Original Article

Ochratoxin A in Food Products in Iran: A Systematic Review of the Evidence

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Abstract

Aims: Ochratoxin A (OTA) is a toxic metabolite, which is produced by *Penicillium* spp. and *Aspergillus* spp. This mold growth increases in abuse adequate moisture and temperature in food storage time and produces mycotoxins. The aim of this study was the evaluation of OTA in various foods with reviews of other studies in Iran from 2000 to 2016. **Instrument and Methods:** The literature was evaluated by searching the electronic databases of the Cochrane Database of Systematic Reviews, PubMed, SID, Science Direct, Iran Medex, Magiran, and Google scholar. **Results:** Based on obtained results, the breakfast cereal, hazelnut, pistachio, walnut, almond, white grape juice, white pepper, dried sour cherry, dried peach, and dried pineapple samples were not contaminated with OTA. In the conducted studies, the highest rate of the contamination with OTA was in grape juice, raisin, black and red pepper, fig, dried quince, and coconut samples. **Conclusion:** The results showed that the most contaminated samples had OTA levels lower than the Iranian national standards and European Union regulations. Nevertheless, it seems necessary to focus on the reduction of mold contamination and OTA in various foods in Iran.

Keywords: Edible grain, grape, Iran, milk, ochratoxin A, raisin

Introduction

Nowadays, most of food toxicologists are interested in solutions to control exposure to mycotoxins and their removal from human foods. Ochratoxin A (OTA), B, and C with some chemical differences in structure are toxic secondary metabolites produced by some mold species as of the genera *Aspergillus* and *Penicillium* [Table 1].[1,2] They are a group of isocoumarin derivatives. OTA is the most common type of ochratoxins.[1] Ochratoxins are produced in high temperatures and moisture conditions, unseasonal rains during harvest and flash floods. Fungi associated with the production of OTA include *Aspergillus ochraceus, Aspergillus alliaceus, Aspergillus sclerotiorum, Aspergillus niger, Aspergillus sulphureus, Aspergillus albertensis, Aspergillus auricomus, Aspergillus wentii*, *Aspergillus carbonarius, Aspergillus westerdijkiae, Penicillium verrucosum*, *Penicillium nordicum*, and species of *Petromyces* and *Neopetromyces*.[1,3] Various agricultural commodities in the human food chain could be contaminated by molds and ochratoxins before harvest or under postharvest conditions. A variety of agricultural products, which can be contaminated with ochratoxins, include cereals and their derivatives (coffee, cocoa, oilseeds, and nuts), spices, fruits, dried fruits and their juices, beverages (wine and beer), and a variety of animal products including milk and dairy products and meat.[1,4] The threat of ochratoxins, especially OTA contamination of foods and feeds resulting in human and livestock poisoning is real and of major concern. The OTA is one of the highest toxicities of ochratoxins and a nephrotoxic, immunotoxic, embryotoxic, mutagenic, teratogenic, neurotoxic, and carcinogenic mycotoxin.[3,5] OTA causes pig nephropathy, Balkan endemic nephropathy in humans, and chronic middle nephropathy on the north of Africa.[3] The International Agency for Research on Cancer has categorized this toxin on 2B group as a carcinogen compound in human.[6] Therefore, tolerable daily intake for OTA has been suggested by the World Health Organization about 5 ng OTA/kg body weight/day [Table 2].[2,7-9]

Lee and Ryu reported based on the global occurrence data during the last 10 years, the incidences and maximum OTA level in raw cereal grains were 29% and 1.164 μg/kg.[10]

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Kolakowski *et al*. tested 6857 cereal-based, fruit-based, and soy-based food samples for OTA in the Canadian retail market from 2009 to 2014. They reported that 47% (3200) of the samples did not contain detectable concentrations of OTA and 53% (3657) of the samples contained OTA at 0.040–631 ng/g. Wheat, oats, milled products of other grains (such as rye and buckwheat), and to a lesser extent corn products and their derived foods were the most significant potential sources of OTA exposure for the Canadian population.[11]

