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Review Article

Occurrence of T-2 Toxin and Aflatoxin B1 in Cereals and Cereal Based Products: A Short Review

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KEYWORDS

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T-2 toxin;
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ABSTRACT: Mycotoxins as secondary metabolites produced by fungi are capable of causing disease and death in humans and animals. T-2 toxin is a member of trichothecene mycotoxin . *Fusarium sporotrichioides*, is the important T-2 toxin production .AFB1 is the strong potent natural carcinogen known, and is usually the major aflatoxin produced by *Aspergillus* species fungi. In this paper, we reviewed recent studies in different scientific databases including Science Direct, PubMed, Springer, Magiran and Google Scholar for T-2 toxin and Aflatoxin B1 contamination in cereals and cereal based products. According to the result of the study, Aflatoxin B1 and T-2 toxin have been found in cereals and cereal-based products in Iran and worldwide and ELISA and HPLC techniques in determining the range of toxins are mostly used.

INTRODUCTION

The worldwide contamination of human food and animal feed with mycotoxins is an important problem [1]. Mycotoxins are produced by *Aspergillus*, *Fusarium*, and *Penicillium* genera that grow on cereals such as wheat, corn, barley, sorghum, peanuts, legumes and oilseeds [2]. Fungal contamination of food usually occurs randomly, but it could occur purposefully as an act of biological warfare. The potent acute toxicity and chemical stability of aflatoxin B1 (AFB1), and T-2 toxin make them apt to be weaponized for bioterrorism [3]. Cereals and cereal-based products represent one of the most important dietary items in Iran and the world. Cereals are very susceptible to fungal attacks on the farm and during storage [4].

T-2 toxin is a member of the fungal metabolites known as trichothecene mycotoxin. The major feature of T-2 toxin is that it inhibits protein synthesis. This toxin affects the actively dividing cells. It can decrease immunoglobolines, antibody levels and other humoral factors. *F. sporotrichioides*, is the main source of T-2 toxin production. Humid and warm weather conditions favor plant infection with *Fusarium* spp., [5].

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Aflatoxins are a group of highly toxic secondary metabolites produced mainly by *Aspergillus* species. AFB1 is a toxic metabolite produced by *A. flavus*, *A. parasiticus* and *A. nomius* [6]. AFB1 are classified as group 1 carcinogens by the International Agency for Research on Cancer (IARC) and is a potent mutagen, carcinogen and teratogen [7]. Aflatoxins act, after bioactivation in the liver by binding of biological molecules and blockage of RNA polymerase, ribosomal translocase and formation of DNA adduct. AFB1-epoxide can bind covalently to different proteins, which may affect functions and structural enzymatic protein [8]. In this paper, we reviewed recent studies on T-2 toxin and aflatoxin B1 contamination in cereals and cereal based products.

MATERIALS AND METHODS

We reviewed recent studies in different scientific databases including Science Direct, PubMed, Springer, Magiran and Google Scholar. Databases were searched to study the occurrence of T-2 Toxin and aflatoxin B1 in cereals and cereal based products in Iran and worldwide.

RESULTS

The presence of mycotoxins in foods is a serious problem in worldwide. It is necessary to detect mycotoxins in in cereals and cereal based products, before they enter human and animal bodies. Aflatoxin B1 and T-2 toxin have been found in cereals and cereal-based products in Iran and worldwide [6, 7, 9-12].

Occurrence of T-2 toxin in Cereals and Cereal Based Products

Based on their chemical characteristics, trichothecenes are classified into A, B, C, and D groups. T-2 toxin, a member of the A-group trichothecenes, is the most poisonous trichothecene [9]. The structure of T-2 toxin is shown in Figure 1. Physico-chemical properties of T-2 toxin are shown in Table 1. T-2 toxin tends to be found in cereal products such as wheat, oats, barley and maize rather than other products [10, 11]. In Iran, the T-2 toxin limit in animal feed is 25μg/kg, but for human is usually lower than in animal food [12]. Many surveys have been carried out worldwide on the incidence of the T-2 toxin in cereals (Table 2). The surveys since 1982 to 2016 shown that T-2 toxin in cereals and cereal based products are mostly seen and ELISA is the most practicable technique used.

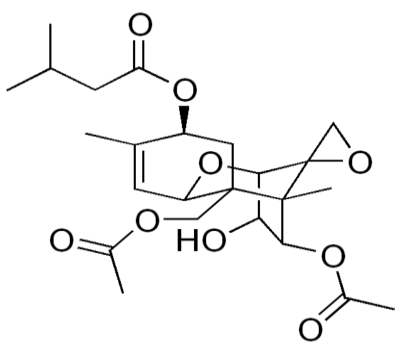

Figure 1. Chemical structures of T-2 toxin

Table 1. Physico-chemical properties of T-2 toxin

Property	Information
Name	T-2 Toxin/ Mycotoxin T 2/ Fusariotoxin T 2
IUPAC name	(2α,3α,4β,8α)-4,15-bis(acetyloxy)-3-hydroxy-12,13-epoxytrichothec-9-en-8-yl 3-methylbutanoate
Molecular formula	$C_{24}H_{34}O_9$
Molar mass	466.53 g/mol
Boiling Point	544.9°C
Melting Point	151-152°C
Flash Point	177°C
Soluble in	Acetone, Acetonitrile, Chloroform, Diethyl ether, Ethyl acetate, Methanol, Ethanol and dichloromethane and very slightly soluble in water

