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The Evaluation of Aflatoxin Contamination in Various Foods in Iran: a Review

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ABSTRACT

Introduction: Aflatoxins are the secondary fungal metabolites produced by *Aspergillus fungi*, particularly *Aspergillus flavus*, *Aspergillus nomius*, and *Aspergillus parasiticus*. Aflatoxins have adverse effects on human and animal health and cause various diseases, including hepatic disorders. The four main types of aflatoxins are B1, B2, G1, and G2. In addition, aflatoxins M1 and M2 are the metabolites derived from aflatoxins B1 and B2. The present study aimed to evaluate aflatoxin contamination in various foods in Iran.
Methods: In this review, we investigated the studies on aflatoxin contamination in different foods via searching in databases such as SID, Science Direct, Pub Med, and Google Scholar using keywords such as aflatoxin, Iran, incidence, food, oil, and milk and dairy products. The abstracts of the related articles were reviewed, and the studies containing data on the levels of aflatoxins were selected.
Results: Aflatoxins were detected in most of the tested foods in the reviewed studies. In the majority of the studies focused on milk and dairy products, the levels of aflatoxins were higher than the recommended values by the Institute of Standards and Industrial Research of Iran and the European Union.
Conclusion: According to the results, practical management and adoption of control strategies are essential to the assurance of consumer safety regarding the aflatoxin residues in different foods in Iran.

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Introduction

Several molds that alternatively produce mycotoxins infect foods and agricultural products. According to the Food and Agriculture Organization (FAO), 25% of the food in the world is contaminated by mycotoxins every year (1). Mold in food products does not necessarily indicate the presence of mycotoxins, while the absence does not imply the lack of toxins in foods since fungal toxins remain in food for a long time after the molds disappear. Molds normally grow better in the foods that are preserved under warm and humid conditions. Fungal toxins are the main cause of mycotoxicosis (1).

Mycotoxins are the secondary fungal metabolites that adversely affect the health of humans, animals, and crops, thereby leading to diseases and economic loss (2). Aflatoxins are one of the most prominent mycotoxins that contaminate food. Aflatoxins are the derivatives of furanocoumarins, which are mainly produced by the fungi of the genus *Aspergillus*, particularly *A. flavus*, *A. parasiticus*, and *A. nomius* (3).

Aflatoxins have various adverse effects on body organs, especially the liver. Studies have confirmed the role of aflatoxins in the development of liver cancer. Furthermore, aflatoxins may cause acute toxicity at high concentrations (4). Aflatoxins have hepatotoxic and carcinogenic properties depending on their concentration and exposure duration. The

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symptoms of aflatoxin poisoning in humans include nausea and vomiting, abdominal pain, gastrointestinal disorders, pulmonary edema, convulsions, jaundice, liver damage, high fever, coma, and death (5). It is extremely difficult to remove aflatoxins from food due to their resistance and thermal stability (6). Although some studies have investigated the levels of aflatoxins in different foods in Iran, there is an urgent need for a comprehensive review focusing on the presence of aflatoxins in different foods (7).

The present study aimed to review aflatoxin contamination in various food products in Iran.

Material and methods

This review was conducted via searching in databases such as SID, Science Direct, Pub Med, and Google Scholar using keywords such as aflatoxin, Iran, incidence, food, oil, milk and dairy products. The abstracts of the related articles were reviewed, and the studies containing the data on the concentration of aflatoxins in foods were selected.

Types of Aflatoxins

The main aflatoxins include aflatoxin B1 (AFB1), aflatoxin B2 (AFB2), aflatoxin G1 (AFG1), and aflatoxin G2 (AFG2). In addition, aflatoxin M1 (AFM1) and aflatoxin M2 (AFM2) are two other metabolic products that directly contaminate food (8).

Aflatoxins B1 and B2

AFB1 is the most toxic metabolite of *Aspergillus* species as it has carcinogenic and genotoxic effects on humans. AFB1 has been classified as a Group 1 human carcinogen by the International Agency for Research on Cancer (IARC) (9). The molecular formula of AFB1 has been established as C17H1206 with the molecular weight of 312, exhibiting a relatively strong fluorescence against ultraviolet light (10).

AFB1 is the strongest carcinogenic toxin with the LD_{50} of 9.5 mg/kg. Liver damage and hemorrhage in the gastrointestinal tract and the peritoneum are the causes of mortality due to aflatoxin poisoning. Concurrent infection with the hepatitis B virus and aflatoxin are the most important etiologies in liver damage. Some of the active metabolites of aflatoxin are considered to be active carcinogens; such example is 2-3 epoxides, which is synthesized by the cytochrome P450 enzyme (11). Moreover, AFB1 has been shown to exert immunosuppressive effects (5).

AFB2 has been confirmed as a dihydroxy derivative of AFB1 (12). Lactic fermentation at the pH of <4 results in the conversion of AFB1 into AFB2, which has lower toxicity (11). The European Union (UN) has regulated the maximum permitted levels of AFB1 and total aflatoxins in dried fruits at 2 and 4 µg/kg, respectively (13). Additionally, the Institute of Standards and Industrial Research of Iran (ISIRI) has set the maximal accepted levels of AFB1 and total aflatoxins in some dried fruits at 5 and 15 µg/kg, respectively (14).