In 2004–2007, OTA was tested in 1358 samples in retail foods in Japan. OTA was detected in wheat flour, pasta, oatmeal, rye, buckwheat flour and dried buckwheat noodle, raisin, wine, beer, coffee bean and coffee products, chocolate, cocoa, and coriander samples. OTA was found in more than 90% of the samples of instant coffee and cocoa, and the highest concentration of OTA, 12.5 μg/kg, was detected in raisin samples.[12]

In recent years, OTA has become an important topic for the Institute of Standards and Industrial Research of Iran (ISIRI).[13] By determining ranges of OTA contamination in foods and beverages, OTA exposure can be estimated from the known intake levels of the specific foods in Iran population. However, the accuracy of this estimation is limited due to the major variability in OTA content in foods, as well as difference in dietary habits. Therefore, the aim of this study was to review the evidence of OTA in various foods and beverages in Iran.

Table 1: Overview of main ochratoxin forms

Name	OTA	OTB	OTC
CAS number	303-47-9	4825-86-9	4865-85-4
Molecular formula	$C_{20}H_{18}ClNO_6$	$C_{20}H_{19}NO_6$	$C_{22}H_{22}ClNO_6$
Molar mass (g/mol)	403.8	369.4	431.9

CAS: Chemical Abstracts Service, OTA: Ochratoxin A, OTB: Ochratoxin B, OTC: Ochratoxin C

Instrument and Methods

In this review, we searched both local and international databases, such as ISI Web of Knowledge, the Cochrane Database of Systematic Reviews, PubMed, Scopus, Google Scholar, Magiran, Iran Medex, Irandoc, and SID. The manuscripts selected from the studies were aimed to cover the presence and levels of OTA in various foods according to their title and/or abstract of the manuscripts selected by the search with no language restriction. The search terms were used without restriction included combinations of: "Iran," "ochratoxin A," "spices," "cereals," "beverages," "meat," "milk," "bread," "dried fruits," "food contamination," "HPLC," "ELISA." In addition, we searched reference lists from retrieved manuscripts and looked up ochratoxin review papers. Our search was limited to manuscripts published ranging from 2000 to 2016. Being conducted in Iran was considered as the inclusion criteria while exclusion criteria were manuscripts that were not in Iran, were published before 2000, conducted on toxicity and other subjects' OTA, and lack of information on the validity parameters and accuracy in the analytical methods such as limit of detection (LOD), limit of quantification, and recovery [Figure 1].

In these papers, high-performance liquid chromatography (HPLC), enzyme-linked immunosorbent

Table 2: Maximum levels and tolerable human intakes of Ochratoxin A

Name	Foodstuff	Maximum levels
All products derived from cereals and fruits	Unprocessed cereals	5 μg/kg
	All products derived from unprocessed cereals, including processed cereal products and cereals intended for direct human consumption	3 μg/kg
	Dried vine fruit (currants, raisins, and sultanas)	10 μg/kg
	Roasted coffee beans and ground roasted coffee, excluding soluble coffee	5 μg/kg
	Soluble coffee (instant coffee)	10 μg/kg
	Grape juice, concentrated grape juice as reconstituted, grape nectar, grape must and concentrated grape must as reconstituted intended for direct human consumption	2 μg/kg
	Processed cereal-based foods and baby foods for infants and young children	0.5 μg/kg
	Dietary foods for special medical purposes intended specifically for infants	0.5 μg/kg
Spices, including dried spices	*Piper* spp. (fruits thereof including white and black pepper), *Myristica fragrans* (nutmeg), *Zingiber officinale* (ginger), *Curcuma longa* (turmeric)	15 μg/kg
	Capsicum spp. (dried fruits thereof, whole or ground, including chilies, chili powder, cayenne, and paprika)	20 μg/kg
	Mixtures of spices containing one of the abovementioned spices	15 μg/kg
Liquorice	Liquorice root, ingredient for herbal infusion	20 μg/kg
	Liquorice extract for use in food in particular beverages and confectionary	80 μg/kg
Tolerable human intakes	PTDI by Health Canada organization	3 ng/kg body weight/day
	PTWI by JECFA 2007	100 ng/kg body weight/week
	PTWI by EFSA	120 ng/kg body weight/week