Table 2. Occurrence of T-2 toxin in cereals and cereal based products

Year	Region	Technique	Sample	Positive (%)	Range or Mean (μg/kg)	Reference
1982	United States	GC	33 Wheat	ND	ND	[13]
1989	New Zealand	GC	20 Maize	55	Below 1000	[14]
1995	Bulgaria	EIA	140 Wheat	0.7	55	[15]
1996	Iran	LC	35 Wheat	ND	ND	[16]
1996-1998	Norway	GC-MS	102 Barley	17	155	[17]
			169 Wheat	14	53	
			178 Oat	57	104	
1997	Romania	EIA	25 Wheat	24	26	[36]
			30 Maize	3.3	63	
1998	Germany	GC-MS	237 Cereal-based foods	4.22	14.33	[35]
1998/1999	Campinas	GC	90 Popcorn	ND	ND	[18]
1999	Germany	HPLC	60 Wheat flour	2	4	[19]
2002	Poland	HPLC	99 Oat grain	15	60000	[20]
2003-2007	Lithuanian	ELISA	371 Grain Product	82.47	24	[37]
2006	Iran	ELISA	23 Rice 16 Barley 7 Wheat	100	17.9	[12]
2006-2007	Turkey	ELISA	180 Feed samples	47.2	8.87	[34]
2007	Iran	ELISA	60 Rice-Iran	100	11.1	[21]
			125 Rice-Thai	100	12.6	
			15 Rice- Pakistan	100	14.5	
2007	Spain	HPLC	25 Corn-based foods	4	Range 41.3 – 47.6	[22]
2009	Spain	GC/MS	75 Bread	Bread 2.66	Bread ND-67.9	[24]
			75 Pasta	Pasta 9.33	Pasta ND-259.6	

Table 2. Contined

2009	Korea	HPLC	214 (45 Brown rice, 30 Barley, 33 Mixed grains, 23 Corn, 49 Wheat and 34 Wheat flour)	5.1	Range 11.5-41.5	[24]
2009	Romania	ELISA	22 Cereals and Cereal based food	100	6.44	[32]
2010	Croatia	ELISA	46 Maize	24.4	4509	[33]
2011	Italy	ELISA	29 Maize 12 Barley 9 Oats 7 Rice bran	Maize 13.8 Rice bran 42.8	Range Maize 12-102 Rice bran 70-80.5	[25]
2011-2012	Sweden	LC-MS/MS	27 Oats	59	Range 1-674	[31]
			41 Barley	22	1-171	
			29 Wheat	7	1-12	
			11 Mixed grain	0	ND	
2011-2014	Italy	ELISA	691 Barley	31.5	Range 26-724	[65]
2012	Serbia	ELISA	50 Maize	52	Range 25.3-185.2	[26]
2013	Iran	ELISA	90 Poultry and cattle feedstuff	15	1.51	[27]
2013	Brazil	HPLC	23 Wheat	ND	ND	[28]
2013	Nigeria	ELISA	104 Maize	36	Range 7.5 - 29	[29]
2014	Serbia	ELISA	41 Poultry feed	75.61	Range 25.07 - 426.08	[30]
2016	Brazil	LC MS/MS	14 Dry pet food	ND	ND	[69]
2016	Hungary	ELISA	45 Swine feedstuff	100	40	[70]
2016	Hungary	ELISA	116 Cereal samples (maize, wheat, barley and oat)	27.5	61.75	[71]

Occurrence of Aflatoxin B1 in Cereals and Cereal Based Products

Most pronounced aflatoxin contamination is in maize, peanuts and grains [38]. Physico-chemical properties of are shown in Table 3. The structure of AFB1 is shown in Figure 2. Conforming to the Food and Agriculture Organization (FAO), the worldwide maximum tolerated levels of AFB1 was reported to be in the range of 1–20 µg/kg in food, and 5–50 µg/kg in dietary cattle feed in 2003 [39]. European maximum limit for AFB1 in baby foods and processed cereal-based foods for infants and children is only 0.10 µg/kg [40]. In Iran, the permissible limit of AFB1 for wheat, rice and peanut is 5 µg/kg [41]. Many researchers from various countries have carried out studies about the incidence of AFB1 in cereals and cereal based products (Table 4). The surveys since 1996 to 2016 shown that aflatoxin B1 in cereals and cereal-based products are mostly seen and HPLC is the most practicable technique used.

