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The prevalence and risk assessment of aflatoxin in sesame-based products

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PAPER

Abstract

The contamination of aflatoxins (AFs) in 120 samples of sesame seeds, tahini, and tahini halva collected from Iran's market were evaluated. The exposed risk due to ingestion of aflatoxin B_1 (AFB_1) via their consumption was estimated with the aid of the Monte Carlo simulation (MCS). The highest prevalence of AF (55%) was associated with sesame seed samples, followed by tahini (45%) and tahini halva (32.5%). The AFB_1 concentration in sesame seeds, tahini, and tahini halva was in the ranges of 0.21–12.35, 0.23–5.81, and 0.27–3.56 µg/kg, respectively. The concentration of the total aflatoxin (TAF) in 7 (17.5%), 8 (20%), and 2 (5%) samples of sesame seeds, tahini, and tahini halva, respectively, was below the limit of European regulations (4 µg/kg), while the levels of AFB_1 in 10 (25%), 7 (17.5%), and 6 (15%) samples of sesame seeds, tahini, and tahini halva, respectively, were higher than the European regulations (2 µg/kg). As the percentile 50 and 95 of margin of exposure (MOE) with AFB_1 for sesame seed, tahini, and tahini halva was more than 10,000, it could conclude the intake of aflatoxin through the consumption of mentioned products did pose a not remarkable cancer risk for adults.

Keywords: mycotoxin; contamination; risk assessment; traditional products; sesame based

Introduction

Today, humans pay considerable attention to food safety and contaminants (Milicevic *et al.*, 2021; Rapa *et al.*, 2021; Xinyu *et al.*, 2020). Mycotoxins produced by fungi are among the most important food contaminants and have a negative impact on public health, food safety, and the national economy of many countries, especially developing countries (Batrinou *et al.*, 2020; Grumi *et al.*, 2020). The most critical factors in food contamination with mycotoxins are moisture, intrinsic properties and nutrients, long shelf life and pH, and high-water activity (Wang *et al.*, 2018). Aflatoxins (AFs) are produced by *Aspergillus* fungi, especially *A. flavus* and *A. parasitics* and rarely by *A. nomius* (De Souza *et al.*, 2021; Heshmati *et al.*, 2019). They pose carcinogenic, mutagenic, immunosuppressive, and teratogenic consequences. The most common AFs are aflatoxin B_1 (AFB_1), B_2 (AFB_2), G_1 (AFG_1), and G_2 (AFG_2) (Heshmati *et al.*, 2017). AFB_1 is the most carcinogenic type for humans and animals (Mokhtarian *et al.*, 2020). The International Agency for Research on Cancer (IARC) classified AFB_1 as a group 1 carcinogen (Elzupir *et al.*, 2010).

Aflatoxins production may occur during harvesting, transportation, storage, or on the farm. AFs are very stable chemical compounds resistant to heat and food processes (Cui *et al.*, 2020). They can contaminate various foods, including cereal, dairy products, oilseeds,

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spices, and nuts (Javanmardi *et al.*, 2020; Khaneghah *et al.*, 2018; Mozaffari Nejad *et al.*, 2020).

Due to the high toxicity of AFs, exposure to these contaminations could threaten human health. The Committee on Food Additives of Joint FAO/WHO (JECFA) recommends that the presence of mycotoxins in meals be minimized to reduce the potential risk (Di Sanzo *et al.*, 2018). Therefore, in order to control AFs in food products, some regulations were established in many countries; the measurement and monitoring of AFs in food products are crucial (Sebaei *et al.*, 2020).

With the scientific name of *Sesamum indicum* L., sesame seed belongs to the Pedaliaceae family and is one of the oldest and most momentous oilseeds globally (Lee *et al.*, 2020). It contains 58%–44% oil, 25%–25% protein, 13.5% carbohydrates, and 5% ash (Kollia *et al.*, 2016). It is also a significant source of dietary fiber and micronutrients such as minerals, including calcium, phosphate, iron, potassium, vitamins such as E, thiamine, and niacin, lignans tocopherols, and phytosterols (Elleuch *et al.*, 2011; Yao *et al.*, 2021). Sesame seeds have antioxidant, anti-inflammatory, anti-fungal, anti-viral, and natural antibacterial effects (Dravie *et al.*, 2020). Sesame seeds are consumed in different forms in the world (Namiki, 2007). It is widely used in the Iranian food industry as an ingredient in confectionery products, bread, and pastries. Therefore, ensuring the mycotoxicological quality of sesame is very important (Asadi *et al.*, 2011; Eghbaljoo-Gharehgheshlaghi *et al.*, 2020; Elleuch *et al.*, 2011; Kollia *et al.*, 2016).

