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Review

Toxigenic fungi and mycotoxin associated with figs in the Mediterranean area

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Summary. Figs are an economically important crop in the Mediterranean area. Fungal infection can be observed on figs on the tree, after shriveling, after falling to the ground, and during the drying process. Fungal growth and subsequent mycotoxin production are influenced by a variety of complex interactions between instrinsic and extrinsic factors as well as stress factors and physical damage. The dominant fungal flora in dried figs consisted of *Aspergillus* section *Nigri, Fusarium* spp., *Aspergillus* section *Flavi* and *Penicillium* spp. Fungal infection can result in mycotoxin contamination including aflatoxins, citrinin, cyclopiazonic acid, fumonisins, patulin and ochratoxin A. This review describes the major fungal infection and mycotoxin contamination in dried figs.

Key words: dried figs, aflatoxin, cyclopiazonic acid, fumonisin, ochratoxin A, endopsis.

Introduction

Fig (*Ficus carica* L.) is a highly valued fruit with high content of fiber and minerals and polyphenols. From the standpoint of cultural and pollination requirements, edible fig cultivars are divided into three horticultural categories, Smyrna, San Pedro and Common (Michailides, 2003).

Figs are an economically important crop in the Mediterranean area with Egypt, Turkey and Algeria being the main fig producing countries in the world. The fig production values for these countries are $135.9 million, $91.6 million, and $35.2 million, respectively (Table 1). Among the Mediterranean countries; Turkey, Spain and Greece are the top three dried fig exporting countries (Table 2) in the world (FAO, 2008).

Fig fruit is also consumed as dried fig, which is an important mineral and vitamin source (USDA, 2010). Regarding dried fig production, Turkey has been the top ranking country followed by Iran, Afghanistan and the United States of America in the world (FAO, 2008).

The properties of the growing stages of fig fruit differ from other fruits. Fungal infection might be observed in figs on the tree after the ripening of the fruit, after shriveling, after falling from the tree onto the ground and during the drying process. Both the skin and inner cavity of fig fruits can be contaminated by fungi (Codex Alimentarius Commission, 2007).

Fungal growth and subsequent mycotoxin production are influenced by a variety of complex interactions between instrinsic and extrinsic factors as well as stress factors and physical damage. Intrinsic factors include moisture content or water activity (a_w), pH, redox potential (E_h), nutrient content (substrate), inhibitors and osmotic pressure. Extrinsic factors are related to environmental conditions such as temperature, relative humidity (ERH) and gases in the environment. Factors promoting mycotoxin production can differ from mould to mould. Recently, effects of environmental factors, especially temperature, on aflatoxin (AF) biosynthetic genes were

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intensively studied. Light, nitrogen, carbon source, temperature and pH influence the regulation of AF biosynthesis (O'Brian *et al.*, 2007; Wilkinson *et al.*, 2007; Bhatnagar, *et al.*, 2008; Cary *et al.*, 2009; Cleveland *et al.*, 2009; Georgianna and Payne, 2009; Ehrlich and Bhatnagar, 2010).

Table 1. Fig producing countries in the world (FAO, 2008).

Rank	Area	Production (Int 1000$)	Production (MT)
1	Egypt	135885	304110
2	Turkey	91630	205067
3	Algeria	35181	78735
4	Morocco	31154	69723
5	Iran (Islamic Republic of)	25494	57057
6	Syrian Arab Republic	17990	40262
7	United States of America	17551	39281
8	Spain	11575	25906
9	Tunisia	11170	25000
10	Brazil	10082	22565
11	Afghanistan	8936	20000
12	Albania	8042	18000
13	Greece	7800	18000
14	Japan	7372	16500
14	Portugal	7372	16500
16	Italy	7104	15900
17	Azerbaijan	4727	10579
18	India	4691	10500
19	Libyan Arab Jamahiriya	4468	10000
20	Iraq	4232	9473