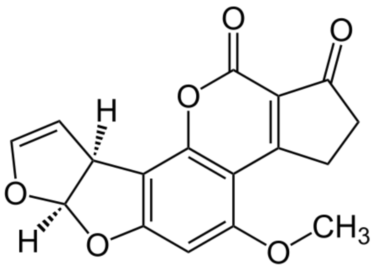

Figure 2. Structure of AFB1

Table 3. Physico-chemical properties of AFB1

Property	Information
Name	Aflatoxin B1
IUPAC name	(6aR,9aS)-2,3,6a,9a-Tetrahydro-4-methoxy-1H,11H-cyclopenta[c]furo[3',2':4,5]furo[2,3-h][1]benzopyran-1,11-dione
Molecular formula	$C_{17}H_{12}O_6$
Molar Weight	312.28 g/mol
Boiling Point	528.15°C
Melting Point	268°C
Flash Point	2°C
Soluble in	Organic solvents such as DMSO , Dimethyl formamide (DMF), Ethanol

Table 4. Occurrence of AFB1 in cereals and cereal based products

Year	Region	Technique	Sample	Positive (%)	Range or Mean (μg/kg)	Reference
1996	Egypt	LC	17 Nuts and seeds	82	24	[42]
			28 Cereal grains	21	36	
1998-1999	Korea	ELISA	30 Barley	0	-	[38]
			32 Barley foods	12	Range 19-35	
			18 Corn	0	-	
			47 Corn foods	8	Range 14-25	
1998-1999	Korea	HPLC	4 Barley foods	100	Range 8-11	[38]
			4 Corn foods	100	Range 8-10	
2001	Colombia	LC	248 Different grains	8.9	12.6	[43]
2002-2005	Canada	HPLC	349 Breakfast and infant cereal	50	Range 0.002-1.00	[40]
2003	Indonesia	HPLC	105 Foodstuffs	27.62	Range 4-357	[44]

Table 4. Contined

			18 Rice	50	4.17	[41]
			18 Bread	0	-	
2005	Iran	HPLC	18 Peanut	77.8	1.97	
			18 Puffed snack	66.6	0.11	
			18 Wheat flour	0	-	
2006	Vietnam	HPLC	100 Rice	51	3.31	[45]
2006	Morocco	HPLC	17 Wheat flour	100	0.07	[46]
			20 Corn flour	80	0.83	
2006-2007	Greece	HPLC	55 Breakfast cereal	56.3	1.42	[7]
2006-2012	Pakistan	TLC	262 Brown rice	95.4	Range 1.07–24.65	[47]
2007-2008	Iran	TLC	97 Feedstuffs	19.6	> 20	[48]
2007-2008	Iran	HPLC	256 Rice	100	1.4	[49]
2008	Pakistan	HPLC	40 Maize	20	Range 8-46	[50]
2009-2010	Brazil	TLC	101 Peanuts and Peanut	14	Range 24-87.5	[51]
2009-2011	India	ELISA	660 Maize	40.22	Range ND- 149.32	[52]
2009-2011	China	HPLC	370 Rice	63.51	0.60	[53]
2010	Iran	HPLC	18 Cereals	72.2	15.59	[54]
2011	Iran	HPLC	125 Rice	75	Range 0.144- 0.875	[55]
2011	Malaysia	ELISA	95 Food products	65.4	Range 700 -4400	[56]
2011	Iran	HPLC	100 Rice yellow	33	0.34	[57]
			100 Rice white	47	0.58	
2012	Iran	HPLC	84 Pistachio nut	100	27.58	[58]
2012	Iran	HPLC	112 Nuts	45.12	Range 0.37-3.78	[74]
2012	Thailand	ELISA	100 Foods	87	3.08	[59]
2012	Pakistan	HPLC	70 Processed Foods	35	Range 0.02–1.24	[60]
2012-2014	China	HPLC	2528 Feed ingredient	70.17	154.77	[61]
2013	Iran	ELISA	200 Nuts	1.68	96.5	[62]
2013	Iran	ELISA	80 Peanut, Almond, Walnut and Hazelnut	25	0.87	[63]
2013	Ethiopia	ELISA	90 Sorghum grain	33.4	Range 2.2-33.1	[67]
2013	Iran	HPLC	123 Rice	27.6	1.02	[75]
2014	Zimbabwe	LC-MS/M	95 Maize	1	11	[66]
2014	Tanzania	HPLC	20 Feed samples	65	8.55	[72]
2014	Nigeria	HPLC	120 Ginger	55	Range 0.11-8.76	[74]
			497 Maize	76	20.12	
2014	Kenya	ELISA	205 Millet	64	11.51	[73]
			164 Sorghum	60	1.81	

339

Table 4. Contined

2014-2015	Iran	HPLC	48 Baby Foods	68.7	Range 0.11, 15.15	[68]
2015	Iran	HPLC	90 Rice	80	Range 0.0009- 0.324	[64]
2016	Brazil	LC MS/MS	14 Dry pet food	21.4	2.16	[69]

CONCLUSIONS

Aflatoxin B1 and T-2 toxin considered as toxins with potential bioterrorism. The occurrence of these toxins in cereals and cereal based products in the world and Iran is a serious problem for public health. Review of the studies in this paper shows ELISA and HPLC methods in determining the range of toxins are mostly used. Storage conditions and monitoring of the effective factors the growth of fungi producing toxins and checked regularly can control and reduce the toxins in cereals and cereal based products.

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The authors declare that there is no conflict of interests.

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