Tahini is made by grinding and roasting sesame seeds known in the Middle East (Gholami *et al.*, 2020; Sebaei *et al.*, 2020). Tahini halva, also known as halva, helva, halawi, halawh, is produced by mixing tahini with sugar, citric or tartaric acid, and *Saponaria officinalis* root extract (Öğütcü *et al.*, 2017; Osaili *et al.*, 2018a; Var *et al.*, 2007). Consumption of tahini halva has increased due to its excellent nutritional value and health properties in other countries, including the United States and European countries, Iran, Turkey, Saudi Arabia, Iraq, Greece, Jordan, Bulgaria, and Bosnia and Herzegovina (Anilakumar *et al.*, 2010). Tahini halva consists of about 45% tahini, 45%–55% sugar, 2% ash, and 2.5% moisture and is consumed with bread in breakfast and dinner (Osaili *et al.*, 2018b).

When sesame seeds were stored improperly, they can be contaminated with mycotoxins, especially AFs (Anthony *et al.*, 2014). Therefore, the EU sets limits for AFB_1 and TAF in sesame and its products as 2 and 4 μg/kg, respectively. In contrast, the limit of these mycotoxins, according to the Iranian Institute of Standards and Industrial Research (ISIRI), was 5 and 15 μg /kg (INSO, 2020). The prevalence of AFs in sesame seeds and their products was demonstrated by previous studies (Anthony *et al.*, 2014; Apeh *et al.*, 2016; Asadi *et al.*, 2011; Esan *et al.*, 2020; Fapohunda *et al.*, 2018; Hosseininia *et al.*, 2014; Kollia *et al.*, 2016; Li *et al.*, 2009; Reddy *et al.*, 2011; Sabry *et al.*, 2016; Sebaei *et al.*, 2020; Sirhan *et al.*, 2014; Tabata, 2007; Torlak and Akan, 2013; Var *et al.*, 2007).

No studies have been performed to evaluate mycotoxin contamination in tahini and tahini halva samples available in Iran's market. Therefore, the current study aimed to determine the level of AFs in sesame seed, tahini, and tahini halva, and halva consumed in western Iran. Furthermore, the exposed risk due to ingestion of AFB_1 via their consumption was estimated with the aid of the Monte Carlo simulation (MCS).

Material and Methods

Materials

Acetonitrile, HNO_3 (65%), phosphate buffer solution (PBS), methanol, Potassium bromide (KBr), were purchased from Merck (Darmstadt, Germany). The AF standards were purchased from Sigma-Aldrich (St. Louis, MO, USA)

Sample collection

Samples (n = 120; 40 fresh sesame seed, 40 tahini, and 40 tahini halva) were collected from the local market in Hamadan province, Iran, from April 2020 until August 2020. Samples were stored in a refrigerator (4°C) until analysis.

Chemical properties

Moisture content (%) of sesame seed, tahini, and tahini halva was determined by drying in an oven at 100°C. The protein and fat contents of samples were determined by the Kjeldahl method and Soxhlet extraction, respectively (Zebib *et al.*, 2015). Extracted fat acidity was measured by titration by sodium hydroxide (0.01°N) in the presence of phenolphthalein as an indicator.

Extract and cleanup of AF

The method applied for the extraction and cleanup of AF was similar to the previous one with slight modifications (Torlak and Akan, 2013). Samples were wholly powdered and mixed. Fifty grams of ground sample was weighed and transferred into a 250 mL flask. Then, 150 mL of a mixture of water and methanol (30:70; v/v) was added and placed on a shaker and stirred for 10 min. Then, it was filtered through filter paper of Whatman No. 2. Twenty milliliters of filtered solutions were collected and transferred into a 100 mL flask, and 40 mL of distilled water was added and mixed for 5 min and filtered. For the cleanup of AFs, 15 mL of filtrate was transferred through the immunoaffinity column at a flow rate of 2–3 drops/s. Further, the column was washed three times with 10 mL distilled water at the same flow rate. The elution of AFs was performed by acetonitrile (1 mL). The eluate was gathered in a vial, and its volume was reached 2 mL with acetonitrile. Then, 100 µL of eluted AFs was injected into a high-performance liquid chromatography (HPLC) instrument.