PTDI: Provisional tolerable daily intake, PTWI: Provisional tolerable weekly intake, EFSA: European Food Safety Authority, JECFA: Joint FAO/WHO Expert Committee on Food Additives, WHO: World Health Organization, FAO: Food and Agriculture Organization of the United Nations

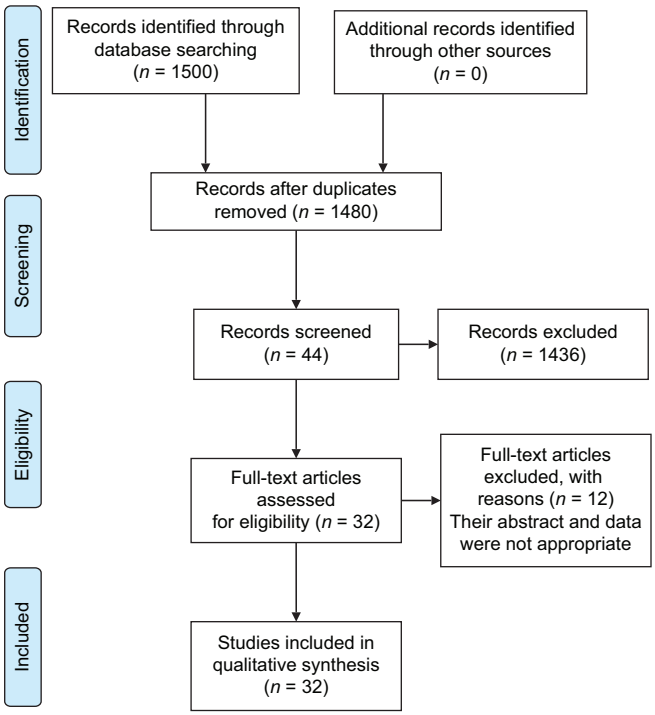

Figure 1: The study selection process

assay (ELISA), liquid chromatography-tandem mass spectrometry (LC-MS/MS), inverse ion MS, and carbon paste electrode chemically modified with gold nanoparticles as reliable methods were used for detection and quantitation of OTA in various foods.

Results were reported only based on place, source, mean concentration (μg/kg), maximum concentration (μg/kg), minimum concentration (μg/kg), method, and excess infection OTA in various foods.

Results

Thirty-two bibliographic records in relevance to the ochratoxin of various foods in Iran were identified based on information in the title, abstract, and reference lists in these selected studies.

Unprocessed and processed cereals and nuts

Almost all studies on cereals and nuts in Iran have shown OTA contamination.[14,15] Hadian *et al*. showed that all 100 tested imported and domestic rice samples were contaminated with OTA at a mean level 1.37 ± 5.72 μg/kg. The OTA level in 3% of domestic rice samples was higher than the Iranian national standards.[16] OTA was detected in rice samples in Isfahan,[17,18] Shahrekord, Mazandaran, Gillan, Tehran and Khuzestan,[14] Urmia,[19] and Tehran[20] with the minimum and maximum amounts of OTA concentrations 0.2 μg/kg and 11.54 μg/kg.

Mahtabani *et al*. showed that OTA was not found out of 18 breakfast cereal samples.[21] The result for 3 breakfast cereal samples was collected from Kerman, showed that the mean OTA amount (0.48 μg/kg) was lower than European Commission (3 μg/kg).[22]

In the study, wheat flour samples of 4 factories in Ahvaz were collected and analyzed using HPLC method. Thirty (93.75%) out of 32 samples were contaminated with OTA, at concentration ranging from 0.004 to 0.809 μg/kg, with an average of 0.09 μg/kg. All of the samples had lower levels of OTA than 5 μg/kg assigned by the standards.[23]

In one study, all 6 salted pistachio, 6 raw pistachio, 12 hazelnut, 12 almond, and 12 walnut samples were not contaminated with OTA.[24]

