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**ORIGINAL ARTICLE**

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

**Reza Kazemi Darsanaki[*1], Saeid Rahbar Takrami[2]**

[1]Young Researchers and Elites Club, Lahijan Branch, Islamic Azad University, Lahijan, Iran

[2] Young Researchers and Elites Club, Rasht Branch, Islamic Azad University, Rasht, Iran

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**KEYWORDS**

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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].

* Corresponding author: darsanaki@hotmail.com (R. Kazemi Darsanaki).

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.

## RESULT

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.

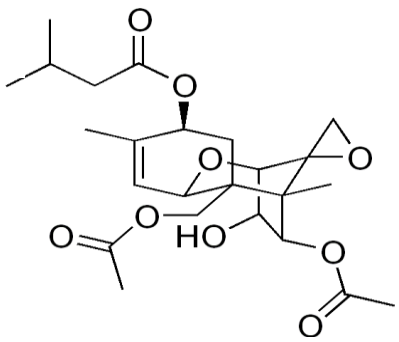


**Figure 1.** Chemical structures of T-2 toxin.

**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<br>16 Barley<br>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<br>41.3 – 47.6 | [22] |
| **2009** | Spain | GC/MS | 75 Bread | Bread 2.66 | Bread<br>ND-67.9 | [24] |

**Table 2.** Contined

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 75 Pasta | Pasta 9.33 | Pasta<br>ND-259.6 | |
| **2009** | Korea | HPLC | 214 (45 Brown rice, 30 Barley, 33 Mixed grains, 23 Corn, 49 Wheat and 34 Wheat flour) | 5.1 | Range<br>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<br>12 Barley<br>9 Oats<br>7 Rice bran | Maize 13.8<br>Rice bran 42.8 | Range<br>Maize<br>12-102<br>Rice bran<br>70-80.5 | [25] |
| **2011-2012** | Sweden | LC-MS/MS | 27 Oats | 59 | Range<br>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<br>26-724 | [65] |
| **2012** | Serbia | ELISA | 50 Maize | 52 | Range<br>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<br>7.5 - 29 | [29] |
| **2014** | Serbia | ELISA | 41 Poultry feed | 75.61 | Range<br>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.

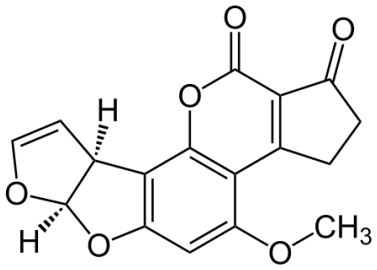

**Figure 2.** Structure of AFB1

**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] |

**Table 4.** Contined

| | | | | | | |
|---|---|---|---|---|---|---|
| **2003** | Indonesia | HPLC | 105 Foodstuffs | 27.62 | Range 4-357 | [44] |
| **2005** | Iran | HPLC | 18 Rice | 50 | 4.17 | [41] |
| | | | 18 Bread | 0 | - | |
| | | | 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] |

**Table 4.** Contined

| | | | | | | |
|---|---|---|---|---|---|---|
| **2014** | Kenya | ELISA | 497 Maize | 76 | 20.12 | [73] |
| | | | 205 Millet | 64 | 11.51 | |
| | | | 164 Sorghum | 60 | 1.81 | |
| **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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