Analysis of AFs

The quantification of AFs in sesame products was carried out by HPLC (Knauer-Germany), equipped with a Smartline Pump, fluorescence detector, reverse phased C18 (150 mm × 4.6 mm i.d and 5 µm particle size). In the fluorescence detector, an excitation wavelength of 333 nm and emission wavelength of 430 nm was applied for AFs determination. The mobile phase was water/methanol/acetonitrile (6:102:94, v/v/v) and contained 100 mg KBr and 100 µL HNO_3. Then, it is diverted into HPLC in the isocratic method with a flow rate of 0.8 mL/min. The column temperature of HPLC was maintained at 40°C.

The validation of AFs analysis method

The linearity, accuracy, repeatability, limit of detection (LOD), and limit of quantification (LOQ) were determined (Heshmati *et al.*, 2017).

Risk assessment

For risk assessment of AFB_1 intake through sesames seed, tahini, and tahini halva, the probabilistic approach was considered and estimated daily intake (EDI). The following equations are used to calculate the margin of exposure (MOE):

EDI (ng/kg bw/day) = the concentration of AFB_1 × average daily consumption (kg)/average body weight (kg)

Per capita consumption of sesame in Iran is 3 g/day (Eghbaljoo-Gharehgheshlaghi *et al.*, 2020). In this study, 70 kg is considered as the mean body weight for an adult in Iran.

MOE = benchmark dose lower confidence limit 10% ($BMDL_{10}$)/EDI

where, $BMDL_{10}$ is the lowest dose that is 95% certain to cause no more than 10% cancer prevalence. The EFSA Panel on Contaminants in the Food Chain (CONTAM) suggested 400 ng/kg BW/day for $BMDL_{10}$ reference value (Chain *et al.*, 2020). A MOE of 10,000 or larger has little concern for public health, while a MOE of less than 10,000 shows a potential danger for consumers (Heshmati *et al.*, 2017). EDI and MOE were estimated by MCS using Crystal ball software (version 11.1.2.3 Oracle).

Statistical analysis

For statistical analysis, the SPSS software version 20 (IBM, PASW Statistics, USA) was applied. The mean and standard deviation of AFs levels in different samples were determined. One sample T-test was used to compare the mean of AFB_1 and TAF with the allowable limit. The significant level was considered $P < 0.05$. One-way ANOVA and Tukey's test were applied to determine the significant difference of moisture, fat, protein content, and extracted fat acidity levels of these samples.

Result and Discussion

The chemical properties of samples

The moisture, fat, protein, and extracted fat acidity amount of sesame seed, tahini, and tahini halva samples are shown in Table 1. Sesame seed had a higher moisture, fat, and protein value than tahini and tahini halva samples.

Method validation

The LOD of AFs for sesame seeds, tahini, and tahini Halva samples ranged from 0.04 to 0.08, 0.05 to 0.09, and 0.07 to 0.08 µg/kg, respectively while LOQ for them ranged from 0.13 to 0.25, 0.18 to 0.31, and 0.21 to 0.27 µg/kg, respectively (Table 2). Moreover, the recovery range for AFs of sesame seeds, tahini, and tahini halva samples was 82.15–96.23, 77.36–95.63, and 83.65–98.65, respectively (Table 3). The determination coefficients ($R^2 > 0.992$) of the

Table 1. Chemical proprieties of sesame and related products.

Parameters	Sesame seed	Tahini	Tahini halva
Moisture (%)	6.87 ± 0.38^a	1.15 ± 0.07^c	2.5 ± 0.06^b
Fat (%)	52.31 ± 2.89^a	49.13 ± 2.12^b	28.45 ± 2.32^c
Protein (%)	22.34 ± 1.87^a	20.67 ± 1.76^b	9.87 ± 0.75^c
Extracted fat acidity (%, in oleic acid)	0.82 ± 0.09^a	0.90 ± 0.10^a	0.76 ± 0.07^a

The different superscript letters within each row indicated significant differences ($P < 0.05$).

regression equations showed acceptable linearity, and good recovery was obtained for spike samples and was similar to values reported in previous studies (Heshmati *et al.*, 2017). The findings obtained during method validation were conformed with accepted criteria (AOAC International, 2002).

The prevalence of AFs in sesame seeds

In this study, 40 samples of sesame seeds were analyzed for AFs. Sesame seeds had the highest prevalence (55%) of total AFs among the three analyzed samples. The detection rates of AFs were higher in sesame seed samples than in the tahini and tahini halva. AFB_1, AFB_2, AFG_1, and AFG_2 were detected in 19 (47.5%), 5 (12.5%), 6 (15%), and 5 (12.5%) of 40 sesame seeds samples, respectively (Table 4). AFB_1 was the most abundant AF, and its level varied from 0.21 to 12.35 μg/kg. In addition, 10 and 6 samples contained AFB_1 more than the accepted limit according to European (2 μg/kg) and Iranian standard (5 μg/kg), respectively, and the total AFs content of samples was lower than the permitted level in Iran (15 mg/kg).