The European Commission has determined the maximum level of AFB1 at 2 ng/g within a range of commodities for human consumption (15). Moreover, the World Health Organization (WHO) has recommended the provisional maximum tolerable daily intake of 1 ng AF/kg/bw/day to be used as the guidance value for the risk assessment of aflatoxin contamination in food (16).

Aflatoxins M1 and M2

Aflatoxin M1 (AFM1) and aflatoxin M2 (AFM2) are 4-hydroxy aflatoxin B1 and 4 - dihydroxy aflatoxin B2, respectively. AFM1 and AFM2 have been found in milk when lactating ruminants eat the foodstuffs contaminated with AFB1 and AFB2 (12). AFM1 is the most abundant mycotoxin in milk and dairy (17). The IARC has classified AFM1 as a possibly carcinogenic substance for humans (18).

AFM1 is resistant to thermal deactivation, pasteurization, and sterilization (19). Furthermore, it is not destroyed during the manufacturing of cheese and yogurt (19). AFM1 is a hydroxylated metabolite of aflatoxin, which is formed by cytochrome P450-associated enzymes in the liver and becomes visible in milk, urine, and stool. The level of AFM1 in milk has a direct correlation with AFB1 contamination in food (20).

AFM1 appears in milk 12 hours after the ingestion of AFB1, and without the recurrence of infection, its concentration reaches an undetectable level after 72 hours, indicating a linear association between AFM1 in milk and

AFB1 contamination in food (20).

According to the literature, approximately 0.3-6.2% of the ingested AFB1 by animals is converted into AFM1 at a variable conversion rate depending on the animal species and duration of lactation and milking (21). The permitted levels of AFM1 are presented in Table 1 (14, 22).

Table 1. Maximum Permitted Levels of Aflatoxin M1 in Milk

European Union	50 ng/l
The United States of America and Most Asian Countries	500 ng/l
Institute of Standards and Industrial Research of Iran	100 ng/l

Aflatoxins G1 and G2

Aflatoxins G1 and G2 emit green fluorescence when exposed to ultraviolet light. Aflatoxin G2 is a derivative of dihydroxy G1 (17). In terms of toxicity, aflatoxins G1 and G2 have the highest toxicity after AFB1 and AFB2, respectively (23).

Results and Discussion

Vegetable Seeds

Aflatoxins are poisonous, carcinogenic Due to the health problems caused by aflatoxins in food, the levels of these toxic substances must be monitored regularly (24). In a study, Feizi et al. (2012) measured the aflatoxin levels in cottonseed using high-performance liquid chromatography. In total, 140 cotton samples were obtained from different hypermarkets in Khorasan province (Iran), and 13 samples (9.35%) had an aflatoxin concentration of more than 0.005 µg/g, and the highest concentration of aflatoxins was reported to be 0.01 µg/g in one of the samples. In the mentioned study, the total aflatoxin level was observed to be lower than the maximum tolerable level recommended in Iran (50 µg/g) and by the EU (µg/g) (25).

In another research, Beheshti et al. (2012) examined the aflatoxin content of 173 samples obtained from sunflower and safflower seeds in Khorasan province (Iran) using high-performance liquid chromatography. According to the findings, the level of AFB1 in five sunflower seed samples (5%) and one safflower seed sample (0.8%) was higher than the maximum tolerable level of AFB1 as recommended by the ISIRI (0.01 ng/g). Moreover, the level of AFB1 in five sunflower seed samples and two safflower seed samples was higher than the maximum permissible level of the EU (0.002 ng/g) (26).

In another study, Hosseiniyan et al. (2014) examined the level of aflatoxins in 9,321 tons of sesame seeds in Khorasan Razavi province (Iran). In the mentioned study, the aflatoxin levels were reported to be higher than 1 µg/kg in 50% of the samples. The mean concentrations of AFB1 and total aflatoxin were reported to be 3.70±1.25 and 3.38±1.38 µg/kg in most of the samples, respectively. In addition, the aflatoxin level in 1.9% of the samples exceeded the regulatory limits of the EU and ISIRI (27). In this regard, Fakoor Jannati et al. (2011) assessed the AFB1 contamination rate in 30 bean samples, estimating the level of contamination to be higher than 0.01 ng/g (28).

Animal Feed

Feeding livestock with mycotoxin-contaminated feed could pose a significant risk to human health. In a study, Beheshti et al. (2014) calculated the aflatoxin levels in 146 feed samples in Mashhad (Iran) using high-performance liquid chromatography. The samples included barley (n=60), wheat bran (n=22), dry wheat pulp (n=29), and canola meal (n=35). The results of the mentioned study indicated that AFB1 contamination was positive in 28 samples, while the level of this toxin was lower than the maximum level set by the EU, as well as the national standard level in Iran (5 µg/kg) (29).