Water activity of figs during cultivation and processing is an important parameter related to toxigenic fungi and mycotoxin formation. Water activities for semidried figs on the tree, fallen figs collected from soil, figs taken from the drying stage and warehouses have been reported as 0.88–0.94; 0.76–0.87; 0.70–0.80 and 0.69–0.73 a_w, respectively (Karbancioglu-Güler and Heperkan, 2009). Semidried figs on the tree and fallen figs collected from soil can be considered as good substrate for mycotoxin formation regarding a_w values. Furthermore, it has been reported that the mycotoxin production begins on the tree (Heperkan, 2006). Even if the a_w values of the drying stage were found to be safe, rain or night dewing during drying can lead to increase moisture levels in dried figs. Further development of toxigenic fungi and mycotoxin production can be observed. Climatic conditions such as high humidity, moderate temperatures and sudden rains may also promote fungal growth (Karaca and Nas, 2006). In addition to the drying stage, storage is another important critical stage for mycotoxin production.

Several reports have shown that fig fruits are a high risk commodity with respect to toxigenic fungi and their mycotoxins. The dominant myco-flora in dried figs can vary widely, depending on different factors such as sampling stages, geographical areas, processing, and commercial varieties. The most common toxigenic fungi reported are *Aspergillus* section *Nigri, Fusarium* spp., *Aspergillus* section *Flavi* and *Penicillium* species (Heperkan, 2006). Other genera of molds were also found in Turkish dried figs such as

Table 2. Fig exporting Mediterranean countries.

Country	Production (tonnes)						
	2002	2003	2004	2005	2006	2007	2008
Turkey	35052	42081	49074	52595	54237	40101	33123
Spain	5540	3551	3377	3851	4143	3654	3509
Greece	2934	3279	2831	2527	3084	1595	1239
France	1104	945	1344	1495	1448	1186	856
Syrian Arab Republic	3227	1323	2898	2090	4077	2894	445
Italy	319	342	487	521	476	327	499

Acremonium, *Byssochlamys*, *Cladosporium*, *Trichoderma*, *Mucor* and *Scopulariopsis* (Zorlugenc *et al.*, 2008; Isman and Bıyık, 2009).

Extensive contamination of dried figs and fruits in the field caused by species belonging to genus *Fusarium* has been reported in Turkey (Karbancioglu-Güler and Heperkan, 2009). High levels of contamination of fresh and dried figs by *F. ramigenum* were also reported for the first time recently in Italy (Moretti *et al.*, 2010). Javanmard (2010) reported that the most frequent species in Iranian dried figs were *A. niger* agg. (90.9%), *A. flavus* (63.7%) and *Acremonium* spp. (54.6%). *Alternaria* spp. and *Penicillium* spp. were isolated at low percentages (9.1% of infection). The consequence of this fungal infection could be the possible occurrence and/or co-occurrence of several mycotoxins. In this respect figs have had the most notifications among the dried fruits (Figure 1). Dried figs from Turkey had the highest number of notifications for AF contamination according to the European Union Rapid Alert System for Food and Feed reports (EU RASFF). The major reason for notifications for figs was AF followed by ochratoxin A (OTA) (Figure 2).

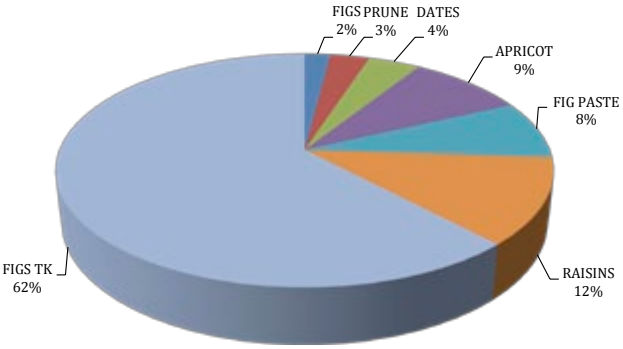

Figure 1. Dried fruits 2009 notifications (EU RASSF, 2009).