Beheshti and Asadi detected OTA content in 100 grain and derived product samples by high-performance liquid chromatography with immunoaffinity column cleanup and fluorometric detection. OTA was found in 32% of green gram, 13.3% of chickpea, 10% of lentil, and 17.5% of wheat flour samples. All contaminated samples had an OTA level lower than the maximum limit of OTA according to standards [Table 3].[25]

Dried vine fruits

An investigation of 40 currant, 16 sultana, and 10 raisin samples from Hamadan showed that 23 (57.5%) currant, 10 (62.5%) sultana, and 6 (60%) raisin samples, respectively, were contaminated with OTA using the HPLC method. However, 5 (7.6%), 3 currant and 2 sultana, samples had higher concentrations than the maximum limit of OTA according to national standard of Iran (5 μg/kg). However, none of the samples had higher OTA than the maximum limit of OTA according to European Commission (10 μg/kg).[40]

Shakerian *et al*., using ELISA method, showed that in 3.1% of the 80 analyzed samples from Isfahan had an average OTA concentration of 3.73 ± 2.27 μg/kg. The incidence rates of OTA contamination in dried coconut and slices of quince samples were 10.0% and 5.6%, respectively. Furthermore, OTA was not found in sour cherry, slices of peach, and pineapple samples. The concentration of OTA in any of contaminated dried fruit samples was not higher than maximum tolerance limit accepted by the European Commission (10 μg/kg).[35] Dried apricot and prunes samples were tested for OTA by Janati *et al*. OTA was found 3.33% of examined apricot samples and 20% of examined prunes samples more than 0.2 μg/kg.[33] Furthermore, OTA was detected in several dried vine fruit samples such as raisin,[4,32] fig,[24,34] and date [Table 3].[34]

Malt beverages, grape, and concentrated grape juices

Consumption of soft drinks based on dietary recommendations in Iran is decreasing. While the consumption of nonalcoholic beers as nutritive beverages is increasing. One study showed that out of 35 local and 35 imported malt beverage samples from Tabriz, all of the samples were contaminated with OTA. The average OTA concentrations in local and imported samples were 96.04 ± 126.13 and 60.71 ± 47.82 ng/kg, respectively, and the difference was not statistically significant. No significant difference was observed between different brands contamination. Furthermore, the OTA levels of samples were under the maximum permitted level by European

Table 3: Ochratoxin A concentrations in food products in Iran

Place	Source	Mean concentration (μg/kg)	Maximum concentration (μg/kg)	Minimum concentration (μg/kg)	Method	Percentage excess infection	References
Mazandaran and Golestan	14 barley samples	N	0.35	N	HPLC	0	[26]
	9 corn samples	0.35					
Tabriz	35 domestic malt beverage samples	0.096	0.524	0.0005	ELISA	0	[27]
	35 imported malt beverage samples	0.061	0.228	0.001			
Tehran	80 domestic rice samples	1.14	46.79	0.015	HPLC	3	[16]
	20 imported rice samples	0.19	1.1				
Tehran	18 breakfast cereal samples	0	0	0	HPLC	0	[21]
Isfahan	182 rice samples	1.6	4.8	0.2	HPLC	0	[17]
Iran	30 bean samples	>0.2	-	-	HPLC Immunoaffinity cleanup step	-	[28]
Fars	Licorice root	-	8.8	-	IMS	-	[29]
Isfahan, Tabriz, Shahrekord and *Urmia*	40 red grape juice samples	1.6	-	-	ELISA	0	[30]
	45 white grape juice samples	0					
Sabzevar	36 red pepper samples	1.48	2.17	0.74	HPLC	0	[31]
		1.35	2.35	0.59	ELISA		
Iran	30 raisin samples	2.21	-	-	HPLC	0	[32]
	18 currant samples	2.99					
Babol	100 grape juice samples	8.14	18.4	1.2	ELISA	32	[4]
	100 raisin samples	4.7	11.4	0.1		4	
Isfahan	120 rice samples	8.2	10.83	1.07	ELISA	-	[18]
Iran	30 dried apricot samples	-	-	>0.2	HPLC	-	[33]
	15 dried prunes samples						
Isfahan	12 pistachio samples	0	0	0	HPLC	-	[24]
	38 fig samples	6.85	10.8	2.9			
	12 almond samples	0	0	0			
	48 raisin samples	7.25	12.2	2.3			
	12 hazelnut samples	0	0	0			
	12 walnut samples	0	0	0			
Central of Iran	38 raisin samples	7	18.2	2.9	ELISA	7.9	[34]
	48 fig samples	7.9	14.3	2.3		2.1	
	20 date samples	2.5	3.6	1.4		0	
	15 dried apricot samples	2.8	-	-		0	
Isfahan	20 dried coconut samples	7.9	5.6	1.2	ELISA	0	[35]
	20 dried sour cherry samples	0	0	0			
	20 dried peach samples	0	0	0			
	20 dried quince samples	4.4	4.4	4.4			
	20 dried pineapple samples	0	0	0			
Sari	136 human milk samples	0.115	0.14	0.09	HPLC	2	[36]
Ahvaz	32 wheat flour samples	0.09	0.809	0.004	HPLC	0	[23]
Hamadan	66 raisin samples	1.72	8.4	0	HPLC	7.58	[37]
Khorasan	25 green gram samples	0.61	1	0.25	HPLC	0	[25]
	20 chickpea samples	0.29	0.39	0.2	immunoaffinity cleanup step		
	15 lentil samples	1.38	2.27	0.5			
	44 wheat flour samples	1.08	2.88	0.52			