There are several reports of AF contamination in sesame seeds (Table 5). The different levels of total AFs and AFB_1 have been reported in previous similar studies. For example, Anthony *et al.* (2014) reported that 8 (26.67%) out of 30 sesame samples studied in Nigeria were contaminated with AFB_1 at levels above the limit of European regulations (Anthony *et al.*, 2014). Esan *et al.* (2020) surveyed the contamination of total AFs in sesame seeds of Nigeria. They demonstrated that the positive samples contaminated with total AFs ranged from 0.29 to 88.5 μg/kg (Esan *et al.*, 2020). In another study, Kollia *et al.* (2016) investigated 30 samples of sesame seeds from the Greek market. They observed that the amount of AFB_1 in eight samples exceeded the limit of European regulations (Kollia *et al.*, 2016). In an investigation, among 28 samples of sesame products from Egypt by Sabry *et al.* (2016), a higher prevalence of AFB_1 and AFG_1 than other mycotoxins in the range of 60%–100% and 33.33%–100%, respectively, were reported. The mean range of AFB_1 and AFG_1 in different provinces was 18.63–66.79 and 14.88–51.47 g/kg, respectively (Sabry *et al.*, 2016).

Table 2. Validated parameters for aflatoxin analysis in sesame and related products.

Aflatoxin type	Equation of calibration curve	Range of linearity (ng/mL)	R^2	Sesame seed		Tahini		Tahini halva	
				LOD	LOQ	LOD	LOQ	LOD	LOQ
AFB_1	Y = 13562.23X + 456.03	0.15–25	0.998	0.06	0.21	0.07	0.23	0.08	0.27
AFB_2	Y =10623.15X – 4856.45	0.25–20	0.997	0.08	0.25	0.09	0.31	0.07	0.22
AFG_1	Y = 20354.67X + 120.09	0.16–20	0.996	0.06	0.22	0.05	0.18	0.08	0.26
AFG_2	Y = 14600.18X – 809.53	0.12–25	0.992	0.04	0.13	0.06	0.19	0.07	0.21

LOD and LOQ in μg/kg.
AF: aflatoxin; LOD: limit of detection; LOQ: limit of quantification.

Table 3. Recovery of aflatoxin from sesame and related products.

Aflatoxin type	Spiked level (μg/kg)	Recovery ± RSD (%)		
		Sesame seed	Tahini	Tahini halva
AFB_1	0.5	82.15 ± 4.51	84.56 ± 10.36	87.65 ± 12.74
	2	87.63 ± 8.56	88.32 ± 13.08	90.23 ± 15.32
	5	85.25 ± 3.65	87.32 ± 8.98	85.32 ± 14.56
AFB_2	0.5	90.23 ± 10.23	79.65 ± 4.56	94.36 ± 12.02
	1.5	92.35 ± 12.32	82.36 ± 7.25	98.65 ± 4.08
	3	95.63 ± 15.36	77.36 ± 14.97	94.82 ± 6.23
AFG_1	0.5	89.69 ± 12.31	83.65 ± 4.56	88.63 ± 4.51
	1.5	92.34 ± 8.96	86.53 ± 45.23	87.56 ± 14.23
	3	94.23 ± 14.85	82.03 ± 12.78	83.65 ± 14.32
AFG_2	0.5	90.23 ± 11.57	90.23 ± 15.63	89.32 ± 4.36
	1.5	96.23 ± 8.69	95.63 ± 10.56	90.56 ± 8.69
	3	94.23 ± 10.23	92.53 ± 8.02	95.36 ± 10.26

AF: aflatoxin; RSD: Relative standard deviation

Table 4. The contamination status of aflatoxin of sesame and related products.