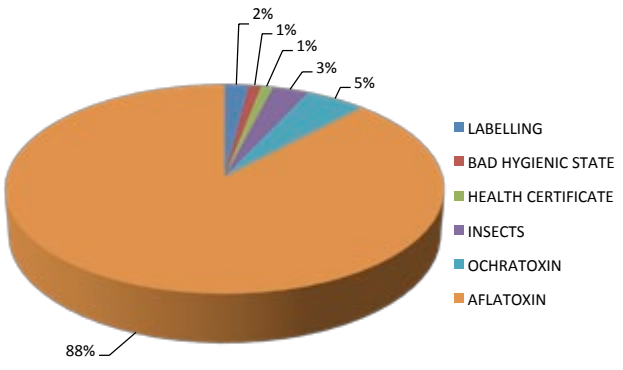

Figure 2. Reasons for notification of dried fruits (EU RASSF, 2009).

Aflatoxins and *Aspergillus* section *Flavi*

Members of *Aspergillus* section *Flavi* such as *Aspergillus flavus* and *A. parasiticus* are responsible for AF production in a great variety of foods for animal and human consumption. *A. nomius* is rarely found in foods (Bennett and Klich, 2003).

The fig fruit has a soft skin which can easily be physically damaged as well as decayed by fungi. Because of these characteristics of fig fruits, AF contamination often occurs (Codex Alimentarius Commission, 2007). Indeed, dried figs have been considered as a favorable for aflatoxigenic strains of *A. flavus* and *A. parasiticus* (Buchanan *et al.*, 1975; Boudra *et al.*, 1994; Iamanaka *et al.*, 2007). Aflatoxin contaminated figs may show bright greenish-yellow fluorescence (BGYF) under UV light (365 nm) (Steiner *et al.*, 1988). The AF levels of figs, showing BGYF are relatively high. Steiner *et al.* (1988) investigated the AF level of fluorescent figs and showed that the level of aflatoxin B_1 (AFB_1) and aflatoxin G_1 (AFG_1) ranged from 0.2 to > 10000 μg kg^{-1}. Karaca and Nas (2006) investigated fluorescent figs, as well. Aflatoxin contamination on fluorescent figs (total AFs: 117.9 – 471.9 μg kg^{-1}) was higher than unfluorescent figs (total AFs: 0.2 – 8.3 μg kg^{-1}).

Natural aflatoxin contamination in figs

Studies on natural aflatoxin contamination of dried figs are shown in Table 3. Turkish, high quality palatable figs, suitable for human consumption, were contaminated only with AFB_1 ranging from non-detectable to 0.2 μg kg^{-1} (Karaca and Nas, 2006). Out of 2643 fig samples from different exporting companies in Turkey, 313 (11.8%) were contaminated with detectable levels of four types of AF. Fifty-six and 50 of the contaminated samples were above EU regulatory limits for total aflatoxin (2.1–162.7 μg kg^{-1}) and AFB_1 (2.1–25.4 μg kg^{-1}), respectively (Bircan *et al.*, 2008a). Recently, AF contamination was investigated in 48 dried figs contaminated with *Aspergillus* section *Flavi* . Eleven of the 48 samples (23%) contained AF (Heperkan *et al.*, 2012a). Iamanaka *et al.* (2007) investigated AF contamination in dried figs

Table 3. Natural aflatoxin contamination in dried figs.

Origin	Mycotoxin	No. of positive sample/ No. of total sample	Range of mycotoxin (μg kg^{-1})	Reference
Cyprus	AF	16/110	<5–337	Gelosa , 1990
Morocco	AFB1 AFG1	1/20 5/20	0.28 0.28–32.9	Juan *et al*., 2008
Syria	AFB_1	2/4	2.5–11.8	Haydar *et al*., 1990
Turkey	AFB_1 AFG_1	52/62 21/62	0.2–>10000 0.2–>10000	Steiner *et al*.,1988
Turkey	AF	11/12	0.2–471.9	Karaca and Nas, 2006
Turkey	AF	313/2643	0.2–162.76	Bircan *et al*., 2008a
Turkey	AF	1575/4917	0.2–259.46	Bircan *et al*., 2008b
Turkey	AF	7/98	0.23–4.28	Bircan, 2009
Turkey	AF	11/48	0.3–763.3	Heperkan, *et al*., 2012a
USA	AF	12/31	1–77200	Doster *et al*., 1996
Yemen	AFB_1	2/20	120–250	Alghalibi and Shater, 2004
Worldwide	AFB_1 AFB_2	11/19	0.3–1500	Iamanaka *et al*., 2007

sold in Brazil. Out of 19 samples, ten were contaminated with AFB_1 and AFB_2 with 0.3–2 μg $kg^{-1}$and one was contaminated with 1500 μg kg^{-1} AFB_1. The AF contamination level ranged from 0.2 to >10,000 μg kg^{-1} in dried figs from Mediterranean countries; the lowest contamination levels were observed on dried figs from Syria and Morocco.