In another research, Mahmoudi et al. (2013) investigated aflatoxin contamination in cattle feed during winter and summer in 216 samples in Qazvin (Iran). According to the findings, mean AFB1 contamination during winter and summer was 1.76±2.27 and 0.8±0.60 µg/kg, respectively (30).

Aiming to remove AFB1 from animal feed, Saheb Ghalam et al. (2013) conducted a study regarding the biological removal of AFB1 using Saccharomyces cerevisiae yeast from livestock feed. According to the obtained results, living and non-living yeast cells were effective biological agents for the elimination of aflatoxins from the contaminated culture medium (31).

Wheat and Its Products

Wheat is one of the most important food products in the world and an essential ingredient in human meals, including bread, cake, and macaroni. As a dietary component, foods made of wheat are provided to one-third of the world's population. Inappropriate conditions of agriculture and storage may cause these products to be contaminated with fungi and fungal toxins. Bread is a foodstuff made of wheat, which is a rich source of energy, protein, vitamins, and minerals.

In 2007, wheat production was estimated to be 12 million tons in Iran, and the consumed bread by each Iranian was 157 kilogram per year. As a result, wheat and bread play a key role in the Iranian diet and food safety (32). In a study, Chelkowski et al. (1981) used ammonia to remove aflatoxins and other mycotoxins from various grains, such as wheat. According to the findings, using 2% of ammonia for 4-6 weeks at the temperature of 20-50°C could reduce the level of aflatoxins and other mycotoxins (33). Table 1 shows the results of the studies focusing on the level of aflatoxins in wheat and its products.

Table 2. Aflatoxin Levels in Wheat and Its Products in Iran

Year	Region	Samples	Results	Reference
2016	Golestan	Wheat	34 samples were tested; 29.4% of the samples were contaminated with aflatoxins; maximum levels of aflatoxins B1, B2, G1, and G2 were 7.08, 6. 91, 0.29, and 0.23 ng/g, respectively In 2.9% of the samples, aflatoxin B1 concentrations were higher than the maximum permitted levels recommended by the Institute of Standards and Industrial Research of Iran.	(34)
2013	Tehran	Bread and Wheat Flour	18 bread samples and 18 wheat flour samples were collected; 50% of the samples were contaminated with aflatoxin B1, and the contamination rate was lower than the maximum level recommended by the Institute of Standards and Industrial Research of Iran. (5 ng/g).	(35)
2013	Babol	Biscuits and Sweets	30 samples were obtained from supermarkets; 86.7% of the samples were contaminated with <4 μg/kg of total aflatoxins, and 13.3% of the samples were contaminated with >4 μg/kg of total aflatoxins.	(36)
2012	Qaemshahr	Wheat	42 samples were collected during November, December, and January; total aflatoxins were positive in seven out of 42 samples (1.1-27.3 ppb); contamination rates were higher in October than in the other months; rate of contamination was higher than the acceptable level set by the Food and Drug Administration (20 ppb) in three contaminated samples during three months.	(37)
2012	Golestan	Wheat Flour	99% of the samples collected in summer and 77% of the samples collected in winter were contaminated with aflatoxins (mean level: 0.89 and 1.23 ng/g, respectively); the rate of aflatoxin contamination was higher in the winter compared to summer; the main aflatoxin was B2 in winter and G1 in summer.	(38)
2008	Karaj	Wheat	Two categories of 50 wheat samples were obtained and stored for four months. Total aflatoxin level in the first series of sampling was identified in only three samples with the values of 0.23, 0.22, and 0.53 ppb. In the second series, total aflatoxin was determined at 0.51 and 0.1 ppb in only two samples.	(39)

Infant Food

Children are one of the most vulnerable populations due to their physiology, lack of food diversity, and consuming more food in proportion to their body weight. Cereals (e.g., rice, wheat, corn, and barley) are the most important sources of infant food (8). From the age of six months, supplementary foods are used to improve the growth of infants (39). Under inappropriate preparation conditions, these foods may be contaminated by aflatoxins, producing fungi (8).

In a study in this regard, Nazari et al. (2011) determined the rate of aflatoxin contamination in infant food commercial brands, such as Mamana and Ghoncheh. In the mentioned study, 14 samples of Mamana and 15 samples of Ghoncheh foods were investigated for AFB1, AFB2, and aflatoxin G1. According to the findings, two out of 15 samples of Mamana food and two out of 14 samples of Ghoncheh food were contaminated with AFB1 and AFB2 (<2 ppb) (8).

In another research, Mottaghianpour et al. (2017) investigated the level of AFB1 in the infant foods in Iran. According to the obtained results, 33 out of 48 baby food samples were contaminated with AFB1 (mean concentration: 2.602±4.065 μg/kg $^{-1}$). In addition, AFB1 concentration in 39.6% of the samples was higher than the approved maximum level in Iran (0.5 μg/kg^{-1}) (39).