Aflatoxin type		Contamination status	Sesame seed	Tahini	Tahini halva
AFB_1	Contamination level (μg/kg)	No. of contaminated samples	19 (47.5)	14 (35)	11 (27.5)
		Mean ± SD (μg/kg)	1.67 ± 0.45	0.85 ± 0.24	0.55 ± 0.17
		0.15–2	9 (22.5)	7 (17.5)	5 (12.5)
		2–5	4 (10)	4 (10)	6 (15)
		>5	6 (15)	3 (7.5)	0
		Range (μg/kg)	0.21–12.35	0.23–5.81	0.27–3.56
AFB_2		No. of contaminated samples	5 (12.5)	3 (7.5)	4 (7.5)
		Mean ± SD (μg/kg)	0.13 ± 0.06	0.1 ± 0.06	0.07 ± 0.03
		Range (μg/kg)	0.25–1.62	0.31–1.75	0.22–0.92
AFG_1		No. of contaminated samples	6 (15)	4 (10)	2 (5)
		Mean ± SD (μg/kg)	0.10 ± 0.05	0.07 ± 0.04	0.04 ± 0.03
		Range (μg/kg)	0.22–1.41	0.18–1.32	0.26–1.02
AFG_2		No. of contaminated samples	5 (12.5)	5 (12.5)	4 (10)
		Mean ± SD (μg/kg)	0.05 ± 0.02	0.08 ± 0.04	0.06 ± 0.03
		Range (μg/kg)	0.13–0.85	0.19–1.02	0.21–0.74
TAF	Contamination level (μg/kg)	No. of contaminated samples	22 (55)	18 (45)	13 (32.5)
		Mean ± SD (μg/kg)	1.95 ± 0.48	1.10 ± 0.30	0.72 ± 0.22
		>4	15 (37.5)	14 (35)	11 (27.5)
		4–15	7 (17.5)	8 (20)	2 (5)
		>15	0	0	0

AF: aflatoxin.

The prevalence of AFs in tahini

A lower rate of AF contamination was observed in tahini than that in sesame seed. Eighteen (45%) of Tahini samples contained total AFs. The highest prevalence of AFs in tahini halva was AFB_1 (35%), followed by AFG_2 (12.5%), AFG_1 (10%), and AFB_2 (7.5%). It was observed that the AFB_1 value of seven samples was higher than the limit of European regulations (2 μg /kg) while only three samples had AFB_1 contamination higher than the recommended standard of Iran (5 μg/kg). Also, 18 samples contained total AF with an average value of 1.10 ± 0.30 μg/kg, among which the concentration of eight samples was higher than the limit of European regulations (4 μg/kg). It seems that washing and peeling of sesame seeds before tahini preparation could reduce the amount of AFs. Before tahini preparation, sesame seeds were roasted. The previous studies indicated that roasting operation could cause AFs degradation (Emadi *et al.*, 2021; Yazdanpanah *et al.*, 2005).

The prevalence of AFs in tahini was reported in other studies. For example, in a study performed by Sebaei *et al.* (2020) in Egypt, mean AFB_1 in 16 samples of branded tahini and 101 samples of local tahini reported 0.10 ± 0.24 μg/kg and 13 ± 19.3 μg/kg, respectively (Sebaei *et al.*, 2020). Li *et al.* (2009) reported that 19% and 32% of 100 of the sesame paste (Tahini) samples studied in China contained AFB_1 at levels higher than the Chinese regulation (5 μg/kg) and European regulations (Li *et al.*, 2009). In addition, Torlak and Akan (2013) studied AFs contamination in 104 samples of tahini from the Anatolia region of Turkey. The mean of AFB_1 and total AFs of samples was 0.93 ± 0.62 μg/kg and 1.17 ± 0.55 μg, respectively, which both were lower than the Turkish standard (AFB_1: 5 μg/kg and TAF: 10 μg/kg) and our study. These authors indicated that the roasting process applied in tahini production does not eliminate AFs (Torlak and Akan, 2013).

For the traditional production of tahini, sesame is roasted for 2 h at a temperature of 100°C to 150°C (Torlak and Akan, 2013). AFs are resistant to heat and are difficult to eliminate at insufficient temperatures. In general, AFs are eliminated at 237°C to 306°C. In foods heated, important parameters determining the reduction of AF include

Table 5. The contamination status of aflatoxin of sesame and related products.