Aflatoxins have 20 different derivatives. However, only AFB_1, AFB_2, AFG_1, and AFG_2 generally contaminate a wide variety of foods and feeds. Among them, AFB_1 has been reported as the most toxigenic type and classified as a Group 1 carcinogen by the International Agency of Research on Cancer (IARC, 1993). Since AFs are carcinogenic, high amounts of AF contamination can make dried figs hazardous from the public health point of view. The maximum levels of AFs, legislated by the European Commission are 2 μg kg^{-1} for AFB_1 and 4 μg kg^{-1} for total AFs in dried fruits and 5 μg kg^{-1} for AFB_1 and 10 μg kg^{-1} for total AFs in dried fruits subject to sorting or other physical treatment before human consumption or use as an ingredient in foodstuffs (European Commision, 2010). The maximum AF level of various foods including figs, legislated by the Turkish Food Codex (2009), is 10 μg kg^{-1}.

Mycotoxigenic characteristics of *Aspergillus* section *Flavi*

Mycotoxigenic characteristics and prevalence of toxigenic fungi in figs also have been investigated (Doster and Michailides, 1998; Heperkan and Karbancioglu-Güler, 2009). Steiner *et al.* (1988) indicated that *A. flavus* and *A. parasiticus* were isolated frequently in dried figs, but *A. fumigatus* and *A. niger* were found only in very rare cases. Moreover, the highest levels of *Aspergillus* growth have been observed in fluorescent figs. Heperkan (2006) reported *A. flavus* and *A. parasiticus* contamination in fig samples after harvesting with values of 41% for ripe fig samples, 42% for sun dried fig samples, 33% for fig samples obtained from various store houses, 25% for fig samples from different processing plants and 25% for fig paste samples. *A. flavus* was determined to be the dominant species and *A. parasiticus* was rare among the *Aspergillus* section *Flavi* members for the dried fig samples (Heperkan and Karbancioglu-Güler, 2009; Isman and Bıyık, 2009). Ninety-eight percent of *A. flavus* isolates from figs produced AF and/or cyclopiazonic acid (CPA) and all of the *A.*

parasiticus isolates produced AF (Heperkan *et al*., 2012b). Iamanaka *et al.* (2007) isolated one *A. flavus* isolate, a producer of AFB_1 and AFB_2, from 19 dried fig samples (2%).

Effects of climatic conditions on AF production in figs also have been discussed in the literature. Haydar *et al.* (1990) indicated that the humid summer and rainy winter in the Mediterranean coastal regions of Syria may support AF production. The temperatures in fig cultivation areas in Turkey (16.5–35.5°C) might be suitable for AF production in fig fruits (Turkish State Meteorological Service, 2010). The climatic conditions of Morocco also include high humidity and temperature and these conditions might contribute to AF occurrence and production (Juan *et al*., 2008). Climatic conditions also can affect the type of AF production. Lin *et al.* (1980) reported that AFB_1 and AFG_1 production by *A. parasiticus* is stimulated at higher temperatures (33°C) and lower temperatures (25°C), respectively. The geography of cultivation also affects the mycoflora of figs which plays a major role in the type of mycotoxin produced. It was reported that *A. tamarii*, producing CPA, occurs at low levels in Turkish dried figs (1/115) (Heperkan and Karbancioglu-Güler 2009), whereas Doster and Michailides (1998) reported that *A. tamarii* contamination is approximately at the same level of *A. flavus* in figs from California.

