kabak, 2012)
Cinnamon powder/AFT	17	0	< LOD	HPLC-FD	–	(Ozbey & Kabak, 2012)
Cumin/AFT	15	0	0	HPLC-FD	–	(Bircan, 2005)
	19	4 (21)	0.32-0.97	HPLC-FD	–	(Ozbey & Kabak, 2012)
Isot/AFT	20	1 (5)	13.8	TLC	-	(Erdogan, 2004)
Paprika/AFT	30	27 (90)	0.5–124.6	HPLC-FD	19 (63)	(Bircan, 2005)
	23	19 (83)	0.38-14.71	HPLC-FD	-	(Bircan, Barringer, Ulken, & Pehlivan, 2008)
Red chilli powder/AFT	30	14 (47)	5–25	TLC	-	(Dokuzlu, 2001)
	26	3(11)	1.8–16.4	TLC	-	Erdogan, 2004)
	15	15 (100)	1.8–85.9	HPLC-FD	4 (27)	(Bircan, 2005)
Fall:	60	60 (100)	n.a.	HPLC	9 (15)	(Set & Erkmen, 2010)
Winter:	60	60 (100)	n.a.	HPLC	5 (8.)	(Set & Erkmen, 2010)
	24	14 (64)	0.24–37.38	HPLC-FD	1 (5)	(Ozbey & Kabak, 2012)
Spring:	60	60 (100)	> 1–36.5	HPLC	12 (20)	(Ebru Set & Erkmen, 2014)
Summer:	60	60 (100)	> 1–97.4	HPLC	26 (43)	(Ebru Set & Erkmen, 2014)
	42	38 (90)	0.38–86.1/17 ± 24	HPLC	13 (34)	(Karaaslan & Arslanğray, 2015)
	25	18 (72)	0.04–18.68/2.30	HPLC	2 (8)	(Yılmaz, 2017)
Red chilli flake/AFT	44	8(18)	1.1–97.5	TLC	-	(Erdogan, 2004)
	38	n.r.	9.46/4.79	ELISA	–	(Kursun & Mutlu, 2010)
	24	19 (79)	0.17-14.29/n.a.	HPLC-FD	3 (13)	(Ozbey & Kabak, 2012)
	75	71 (95)	0.6–31.7/3.5 ± 5.7	HPLC-FD	4 (5)	(Tosun & Ozden, 2016)
	34	34 (100)	3.55-9.55/6.36	ELISA	–	(Kursun & Mutlu, 2010)
Total/AFT	**597**	**452 (76)**			**98 (16)**	
Black pepper powder/OTA	23	4 (17)	0.87-3.48	HPLC-FD	–	(Ozbey & Kabak, 2012)
Cinnamon powder/OTA	17	0	< LOD	HPLC-FD	–	(Ozbey & Kabak, 2012)
Cumin/OTA	19	1 (5)	0.63	HPLC-FD	–	(Ozbey & Kabak, 2012)
Red chilli powder/OTA	24	12 (55)	0.78–98.2	HPLC-FD	3 (14)	(Ozbey & Kabak, 2012)
Red chilli flake/OTA	24	18 (75)	0.46–53.04/12.3	HPLC-FD	4 (17)	(Ozbey & Kabak, 2012)
Total/OTA	**107**	**35 (33)**			**7 (16)**	
TOTAL	**2146**	**1373 (64)**			**210 (10)**	

n.a. not available.

mycotoxins in the products may not explain the symptoms because of the co-occurrence of more than one mycotoxin in the food. Mycotoxins may have synergistic, additive, and antagonistic effects, emphasizing their potential harmful effects on health.

The occurrence and contamination levels of mycotoxins differ significantly according to harvest year (Pereira, Fernandes, & Cunha, 2014). The addition of adsorbent materials to feeds is used widely to prevent mycotoxicosis, particularly aflatoxicosis. Cleaning, sorting, segregation, milling, and some cooking practices have also been also reported for mycotoxin control. Additionally, acidification, ammoniation, alkalinization, deamination, ozonation, and chlorine treatment may transform or degrade mycotoxins to remove their toxicity (Gullino, Stack, Fletcher, & Mumford, 2017). Nevertheless, these treatments are limited to some foods and feeds.