Country	Sample type	No of samples	Positive *n* (%)	Method	Mycotoxin	Range (μg/kg)	Mean ± SD (μg/kg)	Reference
Iran	Sesame seeds	269	50%	HPLC	TAF		1.43 ± 4.38	Hosseininia *et al.* 2014
Iran	Sesame seeds	269	50%	HPLC	AFB_1		1.25 ± 3.7	Hosseininia *et al.* 2014
Egyptian	Tahini (Brand)	16		HPLC	AFB_1		0.10 ± 0.2	Sebaei *et al.* 2020
Egyptian	Tahini (Local)	101		HPLC	AFB_1		13 ± 19.3	Sebaei *et al.* 2020
China	Sesame paste	100	37 (37%)	LC	TAF	0.54–56.89	6.75	Li *et al.* 2009
China	Sesame paste	100	37 (37%)	LC	AFB_1	0.39–20.45	4.31	Li *et al.* 2009
Iran	Sesame seeds	182	33 (18.1%)	LC	AFB_1		1.62 ± 1.32	Asadi *et al.* 2011
Malaysian	Sesame seeds	8	7 (87.5%)	ELISA	AFB_1	0.5–1.82	0.9	Reddy *et al.* 2011
Nigeria	Sesame seeds	60	12	LCMS/MS	TAF	0.29–88.5	16.9	Esan *et al.* 2020
Nigeria	Sesame seeds	60	12	LCMS/MS	AFB_1	0.29–79.3	14.8	Esan *et al.* 2020
Nigeria	Sesame seeds	30	26.66	HPLC	AFB_1	14.71–140.90	69.72 ± 41.68	Anthony *et al.* 2014
Turkey	Tahini	104	14.42	HPLC	AFB_1		0.93 ± 0.62	Torlak and Akan 2013
Turkey	Tahini	104	15.38	HPLC	TAF		1.17 ± 0.55	Torlak and Akan 2013
Turkey	Tahini Helva	34	0	TLC	AFB_1	<1	<1	Var *et al.* 2007
Egyptian	Sesame seeds	28	88.89	HPLC	AFB_1		33.66 ± 1.35	Sabry *et al.* 2016
FCT, Abuja, Nigeria	Sesame seeds	24	13	LCMS/MS	AFB_1		3.6	Fapohunda *et al.* 2018
Nigeria	Sesame seeds	46	23 (50%)	TLC	AFB_1	0.79–37.25		Apeh *et al.* 2016
Japan	Sesame seeds	47	5	HPTLC	AFB_1	0.6–2.4		Tabata 2007
Jordan	Sesame seeds	46	2	HPLC	TAF	100–1280		Sirhan *et al.* 2014
Greek	Sesame seeds	30	77.60%	HPLC	AFB_1		2.0 ng AFB1 g-1	Kollia *et al.* 2016

moisture content, heating temperature, and nutrient media. It has been reported that roasting dried wheat at 150°C for 30 min, Green coffee beans at 150°C to 180°C for 10 to 15 min, and Pistachio nuts at 150°C for 30 min will reduce AF levels to 50%, 42.2%–55/9%, and 63%, respectively (Pankaj *et al.*, 2018).

The prevalence of AFs in tahini halva

The results showed that tahini halva samples contained four types of AF, i.e., AFB_1, AFB_2, AFG_2, and AFG_2, with mean values of 0.55 ± 0.17, 0.07 ± 0.03, 0.04 ± 0.03, and 0.06 ± 0.03 μg/kg, respectively (Table 4). Except for AFB_2, the detection rate of AFB_1, AFG_2, and AFG_2 was lower in tahini halva samples than in the sesame seeds and tahini samples. The average total AFs of tahini halva samples was 0.72 ± 0.22 μg/kg. According to Iranian standards, the concentration of total AFs and AFB_1 was not higher than the allowable limit. In contrast, the total AFs level of two samples was higher than the limit of European regulations (4 μg/kg). Also, in six samples, the concentration of AFB_1 was higher than the limit of European regulations (2 μg/kg). The lower level of AFs in tahini halva could be related to the dilution effect of other products, including sugar, emulsifier, in the formulation. Few studies have been performed to evaluate AFs in tahini halva. Var *et al.* (2007) investigated AFB_1 contamination in 34 samples of helva in Turkey. No AFB_1 was found in helva samples. It seemed the discrepancies in AFs contamination prevalence in different studies could be due to differences in sampling geographical areas and storage conditions and the AFs measuring method.

Risk assessment of AFB1 intake

Findings of percentile 50 (as the median of the population) of EDI of AFB_1 calculated using the MCS approach showed the lowest (0.02 ng/kg bw/day) and highest (0.05 ng/kg bw/day) of EDI in sesame seed and tahini halva, respectively (Figure 1). The percentile 95 of EDI of AFB_1 through sesame seed, tahini, and tahini halva was 0.09, 0.05, and 0.03 ng/kg bw/day, respectively.