Rice

Similar to wheat and corn, rice is one of the most important food products in the world, which is an abundant source of carbohydrates in Asian countries, including Iran. Iran is one of the main importers of rice. The per capita consumption of rice in Iran has been estimated at 42.5 kilograms (40). Rice is cultivated in 15 provinces in Iran, especially Mazandaran and Gilan. Temperature and rainfall vary within the ranges of 19-25°C and 25-125 millimeters, respectively. These conditions are considered favorable for the production of mycotoxins by the fungi that contaminate the rice plant (41).

The risk of rice contamination with storage fungi (e.g., *Aspergillus* species) is high during transportation and storage. The mentioned species is one of the most important fungi that contaminate cereals and foods due to their ability to produce aflatoxins, as well as their presence in various places (42). The results of the studies that have investigated aflatoxin contamination in rice are presented in Table 2.

Table 3. Aflatoxin Contamination in Rice in Iran

Year	Region	Samples (N)	Results	Reference
2014	Tehran	64	21% of the samples were contaminated with aflatoxin B1 (mean concentration: 3.9 μg/kg); contamination rate in three samples was higher than the permitted values by the Institute of Standards and Industrial Research of Iran (5 μg/kg); contamination with aflatoxin B2 was observed in two samples (concentration: 1.3 μg/kg); contamination with aflatoxins G1 and G2 was not reported.	(41)
2014	Golestan	80	78.75% and 18.75% of the samples were contaminated with aflatoxins B1 and B2, respectively; contamination with aflatoxins G1 and G2 was not reported.	(43)
2013	Tehran	18	50% of the samples were contaminated with aflatoxin B1 (mean concentration: 4.17 ng/g); the rate of contamination in one sample was higher than the maximum tolerated level in Iran (5 ng/g).	(35)
2013	Zahedan	200	33% and 47% of yellow and white rice samples were contaminated with 0.34 and 0.58 ppb of aflatoxin B1, respectively; 13% and 21% of the samples were contaminated with 0.06 and 0.08 ppb of aflatoxin B2, respectively; aflatoxins G1 and G2 were not detected in any of the samples.	(44)
2011	30 Provinces of Iran	256	Aflatoxin B1 was detected in all the samples; 21.5% of the samples were contaminated with more than 2 μg/kg of aflatoxin B1, and seven samples (2.7%) contained more than 4 mg/kg of total aflatoxins.	(45)
2009	Hormozgan, Azerbaijan, and Bushehr	71	83% of the samples were contaminated with aflatoxin B1, and 2.8% of the other samples had aflatoxin B1 level of more than the maximum permitted level in Iran; the level of total aflatoxin in nine samples was higher than the maximum level set by the European Union.	(46)

Nuts

Fungal metabolites are produced rapidly in various foods. These microorganisms could easily spread by wind, insects, and rain, which help their survival in the environment. These microorganisms are one of the main concerns of the 21st century due to the importance of pathogenicity (47). Nuts are exposed to fungal attacks and aflatoxin production due to theire chemical composition and storage conditions.

Various epidemiological studies have indicated that aflatoxins play a pivotal role in the quality and safety of nuts and could cause gastrointestinal disorders, hepatitis, and liver carcinoma. Since nuts are considered to be healthy and nutritious, they are a common source of nutrition in the community (48). In a study, Haji Mohammadi et al. (2016) investigated the effect of electron beams on the production of AFB1 in the pistachios inoculated with *Aspergillus flavus*. According to the findings, exposing the pistachio samples to electron beam radiation could prevent aflatoxin production by eliminating fungi (49).

In another study, Jubin et al. (2012) investigated the effect of ultraviolet radiation on the reduction of aflatoxins in walnuts, pistachios, peanuts, and almonds. In the mentioned study, the samples were exposed to ultraviolet radiation (256 nm) for 15, 30, and 45 minutes. The results indicated a relative reduction in the aflatoxin levels by increasing the exposure time (5٠). The results of the studies that have examined the aflatoxin levels in different nuts are presented in Table 3.