Toxigenic fungi in naturally contaminated dried figs might differ in level and the types of AF production. *A. parasiticus* and *A. nomius* produce all four types of AF whereas most toxigenic *A. flavus* strains produce AFB_1, AFB_2 and CPA (Vaamonde *et al*., 2003; Pitt and Hocking, 2009). However AFG production by some isolates of *A. flavus* has been reported (Pildain *et al*., 2004; Giorni *et al*., 2007).

Ochratoxin A and *Aspergillus* section *Nigri*

Figs are suitable not only for growth of aflatoxigenic moulds but also for ochratoxin-producing black *Aspergilli*. Ochratoxin A is another important mycotoxin occurring in figs. Ochratoxin A is produced mainly by three species of fungi: *Penicillium verrucosum*, *A. carbonarius* and *A. ochraceus*. In addition to these fungi, only a few strains of *A. niger* can produce OTA (Aish *et al*., 2004; Battilani *et al*., 2006). *Penicillium verrucosum* is the major producer of OTA in cereals grown in temperate climates (Frisvad *et al*., 2006; Pitt and Hocking, 2009). *Aspergillus carbonarius* is another important OTA producer, occuring in grapes and grape products, including juices and wines (Leong *et al*., 2006). A*spergillus carbonarius* and *A. niger* also were reported as sources of OTA in maturing and drying grapes in Italy (Battilani *et al*., 2003) and in dried vine fruits from Argentina (Magnoli *et al*., 2004). *A. ochraceus* can occur in cereals and coffee beans and is responsible for the production of OTA on these products (Taniwaki, 2006). Both *P. verrucosum* and *A. ochraceus* were rarely found in Turkish dried figs. Major OTA producers in figs were species of *Aspergillus* section *Nigri* such as *A. carbonarius* and *A. niger* (Karbancioglu-Güler and Heperkan, 2008). Iamanaka *et al.* (2005) isolated 43 isolates of *A. niger* from dried figs sold in Brazil, but no *A. ochraceus* was isolated from these samples. Since the members of *Aspergillus* section *Nigri* are xerotolerant, the drying process can create a selective and suitable environment for these fungi; while the moisture content decreases, the sugar content increases (Abarca *et al*., 2003; Samson *et al*., 2006; Zinedine *et al*., 2007). Moreover, *A.carbonarius* and *A. niger* have tolerance against ultraviolet C (UVC) due to their melanin content in the cell walls (Pitt and Hocking, 1997; Valero *et al.* 2007). This trait could make them dominant in fruits exposed to sun-drying (Valero *et al*., 2005). It has been reported that the occurrence of *Aspergillus* section *Nigri* was 64% in figs fallen on the ground, 75% at the drying stage and 100% in samples obtained from storage during processing and from fig paste (Heperkan, 2006).

Natural ochratoxin A contamination in figs

Several reports have shown that dried figs can be contaminated with OTA. Karbancıoğlu-Güler and Heperkan (2008) reported OTA contamination in 46.5% and 50% of 115 samples of dried figs collected from orchards in a two year study in Turkey, with a maximum concentration of 15.3 μg kg^{-1} of OTA. In another study, 98 dried fig samples collected before packaging from different exporting companies were investigated (Bircan, 2009). Eighteen of the samples were contaminated with OTA (0.87–24.37 μg kg^{-1}) (Bircan, 2009). High OTA contamination (60–120 μg kg^{-1}) was reported in dried figs from Egypt (Zohri and Abdel-Gawad, 1993). Iamanaka *et al.* (2005) investigated dried figs obtained from Brazil markets,

showing that almost all of them were contaminated with OTA. In dried figs from Morocco, OTA prevalence has been reported as 65% with levels up to 1.42 μg kg^{-1} (Zinedine *et al.*, 2007). Studies on natural OTA and other mycotoxin contamination in dried figs are shown in Table 4. The OTA contamination level varies from 0.03 to 120 μg kg^{-1} on dried figs from Mediterranean countries.