As shown in Figure 2, the percentile 95 of MOE with AFB_1 through sesame seed, tahini, and tahini halva was calculated as 25,485, 50,092, and 77,114, respectively. Because data

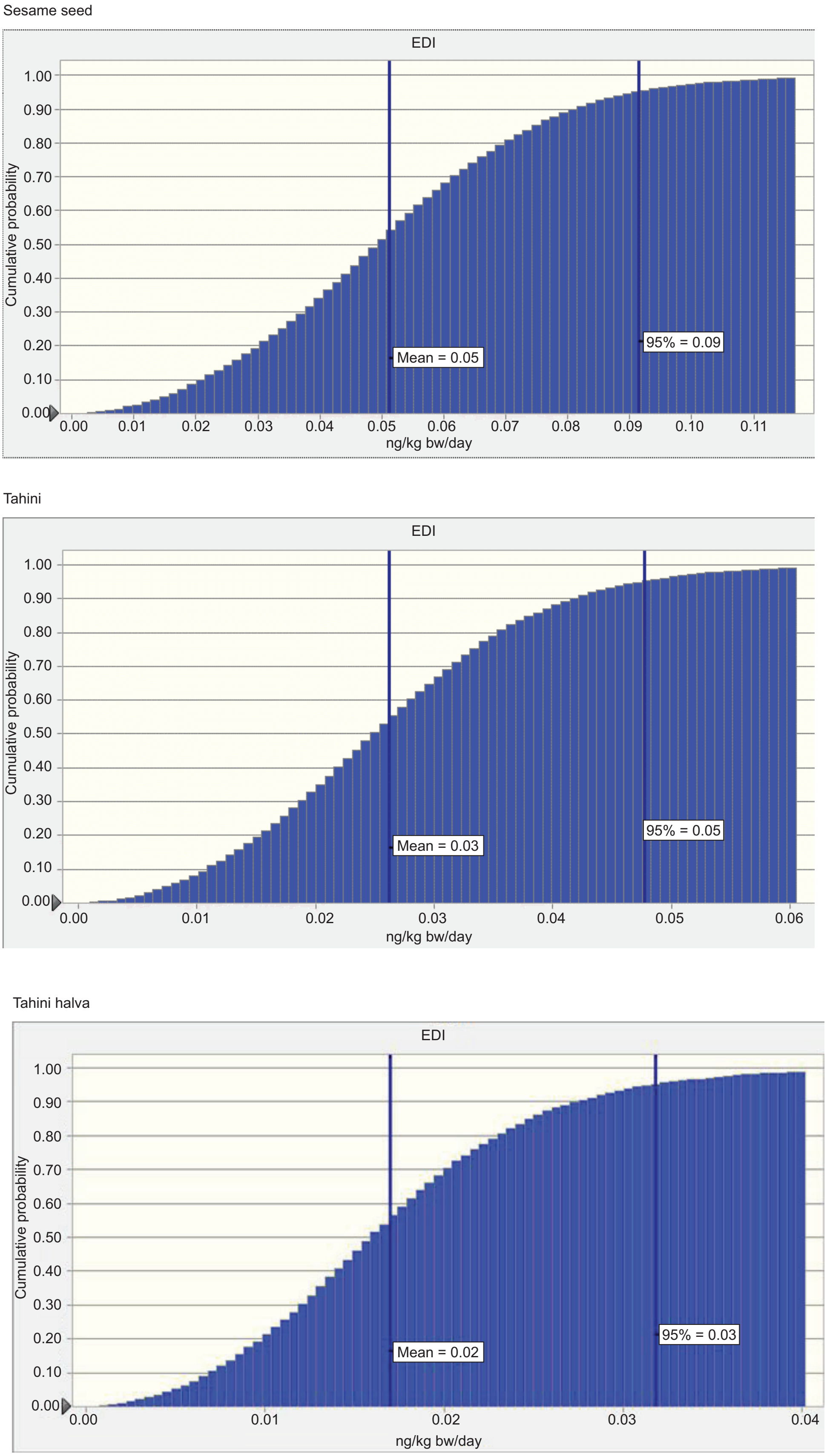

Figure 1. Cumulative probability plot of EDI of AFB1 through sesame seed, tahini, and tahini halva consumption.