Contd...

Table 3: Contd...

Place	Source	Mean concentration (μg/kg)	Maximum concentration (μg/kg)	Minimum concentration (μg/kg)	Method	Percentage excess infection	References
Tehran	62 Iranian rice samples	0	0	0	HPLC	0	[38]
	18 imported rice samples	0	0	0			
Urmia	135 rice samples	2.09	4.46	ND	ELISA	0	[19]
Khorasan, east Azerbaijan and Qazvin	44 raisin samples	50.2	100	0.4	HPLC	-	[5]
Shahrekord	86 bread samples	2.61	10.37	0.19	ELISA	15	[15]
Fars	87 human milk samples	0.02457	0.06	0.0016	ELISA	14	[39]
Tehran	65 rice samples	5.02	11.54	0.65	LC-MS/MS	1.53	[20]
Hamadan	40 currant samples	2.73	7.1	<0.16	HPLC	0	[40]
	16 sultana samples	3.23	8.4	<0.16			
	10 raisin samples	3.54	4.1	<0.16			
Khorasan	20 grape juice concentrate samples	0.6	1.74	0.24	HPLC	0	[41]
Tehran	10 raisin samples	0.88	-	-	HPLC-FLD	0	[42]
Shahrekord, Mazandaran, Gillan, Isfahan, Tehran and Khuzestan	308 rice samples	3.6	6.26	0.94	ELISA	-	[14]
Tehran	23 imported red pepper samples	5.66	18.64	0.56	HPLC	3.5	[43]
	23 imported black pepper samples	3.31	7.64	0.7		0	
	23 imported turmeric samples	2.77	8.49	0.60		3.5	
	23 imported cinnamon samples	5.46	16.1	0.45		0	
Kerman	3 baby food samples	0.075	0.08	0.07	Carbon paste electrode chemically modified with gold nanoparticles	-	[22]
	3 beer samples	5.22 nM	6.11 nM	4.13 nM			
	3 breakfast cereal samples	0.48	0.52	0.43			

N: Noninfection, ND: Levels were below minimum detection limits, IMS: Inverse ion mobility spectrometry, HPLC: High-performance liquid chromatography, ELISA: Enzyme-linked immunosorbent assay, LC: Liquid chromatography, MS: Mass spectrometry, FLD: Fluorescence detection

Commission.[27] Afzali *et al*. used a carbon paste electrode chemically modified with gold nanoparticles as a sensitive electrochemical sensor for determination of OTA. They have shown that this method has been applied to the determination of OTA in cereal-derived products such as beer samples. The minimum and maximum amounts of OTA concentrations in beer samples were 4.13 and 6.11 nM, and OTA levels in beer samples were below the maximum limit permitted by the European Commission.[22]