The techniques that are most commonly used for mycotoxin analysis involve chromatography, e.g., high-performance chromatography, thin-layer chromatography, liquid chromatography mass spectrometry, and enzyme-linked immunosorbent assay. Even with clearly defined mycotoxin test procedures, variability in results among laboratories can occur. Notably, all data presented in this review were obtained from different methodologies, with different accuracies and sensitivities; hence, making quantitative comparison difficult. It is important to emphasize that the occurrence and contamination levels of mycotoxins differ significantly according to harvest year, geographic location, climatic conditions, and the product (Scudamore & Patel, 2009).

Mycotoxin prevention should be approached as a government policy, and efforts should be made to transfer prevention systems into practice. Special education programs are needed for producers, sellers, and consumers. Control is another important topic to be considered. Food products sold in the market should be controlled periodically, and penalties should be enforced on products with mycotoxin levels exceeding the EU limits.

Table 9
Presence of mycotoxins in various nuts.

Product	No of samples	Positive No (%)	Range/mean (μg/kg)	Method	> EU Legal limit No (%)	Reference
Almond/AFB$_1$	13	3 (23)	1-13/n.a.	TLC	–	(Gürses, 2006)
Hazelnut/AFB$_1$	51	43 (84)	< 1.0-≥10 n.a.	ELISA	1 (2)	(Aycicek et al., 2005)
	28	9 (32)	1-113 n.a.	TLC	6 (21)	(Gürses, 2006)
	1267	22	0.07–8.98/n.a.	HPLC	–	(Baltaci, İlyasoğlu, & Cavrar, 2012)
Roasted hazelnut/AFB$_1$	479	7	0.07–43.6/n.a.	HPLC	–	(Baltaci et al., 2012)
Roasted sliced hazelnut/AFB$_1$	823	9	0.07–39.17/n.a.	HPLC	–	(Baltaci et al., 2012)
Hazelnut puree/AFB$_1$	619	1	0.07–11.2/n.a.	HPLC	–	(Baltaci et al., 2012)
Peanut/AFB$_1$	18	7 (38.9)	8-94/n.a.	TLC	5 (28)	(Gürses, 2006)
Spring: Pistachio/AFB$_1$	60	21 (35)	n.a.	HPLC	1 (2)	(Ebru Set & Erkmen, 2014)
Summer: Pistachio/AFB$_1$	60	14 (23)	n.a.	HPLC	–	(Ebru Set & Erkmen, 2014)
Walnut/AFB$_1$	24	6 (25)	3-28/n.a.	TLC	3 (13)	(Gürses, 2006)
Total/AFB$_1$	**3442**	**143 (4)**			**16 (0.5)**	
Hazelnut/AFT	51	47 (92)	< 1.0-≥10 n.a.	ELISA	1 (2)	(Aycicek et al., 2005)
	72	12 (17)	0–4.75/n.a.	HPLC	–	(Basaran & Ozcan, 2009)
	1267	18	0.02–69.14/n.a.	HPLC	–	(Baltaci et al., 2012)
	64	39 (61)	0.43–63.4/8.43	HPLC	17 (27)	(Golge, Hepsag, & Kabak, 2016)
	50	6 (12)	0.09–1.3/0.64	HPLC	1 (2)	(Kabak, 2016)
Hazelnut in shell/AFT	60	-	–	HPLC	–	(Kabak, 2016)
Roasted hazelnut/AFT	479	6	0.07–14.6/n.a.	HPLC	–	(Baltaci et al., 2012)
	60	5 (8)	0.17–1.2/0.39	HPLC	1 (2)	(Kabak, 2016)
Roasted sliced hazelnut/AFT	823	7	0.02–37.1/n.a.	HPLC	–	(Baltaci et al., 2012)
Hazelnut puree/AFT	619	–	0.02–3.52/n.a.	HPLC	–	(Baltaci et al., 2012)
Peanut/AFT	73	24 (33)	0–33.4/n.a.	HPLC	2 (3)	(Basaran & Ozcan, 2009)
	151	29 (IARC)	0.16–60.9/1.2	HPLC	6 (4)	(Hepsag, Golge, & Kabak, 2014)
Spring: Pistachio/AFT	60	21 (35)	n.a.	HPLC	1 (2)	(Ebru Set & Erkmen, 2014)
Summer:	60	16 (27)	n.a.	HPLC	–	(Ebru Set & Erkmen, 2014)
	72	12 (17)	0–36.81/n.a.	HPLC	2 (3)	(Basaran & Ozcan, 2009)
	151	22 (15)	0.26–385/4.95	HPLC	8 (5)	(Hepsag et al., 2014)
Walnut/AFT	48	21 (44)	0.58-15.2/1.33	HPLC	4 (8)	(Golge et al., 2016)
	25	16 (64)	0.66-10.3/1.68	HPLC	1 (4)	(Yılmaz, 2017)
Total/AFT	**4196**	**301 (7)**			**44 (1.)**	
TOTAL	**7638**	**444 (6)**			**60 (1.)**	

n.a. not available.