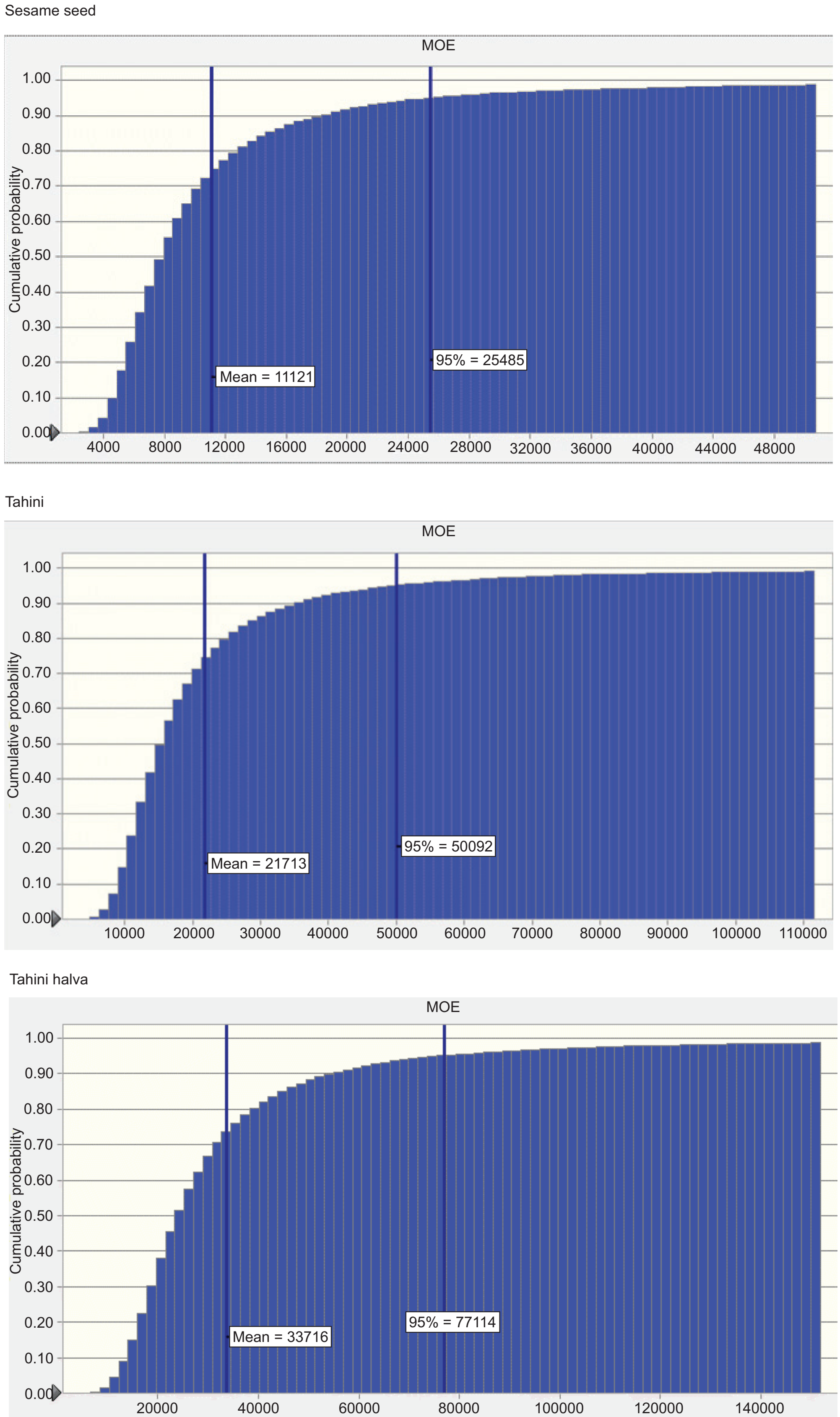

Figure 2. **Cumulative probability plot of MOE of AFB_1 through sesame seed, tahini, and tahini halva consumption.**

regarding the percentile 50 and 95 of MOE was more than 10,000 (Heshmati *et al.*, 2017), it could be concluded that AFB_1 intake through sesame seed, tahini, and tahini halva consumption has no remarkable cancer risk for adults.

Conclusions

The results of this study indicated the high prevalence of AFs in sesame seed (55%), tahini (45%), and tahini halva (32.5%) samples. In addition, the levels of TAF in 7 (17.5%), 8 (20%), and 2 (5%) samples of sesame seeds, tahini, and tahini halva exceeded the limit of European regulations (4 μg/kg), respectively. Furthermore, 10 (25%), 7 (17.5%), and 6 (15%) samples of sesame seeds, tahini, and tahini halva contained AFB_1 more than the limit of European regulations (2 μg/kg), respectively. However, risk assessment indicated that the intake of AF through the consumption of mentioned products had no remarkable cancer risk for adults.

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The ethical and scientific committee of Hamadan University of Medical Science approved this study (ethical code: IR.UMSHA.REC.1400.177).

Conflict of interest

The authors declare that they have no conflict of interest.

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