Table 4. Aflatoxin Levels in Nuts in Iran

Year	Region	Product	Samples (N)	Results	Reference
2017	Hamedan	Dried Mulberry, Dates, Figs, and Apricots	88	Incidence of aflatoxin B1 contamination in dried berries, dates, apricots, and figs was 45.5%, 40.9%, 59.1%, and 81.8%, respectively (mean concentration: 2.61 µg/kg). The mean total aflatoxin content in dates, figs, and apricots was 2.6, 3.43, and 2.91 µg/kg, respectively, which was lower than the designated limit by the European Union (4 µg/kg). Dried strawberry samples had higher contamination levels (12.4 µg/kg).	(51)
2016	Hamedan	Walnuts	40	The concentration of aflatoxins G1 and B1 was 1.7-18.2 and 0 - 8.2 ng/g^{-1}; none of the samples had contamination rate of higher than the maximum tolerable level set by the European Union (2 ppb).	(52)
2013	Arak	Figs, Almonds, Hazelnuts, Walnuts, Pistachios, and Sunflowers	167	59.9% of the samples were positive; mean concentration of aflatoxin in all the samples was 1.12 µg/kg; the level of aflatoxin in all the samples was lower than the permitted level of aflatoxin in nuts by the Institute of Standard and Industrial Research of Iran (15 µg/kg).	(53)
2013	Tabriz	Pistachios, Almonds, and Walnuts	171	The highest and lowest contamination rates were observed in walnuts (90%) and pistachios (2.3%), respectively; 58.6%, 48.4%, and 47.6% of the pistachio, almond, and walnut samples had contamination rate of higher than the Institute of Standard and Industrial Research of Iran limit (15 µg/kg) (mean concentration: 19.88±19.41 µg/kg)	(48)
2012	Kerman and Rafsanjan	Pistachios	3,181	Mean total aflatoxin (2.42±14.7 ng/g) and aflatoxin B1 (2.18±13.1 ng/g) were lower than the maximum level set by the Institute of Standard and Industrial Research of Iran.	(54)
2012	Mashhad	Dried Grapes	40	Three samples were contaminated with aflatoxin B1 (mean concentration: 0.41 ng/g), one sample was contaminated with aflatoxin B2, and one sample was contaminated with aflatoxin G2 (mean concentrations: 0.33 and 0.49 ng/g, respectively); contamination rates were lower than the permissible limit of the Institute of Standard and Industrial Research of Iran for aflatoxin B1 and total aflatoxins (5 and 15 ng/g, respectively).	(25)
2011	Mashhad	Dried Fruits (apricots and prunes)	45	30% of the apricot samples and 13.3% of the prunes were contaminated with aflatoxin B1 (>0.2 µg/kg); total aflatoxins and aflatoxin B1 were lower than the level set by the Institute of Standard and Industrial Research of Iran in all the specimens (5 and 15 µg/kg in apricots and prunes, respectively).	(55)

Milk and Dairy Products

Milk is an important nutrient in the human diet, especially for infants and children. Milk plays a key role in human health considering its high calcium and protein contents (56). AFM1 is the most important aflatoxin evaluated in milk. When lactating animals are fed with AFB1-contaminated food, this aflatoxin is metabolized to AFM1 in the animal's body and appears in the livestock milk (57). Most of the studies in this regard have indicated that processes such as pasteurization, sterilization, evaporation, condensation, and drying do not result in the reduction of AFM1 in milk and its products (58). However, *Lactobacillus casei*, *Bifidobacterium bifidum*, and *Lactobacillus rhamnosus* have been shown to have significant effects on the reduction of AFM1. In the current research, we reviewed the studies evaluating the aflatoxins in milk and dairy products (e.g., cheese, yogurt, cream, and ice cream), and the results are shown in Table 5.

Table 5. Aflatoxin in Milk and Dairy Products in Iran

Year	Region	Product	Results	Reference
2017	Azerbaijan, Mazandaran, Gilan, and Shiraz	Cheese	360 samples were examined; 194 samples (53.8%) were positive for AFM1; mean contamination concentration was 139.4±2.4 ng/kg; contamination rate in 10.5% of the samples was higher than the level set by the Institute of Standard and Industrial Research of Iran (250 ng/kg)	(59)
2017	Isfahan	Cheese	100 samples were examined; 52% (n=52) of the samples were	(60)