Ochratoxin A is nephrotoxic, immunosuppressive, teratogenic and carcinogenic (Barkai-Golan., 2008), and it has been related with Balkan Endemic Nephropathy (BEN). High OTA contamination has been observed in human blood samples and food samples which were taken from the region of BEN endemic areas (Hult *et al.*, 1982; Vrabcheva *et al.*, 2000). Ochratoxin A has been considered as a potential carcinogen (Group 2B) (JECFA, 2001). The European Food Safety Agency (EFSA) has established Tolerable Weekly Intake (TWI) to be 120 ng per kg body weight for OTA (EFSA, 2006). Regarding the negative impact of OTA on human health, many countries have regulated OTA in foodstuffs. There is no regulation for OTA in dried figs issued by the European Commission, whereas the maximum limit for OTA in dried vine fruits has been set at 10 μg kg^{-1} (European Commission, 2006). Turkish Food Codex has set the maximum limit for OTA in potential OTA-contaminated foods at 10 μg kg^{-1} (Turkish Food Codex, 2008). However, in Germany the maximum limit for OTA in dried figs was 8 μg kg^{-1} (Bundesgesetzblatt Jahrgang, 2004).

Even if the incidence and level of OTA is low, these findings revealed the potential risk for OTA contamination in dried figs.

Mycotoxigenic characteristics of *Aspergillus* section *Nigri*

The ochratoxigenic species belonging to *Aspergillus* section *Nigri* have been reported in regions with warmer or tropical climates; they are able to grow on various substrates and to tolerate diverse conditions of moisture, pH and temperature (Abarca *et al.* 2001). The high frequency of *Aspergillus* section *Nigri* species in grapes from specific regions of Europe or during certain seasons, was explained by the hot and dry weather in southern latitudes (Hocking *et al.*, 2007). The mean temperature in the Bari province, which is an important grape cultivation area in South Italy, has been reported as 16.6–25.8°C for July, 19.1–28.4°C

Table 4. Natural ochratoxin A and other mycotoxin contamination in dried figs.

Origin	Mycotoxin	No. of positive sample/ No. of total sample	Range of Mycotoxin (μg kg^{-1})	Reference
Egypt	OTA	4/4	60–120	Zohri and Abdel-Gawad,1993
Morocco	OTA	13/20	0.03–1.42	Zinedine *et al.*, 2007
Turkey	OTA	3/103	5.2–8.3	
Turkey	OTA	55/115	0.12–15.31	Karbancıoğlu-Güler and Heperkan, 2008
Turkey	OTA	18/98	0.87–24.37	Bircan, 2009
USA	OTA	11/15	<10–9600	Doster *et al.*, 1996
Yemen	OTA	2/20	70–160	Alghalibi and Shater,2004
Worldwide	OTA	18/19	0.1–30	Iamanaka *et al.*, 2005
Egypt	CIT	1/10	60	Aziz and Moussa, 2002
Turkey	CPA	28/48	23–187	Heperkan *et al.*, 2012a
Turkey	FB_1	86/115	46–3649	Karbancıoğlu-Güler and Heperkan, 2009
Turkey	PAT	12/12	4.8–151.6	Karaca and Nas, 2006

for August and 16.5–25.4°C for September for a 30-year period between 1961–1990 (World Meteorological Organization, 2010). High temperatures may also be associated with *Aspergillus* section *Nigri* species on fig fruits. In Turkey, the temperature range of the Aydın province, an important fig cultivation area, has been 20.0–35.5°C for August (mean 27.4°C) and 16.5–31.9°C for September (mean 23.3°C) during the harvesting period between 1975–2008 (Turkish State Meteorological Service, 2010). The optimum temperature for mould growth and OTA production for *A. carbonarius* and *A. niger* isolated from European samples were reported as 30–35°C and 15–25°C, respectively (Belli *et al*., 2004a; Belli *et al*., 2004b; Esteban *et al*., 2004; Mitchell *et al*., 2004; Belli *et al*., 2005). As far as the temperature effect on *Aspergillus* section *Nigri* is concerned, temperature conditions of the Bari and Aydın province may provide a favorable environment for the growth of ochratoxigenic *Aspergillus* species and the production of OTA (Karbancıoglu-Güler and Heperkan, 2008; Bircan, 2009).