In this study, three studies were examined regarding OTA concentrations in grape and concentrated grape juices. Khiabani and Sani showed that 12 samples (60%) of 20 tested concentrated grape juice samples collected from retail stores of 9 cities in Khorasan province had an average OTA concentration of 0.6 ± 0.71 μg/kg which was lower than EU standards (2 μg/kg). The maximum and minimum concentrations of OTA in the samples were 0.24 and 1.74 μg/kg.[41] Ghafari *et al*. reported that only one sample (1.2%) of 40 red grape juice samples contained OTA (1.6 μg/kg) which was below the maximum tolerance accepted by the European Commission (5 μg/kg).[30] OTA was not found in white grape juice samples. However, in a previous study, 32 grape juice samples, out of 100 samples examined, contained OTA above the European Commission (10 μg/kg) with the average 8.14 μg/kg.[4]

Milk and processed cereal-based baby foods

In this study, two studies were examined regarding OTA concentrations in human milk samples. Afshar *et al*. showed that of a total 136 human milk samples tested using HPLC,

only two were contaminated with OTA, at 90 and 140 ng/L. While samples tested using ELISA, five were contaminated with OTA, at ranged between <5 and 16.42 ng/L. They reported that the occurrence of OTA contamination in human milk samples in Sari (northern Iran) was low.[36] A study by Dehghan *et al*. showed that 84 samples (96.6%) of 87 human milk samples from Khorrambid (southern Iran) had OTA levels at a mean level of 24.57 ± 13.6 ng/kg. According to the European Union Standard, 14 (16%) positive samples revealed more than the maximum limit of 40 ng/kg for ochratoxin (range, 1.6–60 ng/kg).[39]

OTA was detected in two baby food samples in Kerman; all of the samples had toxin levels lower than European Union regulations (0.5 μg/kg). The mean OTA concentration of baby food samples was 0.075 μg/kg.[22]

Spices

Spices including variety of seeds, fruits, and roots or other plant substances primarily are used for flavoring, coloring, and preserving foods. A study cited by Salari *et al*. to compare HPLC and ELISA methods for OTA determination in red pepper samples showed a good correlation between ELISA and HPLC methods for detection of OTA ($r^2 = 0.947$). Based on their results, ELISA can be used as a reliable screening method, but the confirmation of positive results must be done by HPLC method. ELISA and HPLC detected OTA in 8 (22%) and 6 (16.7%) samples within the range of 0.59–2.35 and 0.74–2.17 μg/kg, respectively.[31]

Jalili reported that out of 92 spice samples from different markets in Tehran, 29 samples (31.5%) were contaminated with OTA ranged from 0.45 to 18.64 μg/kg. Occurrence of OTA contamination in red pepper and cinnamon samples was significantly higher than in black pepper and turmeric samples. The maximum OTA level was detected in a red pepper sample (18.64 μg/kg) [Table 3].[43]

Liquorice

In this investigation, only one study was examined regarding OTA concentration in licorice root sample. Khalesi *et al*. reported that amount of OTA in the licorice root sample was 8.8 ± 0.6 μg/kg, using inverse ion mobility spectrometry.[29]

Discussion

The mold growth and production of OTA are related to several factors including temperature, moisture, and water activity during the harvesting, drying, storage, process and distribution of the crops. For inhibition of fungous growth on grains and dried fruits, it is necessary to dry them fast and wholly and maintain them on dry place.[1]

In order to examine the OTA contents in various samples, a myriad of investigations has been performed hitherto, which can be roughly categorized into two criteria, instrumental analyses and immunoassays. Instrumental analyses generally boast good accuracy and reproducibility, which include HPLC and LC-MS/MS; the LOD being as low as 0.05 μg/kg and 0.01 ng/mL, respectively. However, it is also noteworthy that the LC-MS/MS technique has in recent years emerged as the method of choice for multiresidue analyses of mycotoxins. Recently, affinity probe capillary electrophoresis assay, which combines the separation power of CE and ligand specificity of biomolecules, has emerged as a powerful tool for small molecule assay. In one advanced application, OTA could be selectively discerned in the presence of other targets such as adenosine and tyrosinamide by applying their corresponding aptamers as crucial signal tracers to sample solution. On the other hand, immunoassays such as enzyme-linked immunosorbent assay (ELISA) have been employed to accomplish the analyses within a relatively short time with high accuracy.[2,3,44]