			contaminated with AFM1 (mean concentration: 169.13±32.4 ng/kg); 8% of the positive samples had contamination rates of higher than the European Union limit (250 ng/kg).	
2016	Shiraz	Milk	168 milk samples were collected; mean concentration of AFM1 in 55.56% of the samples was 21.31 ng/l; concentration of AFM1 in all the samples was less than the limit set by the Institute of Standard and Industrial Research of Iran (100 ng/l); in 30% of the samples, the contamination level was higher than the maximum tolerance limit accepted by the European Union (50 ng/l).	(61)
2016	Yazd	Milk	808 milk samples (78 cows, 52 sheep, 41 goats, and 31 camels) were collected; rate of AFM1 contamination in cow, sheep, goat, and camel milk samples was 46.5%, 21.6%, 20.1%, and 4.03%, respectively; level of toxins in 15.4% of cow milk samples, 11.5% of sheep milk samples, and 9.15% of goat milk samples exceeded the limit recommended by the Institute of Standard and Industrial Research of Iran (100 ng/l); none of the camel milk samples exceeded the legal limit.	(62)
2016	Kermanshah, Ilam, Hamedan, and Kurdistan	Milk	172 milk samples were collected (64 male cows, 56 goats, and 52 sheep); AFM1 was detected in 84.3%, 44.6%, and 65.3% of cow milk, sheep milk, and goat milk samples, respectively. In 35.9%, 11.1%, and 26.9% of the cow milk, goat milk, and sheep milk samples, AFM1 was above the approved level by the European Union.	(63)
2016	Iranshahr	Milk	40 milk samples were examined; 81.6% of the milk samples were contaminated with AFM1 (mean concentration: 23.30±18.84); 8.1% of the milk samples had contamination rates of higher than the limit proposed by the Institute of Standard and Industrial Research of Iran (50 ng/l); contamination level of AFM1 was higher in winter compared to summer.	(64)
2016	Gilan	Yogurt	90 samples were examined; 100% of the samples were contaminated with AFM1; mean concentration of AFM1 was 32.11 ng/kg; 20 (22.22%) of the samples had contamination rates of higher than the limit accepted by the European Union (50 ng/l).	(65)
2016	Kermanshah, Ilam, Hamedan, and Kurdistan	Yogurt Drink	44 yogurt drink samples were examined; 13.6% of the samples were contaminated with AFM1 (concentration: 7-12.1 ng/l); the mean concentration of contamination in the positive samples was 9.0±0.9 ng/l; the level of contamination was lower than the amount set by the Institute of Standard and Industrial Research of Iran (50 ng/l).	(63)
2016	Kermanshah, Ilam, Hamedan, and Kurdistan	Cheese	40 samples were assessed; 65.5% (n=25) of the samples were contaminated with AFM1 (mean concentration: 1306±15804 ng/kg); 10% of the positive samples had contamination rates of higher than the amount set by the Institute of Standard and Industrial Research of Iran (250 ng/kg).	(63)
2015	Kermanshah, Ilam, Hamedan, and Kurdistan	Yogurt	42 samples were examined; AFM1 was observed in 10 samples (23.8%); mean concentration of aflatoxin was 15.1±1.7 ng/l; level of contamination was lower than the amount set by the Institute of Standard and Industrial Research of Iran (50 ng/l).	(66)
2014	Semnan	Milk	311 samples were collected and analyzed; 92% of the samples were contaminated with AFM1, and in 16% of the samples, AFM1 concentration level was higher than the amount set by the Institute of Standard and Industrial Research of Iran (100 ng/l); mean concentration of AFM1 in raw milk was 80.1±55.1 ng/l; the highest level of AFM1 was 743 ng/l.	(67)
2014	Isfahan	Ice Cream	60 samples were examined; 34 samples (56.7%) were contaminated with AFM1 (concentration: 147.4-14.9 ng/l); mean concentration of AFM1 in the positive samples was 65.1±31.4 ng/l; contamination rate was lower than the amount set by the European Union.	(68)
2014	Isfahan	Yogurt	60 samples were examined; 48 samples (80%) were contaminated with AFM1 (mean concentration: 73.1±130.5 ng/l); three of the samples (5%) had AFM1 contamination levels of higher than the accepted limit by the European Union (50 ng/l).	(68)
2014	Isfahan	Cheese	80 samples were examined; 86.3% of the samples (69) had a mean AFM1 concentration of 120.4±133.2 ng/kg. In 11.8% of the positive samples, the contamination level was higher than the limit permitted by the European Union (250 ng/kg).	(69)
2013	Rafsanjan	Cheese	45 white cheese samples and 37 Lighvan cheese samples were analyzed; 29 (64.4%) and 10 samples (27%) of white cheese and Lighvan cheese had AFM1 contamination; mean concentration of AFM1 in the samples was 25.6±124 ng/kg. In 20% of the white cheese samples and 2.7% of Lighvan	(70)