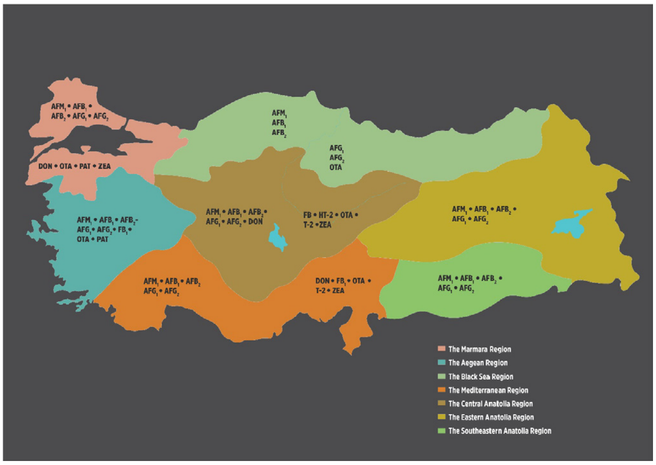


Fig. 2. The relationship between geographical region and mycotoxin occurrence in foods and feeds in Turkey.

Table 10
The mycotoxin levels that exceeded the EU limit in food and feeds.

Products	> EU Legal limit No (%)
Infant formulas and baby foods/PAT	121 (35)
Milk/AFM$_1$	276 (21)
Dairy products/AFM$_1$	316 (12)
Cereal/AFT	7 (3)
Cereal/OTA	4 (3)
Flour/AFT	6 (4)
Flour/OTA	3 (2)
Feed/AFB$_1$ + AFB$_2$ + AFG$_1$ + AFG$_2$	1 (4)
Feed/AFT	10 (2)
Dried fruits and vegetables/AFT	3 (2)
Dried fruits and vegetables/OTA	121 (20)
Herbs/AFB$_1$	105 (12)
Herbs/AFT	98 (16)
Herbs/OTA	7 (16)
Nuts/AFB$_1$	16
Nuts/AFT	44

6. Conclusion

Disparities in agricultural practices, pre- and post-harvest conditions, and external factors may create massive differences among mycotoxin contamination levels in foods and feeds. Thus, mycotoxin risk management strategies must be used to find a solution to the mycotoxin occurrence problem. In this review, I provided a basis for mycotoxin risk assessment research and improvement of safety monitoring of mycotoxin contamination in Turkish food and feeds. Additionally, these findings can contribute to updating limit standards for mycotoxin incidence in green bell peppers, dried eggplants, and cattle and sheep feed. The current results supported that these limits must be extended until EU regulations are set. These findings are critical for monitoring of key critical control points in pre- and post-harvest to optimize prevention strategies at all phases of food and feeds production.

To date, no studies have examined the occurrence of emerging mycotoxins, i.e., beauvericin, moniliformin, citrinin, α-ZOL, and β-ZOL, in foods and feeds in Turkey. The occurrence of different forms of mycotoxins, such as conjugated (masked) or bound forms arising from plant growth and/or food processing, could lead to significant underestimation of the amount of a mycotoxin actually ingested since the toxins can be converted from conjugated to free toxins in the gastrointestinal tracts of humans and animals. Some mycotoxin combinations can result in additive or synergistic effects and should therefore be investigated in the future to protect public health. There are no reports of mycotoxin contamination on a yearly basis. Thus, the toxicity of mycotoxins and their implications in some diseases and food safety expenditures must be evaluated to determine the cost of mycotoxin contamination to the government. The development of an integrated prevention model for the production and distribution food chain, from producers to consumers, with safer foods, is required to reduce the risks of mycotoxin contamination. Related studies of contamination must cover all mycotoxins that may be consumed. Using the collected data for mycotoxin occurrence levels in Turkish foods and feeds and Turkish food consumption data (from a nutrition and health survey launched in 2017), the PDI can be estimated for each mycotoxin.

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