Cereals such as barley, wheat, rice, corn, green gram, chickpea, and lentil are very susceptible to fungal attacks while in the field and during storage. Rice and wheat flour are the most important staple food crops in the diet of many people in Iran that are used in food products such as breads, cakes, and biscuits.[14,15] Furthermore, certain nuts such as pistachio, almond, hazelnut, and walnut are common in Iran. This review demonstrated that almost unprocessed and processed cereals and nuts were contaminated with OTA. Rahimi *et al*. analyzed 86 bread samples for OTA contamination, and the detection rates in autumn, winter, and spring, respectively, were 53.6%, 50%, and 46.2%, at 3.02, 2.52, and 2.27 μg/kg. Seasonal evaluation of the data did not indicate a significant difference in contamination levels.[15]

Dried fruits are fruits that are produced by removing the moisture content, through traditional sun drying or artificially drying. Today, dried fruits such as date, apricot, peach, fig, and raisin consumption is widespread in Iran. Dried fruits as nonperishable foods can support growth of molds and produce of mycotoxins such as OTA. In the conducted studies, the highest rate of the contamination with OTA was in raisin, fig, and dried quince and coconut samples. However, the most contaminated samples had OTA levels lower than the Iranian national standards and European Union regulations. A previous study showed that apparent quality of raisin samples, defective seed percentage, was not significantly correlated with the amounts of OTA[37] while Mirabolfathi *et al*., showed that the highest contamination with OTA was found in injured not directly edible raisin samples.[5]

We can use food processing to reduce OTA exposure by destruction or removing OTA, transforming them into less toxic derivatives and adsorbing OTA to chelating agents.

Some processing techniques, especially physical treatments such as sorting, sieving cleaning, flotation and density segregation, washing, dehulling, steeping, milling, heat treatment, and mycotoxin binder, have been in use for a long time.[1,45] A previous study demonstrated that roasting can reduce OTA levels in coffee beans up to 97%.[45] Heat treatment can reduce OTA toxicity due to degradation of OTA to 14-(R)-OTA, 14-decarboxy OTA, and OTA alpha amide.

However, OTA is generally stable at temperatures ued during ordinary cooking.[46]

Chemical methods and food additives can be used to reduce OTA. Ammoniation decreases OTA levels in maize, wheat, and barley after treatment with 2% aqueous NH3.[47] Chemical agents such as formic, propionic, and sorbic acids, H_2O_2, and sodium hypochlorite have been shown to degrade OTA.[48] Furthermore, microbes such as *Saccharomyces cerevisiae*[49] and their enzymes can be able to detoxify OTA, including carboxypeptidase, chymotrypsin, and lipases.[45] Antioxidant and antimicrobial agents such as extracts and essential oils of medicinal plants, melatonin, N-acetylcysteine, and reducing sugars could reduce the toxicity of various agents including mycotoxin and also have protective role.[48-50] Therefore, the factors that may increase the antimicrobial and antioxidant capacity of the food products should be more investigated.

Conclusion

OTA causes serious public health hazard due to consumption of contaminated food. This study carried out in different regions and provinces of Iran has demonstrated that almost all various food samples had the levels of OTA. Nevertheless, the results showed that the most contaminated samples had OTA levels lower than the Iranian national standards and European Union regulations.

Anyway, farm management and food storage practices as a part of Hazard Analysis and Critical Control Points (HACCP) in critical points on foods chain are the most effective approaches for reducing ochratoxin. Finally, it is suggested that extensive researches identify more effective processing techniques that can be used safely for decreasing OTA in foods, especially effects of extracts and essential oils from medicinal plants. Furthermore, it is offered that human risk is assessed for OTA in each food.

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Conflicts of interest

There are no conflicts of interest.

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