			cheeses samples, the AFM1 contamination rates were higher than the level set by the Institute of Standard and Industrial Research of Iran (200 ng/kg).	
2013	Qazvin	Milk	288 milk samples were collected; 163 samples (56.59%) were contaminated with AFM1. AFM1 was detected within the range of 0.01-0.22 ppb. In 113 samples (69.32%), the AFM1 contamination rate was higher than the maximum tolerated limit (0.05 ppb) set by the European Commission/Codex Alimentarius.	(30)
2013	Gilan	Ice-cream	90 samples were examined; AFM1 was detected in 62 samples (68.88%) with the concentration of 147.7-8.4 ng/l. AFM1 was detected in 11 samples (12.22%), which was not above the maximum tolerated level set by the Institute of Standard and Industrial Research of Iran (50 ng/l).	(71)
2012	Tehran	Cheese	50 samples were examined; 60% of the samples were contaminated with AFM1 (mean concentration: 51.90±53.39 ng/kg), and 6% of the positive samples had contamination rate of higher than the level set by the Institute of Standard and Industrial Research of Iran.	(72)
2012	Shahrekord	Yogurt	40 samples were examined; 35% of the samples were contaminated with AFM1 (mean concentration: 130.5%). The concentration of AFM1 in all the samples was below the maximum tolerated level set by the Institute of Standard and Industrial Research of Iran (50 ng/l).	(73)
2012	Shahrekord	Cheese	40 samples were analyzed; AFM1 was detected in 40% of the samples (mean concentration: 133.2 ng/kg); seven samples had contamination rate of higher than the level set by the Institute of Standard and Industrial Research of Iran (250 ng/kg).	(75)
2012	Gilan	Cheese	90 samples were examined; AFM1 was detected in 86.66% of the samples (mean concentration: 413-7.2 ng/kg). In 23.33% of the samples, the contamination rate was higher than the European Union limit (250 ng/kg).	(74)
2012	Babol	Ice Cream	45 samples were analyzed. In 10 samples (22.2%), AFM1 contamination rate was above the European Union limit (50 ng/l); concentration of AFM1 was 103-1.2 ng/l (mean value: 33.98 ng/l).	(75)
2012	Shiraz, Khuzestan, and Yazd	Milk	149 samples (90 pasteurized, 59 UHT) were collected; AFM1 was detected in 95.3% of the samples (mean concentration: 41 ng/l); mean concentration of AFM1 in pasteurized and UHT milk was 39 and 46 ng/l, respectively. In 22.1% of the samples, AFM1 contamination rate was higher than the approved level by the European Union (50 ng/l).	(76)
2012	Shahrekord	Ice Cream	40 samples were assessed; 29% of the samples with concentrations of 197.4-20.1 ng/l were contaminated with AFM1; mean concentration of AFM1 in the contaminated samples was 65.1 ng/l. In all the samples, AFM1 contamination level was lower than the maximum level set by the European Union.	(73)
2012	Ahvaz	Milk	100 samples were analyzed; AFM1 was detected in all the pasteurized milk samples (concentration: 0.45-9.760 ng/l). Mean concentration of AFM1 in the pasteurized milk samples was 2.7 ng/l, which was below the limit set by the Institute of Standard and Industrial Research of Iran (50 ng/l).	(69)
2011	Urmia	Milk	100 samples of raw milk were examined; 100% of the samples were contaminated with AFM1 (mean concentration: 76.5±1.43 ng/l). The contamination rate of all the samples was higher than the European Union limit.	(77)
2011	Tehran, Isfahan, Tabriz, and Shiraz	Milk	225 samples of raw milk (88 cow milk, 65 goat milk, and 72 sheep milk) were investigated; 84.1% of the cow milk samples, 43.1% of the goat milk samples, and 59.7% of the sheep milk samples were contaminated with AFM1 (mean concentrations: 0.052±0.006, 0.018±0.003, and 0.027±0.004; 35.2%, 10.8%, and 25% of the cow milk, goat milk, and sheep milk samples had AFM1 contamination rates of higher than the limit set by the Institute of Standard and Industrial Research of Iran (50 ng/l).	(78)
2011	Tehran, Isfahan, Tabriz, and Shiraz	Yogurt	61 samples of industrial yogurt and 60 samples of traditional yogurt were examined; 30 (49.2%) and 14 samples (23.3%) were contaminated with AFM1 (mean concentrations: 0.026±0.004 and 0.007±0.002 ng/l, respectively). Contamination rate of AFM1 in 10 samples (16.4%) of industrial yogurt was higher than the level set by the Institute of Standard and Industrial Research of Iran (50 ng/l). Level of contamination in all the samples of traditional yogurt was below the level set by the Institute of Standard and Industrial Research of Iran (50 ng/l).	(78)
2011	Tehran, Isfahan,	Cheese	75 samples were examined; 65.3% samples (49) were contaminated with AFM1 (mean concentration: 0.010±0.085 µg/l). Contamination rate in	(78)

	Tabriz, and Shiraz		9.3% of the samples (n=7) was higher than the Institute of Standard and Industrial Research of Iran (250 ng/kg).	
2011	Tehran, Isfahan, Tabriz, and Shiraz	Industrial and Traditional Yogurt Drink	71 industrial yogurt drink samples and 65 traditional yogurt drink samples were investigated; 16 of industrial (22.5%) and nine traditional yogurt drink samples (13.8%) were contaminated with AFM1. Only three industrial yogurt drink samples (4.2%) had AFM1 contamination rate of higher than the European Union limit.	(78)
2010	Ardabil	Milk	90 samples were examined. All the samples (100%) were contaminated with AFM1 (concentrations: 2.9-85 ng/l). In 30 samples (33% of the total samples), the AFM1 contamination rate was higher than the maximum residue limit set by the European Union (50 ng/l).	(79)
2010	Ahvaz	Milk	311 milk samples (75 cows, 75 buffalos, 75 camels, 51 sheep, and 70 goats) were examined. AFM1 was detected in 42.1% of the samples (mean concentration: 43.8±43.3 ng/l). The incidence of AFM1 contamination in cow, buffalo, camel, sheep, and goat milk was 78.7%, 38.7%, 12.5%, 37.3%, and 27.1%, respectively. The concentration of AFM1 in all the samples was lower than the level set by the Institute of Standard and Industrial Research of Iran and Food and Drug Administration (500 ng/l).	(80)
2010	Tehran	Milk	210 UHT milk samples were examined. AFM1 was detected in 52.2% of the samples. AFM1 levels in 70 samples (33.3%) were higher than the maximum tolerance limit (50 ng/l) approved by the European Union. The highest mean concentration of AFM1 was 0.087 μg/l.	(81)
2010	Yazd and Isfahan	Milk	225 samples (116 pasteurized and 109 UHT milk samples) were collected. AFM1 was detected in 71.5% of the pasteurized samples (mean concentration: 52.8 ng/l) and 62.3% of the UHT samples (mean concentration: 46.4 ng/l). The AFM1 contamination rate was higher than the European Union limit in 26.7% of the pasteurized samples and 17.4% of the UHT samples.	(82)
2010	Tehran	Cheese	100 samples were examined. In 62% of the samples, AFM1 was confirmed with the mean concentration of 53.39 ng/kg; 9.3% (n=6) of the samples had a contamination rate of higher than the level set by the Institute of Standard and Industrial Research of Iran.	(83)
2010	Tehran, Isfahan, Shiraz, and Yazd	Cheese	72 samples were examined; 81.9% (n=59) of the samples were contaminated with AFM1 (mean concentration: 0.038±0.297 μg/l). In 30.5% (n=22) of the positive samples, the contamination rate was higher than the level set by the Institute of Standard and Industrial Research of Iran (250 ng/kg).	(84)
2010	Khorasan	milk	196 samples were studied. AFM1 was detected in 100% of the milk samples (mean concentration: 77.92 ng/l). AFM1 concentration in all the samples was below the level set by the Institute of Standard and Industrial Research of Iran and Food and Drug Administration (500 ng/l); 80.6% of the samples had AFM1 contamination rates of higher than the European Union limit (50 ng/l).	(85)
2010	Tehran, Isfahan, Shiraz, and Yazd	Yogurt	68 samples were examined. AFM1 was detected in 45 samples (66.1%) with the mean concentration of 0.032±0.004 μg/l. In 14 samples (20.6%), the AFM1 contamination rate was higher than the level set by the Institute of Standard and Industrial Research of Iran (50 ng/l).	(84)
2010	Tehran, Isfahan, Shiraz, and Yazd	Ice Cream	36 samples were analyzed; 25 samples (69.4%) were contaminated with AFM1 (mean concentration: 0.041 μg/kg; range: 0.015-0.132 μg/kg). The AFM1 level in winter was significantly higher than summer, and 27.7% of the samples showed AFM1 concentrations of higher than the level set by the Institute of Standard and Industrial Research of Iran (0.050 μg/kg).	(84)
2010	Sanandaj	Milk	In 257 of the milk samples (94.49%), AFM1 was positive with the concentrations of 0.007-115.930 ng/l. Level of AFM1 in 12 samples (4.4%) was higher than the limit set by the European Union (50 ng/l) and the Institute of Standard and Industrial Research of Iran (100 ng/l).	(86)
2010	Tehran, Isfahan, Shiraz, and Yazd	Butter	31 samples were analyzed; eight samples (28.5%) were contaminated with AFM1. Mean concentration of AFM1 was 0.005±0.002 μl/kg; 9.6% of the samples (n=3) had a contamination rate of higher than the level set by the Institute of Standard and Industrial Research of Iran (0.020 ppb).	(84)
2009	Isfahan and Yazd	Cheese	210 samples were examined; 161 samples (76.6%) were contaminated with AFM1 (mean concentration: 12.5±184.2 ng/kg); 24.2% of the samples had contamination rates of higher than the European Union limit.	(87)
2009	Tehran	Milk	210 milk samples were examined. AFM1 was detected in 116 (55.2%) of UHT milk samples. AFM1 contamination rate in 70 samples (33.3%) was higher than the maximum limit approved by the European Union (0.05	(81)

			µg/l). The highest mean concentration of AFM1 was 0.08 µg/l.	
2008	Babol	Milk	120 milk samples were collected. AFM1 was detected in 56.7% of the samples with the concentration of 50-352.3 ng/l; 43.3% of the samples were contaminated with the AFM1 concentration of 50-4 ng/l; 56.7% of the samples had contamination rates of higher than the European Union limit (50 ng/l).	(88)

Conclusion

Aflatoxins are a group of fungal metabolites with numerous toxic effects. Even a common diet might be associated with the risk of aflatoxin exposure. Since milk and dairy products are inherent to the diet of many individuals, several surveys have been focused on the aflatoxin residues in these products. In the majority of the studies in this regard, the level of aflatoxin has been reported to be higher than the recommended values by the ISIRI and the European Union.

According to the investigations on rice, AFB1 contamination is higher in rice compared to the other aflatoxins although its concentration in most of the studies has been reported to be lower than the permissible limit. In other foods (e.g., wheat and flour, seeds and grains, animal feed, and infant food), AFB1 has been shown to have the highest frequency among the other aflatoxins. Since AFB1 has been classified as a Group 1 human carcinogen by the IARC, contamination in these foods could be a severe threat to the health of the consumers, especially children.

It is not possible to completely destroy toxins in food products; therefore, effective management and adoption of control strategies are essential to ensuring the safety of consumers. A practical approach in this regard is to use an HACCP-based food safety management system or hazard analysis and critical control points during the procurement and production of raw materials, as well as the storage, production, and post-production operations of food products. Food safety management systems should function in such a way that consumers could ultimately be exposed to the lowest levels of aflatoxins.

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