In addition to OTA production, members of *Aspergillus* section *Nigri* can lead to decay in figs called fig smut (Doster *et al*., 1996). Infection by fungi that cause fig smut, occurs on injured figs regardless of the stage of the fruit development (Subbarao and Michailides, 1996). Doster and Michailides (2007) identified isolates obtained from decayed main crop figs in California and reported the major cause of fig smut as *A. niger* (98.5%), followed by *A. japonicus* (0.9%) and *A. carbonarius* (0.6%). Regarding favorable temperatures for these species, they are able to grow well during the summer period in California (Doster and Michailides, 2007).

Fumonisins and *Fusarium* species

Fumonisin (FUM) contamination is very common in grains and grain-based products including maize and sorghum (Weidenbörner, 2001; Jackson and Jablonski, 2004; Scaff and Scussel, 2004). Fumonisins have also been detected in a wide number of products such as asparagus (Logrieco *et al*., 1998; Waskiewicz *et al*., 2010), rice (Abbas *et al*., 1998), black tea (Omurtag and Yazıcıoglu, 2004), pine nuts (Marin *et al*., 2007) and incaparina (Trucksess *et al*., 2002). A wide contamination by *Fusarium* species has been reported in dried figs in Turkey and fig fruits in Italy (Heperkan, 2006; Moretti *et al*., 2010). Seventy four point seven percent of the dried fig samples collected from the Aegean Region in Turkey were contaminated with fumonisin B_1 (FB_1) at levels up to 3.649 $\mu g\ g^{-1}$. Although, dried figs were mostly contaminated with AFs (12–58%) and OTA (18–47%), the number of samples contaminated with FUM was higher than the number of samples contaminated with other mycotoxins. Therefore fumonisins are more common mycotoxins than others in Turkish figs (Karbancioglu-Guler and Heperkan, 2009).

Members of the genus *Fusarium*, especially *F. verticillioides* and *F. proliferatum,* are commonly reported FUM producers (Desjardins, 2006; Marasas, 2001; Wang *et al*., 2010). However, recently, new species have been reported to produce fumonisins: *F. ramigenum* (Moretti *et al*., 2010) and *F. oxysporum* (Waskiewicz *et al*., 2010).

The occurrence of *Fusarium* species on figs has been related to fig endosepsis, a serious disease of figs, so called for the internal fruit rot (Subbarao and Michaillides, 1993; Michailides *et al*., 1996; Logrieco *et al*., 2003). Endosepsis has been observed in California, Greece, Turkey and other areas where the Smyrna variety of fig is cultivated (Michailides *et al*., 1996; Michailides, 2003). *Fusarium verticillioides* (syn. *F. moniliforme*) and *F. solani* were reported as the causative agents of endosepsis for cultivated and wild caprifigs collected in California and figs produced in Turkey (Subbarao and Michaillides, 1993; Yıldız *et al*., 2008). However, in both studies, the identification of *Fusarium* strains was based on morphological characters only, therefore the strains isolated from figs might have been incorrectly identified. O'Donnell *et al*. (1998) re-evaluated strains from Californian figs that were previously identified by Subbarao and Michailides (1993) as *F. moniliforme,* and identified these strains as *F. ramigenum* or *F. lactis. Fusarium lactis* and *F. ramigenum* are morphologically and genetically closely related (Leslie and Summerell, 2006; O'Donnell *et al*., 1998). Finally, Moretti *et al.* (2010) isolated 72 strains of *F. ramigenum*, 49 strains of *F. solani* and 5 strains of *F. proliferatum* from fig samples having endosepsis-like symptoms, collected in the Apulia region of Italy. They reported that *F. ramigenum* showed higher virulence compared to the other *Fusarium* species isolated.

The fumonisins can be divided into four series A, B, C and P (Nielsen *et al*., 2009). Among these series, fumonisin B_1 (FB_1) is most abundant in agricultural commodities followed by FB_2 and FB_3. Fumonisin B_2 (Frisvad *et al*., 2007), FB_4 (Logrieco *et al*., 2009;

Noonim *et al*., 2009) and FB_6 (Mansson *et al*., 2010) are produced by *A. niger*. In addition to FUM contamination due to *Fusarium* species, *A. niger* strains present, can also participate to FUM contamination in dried figs. In fact, FB_2 production by *A. niger* isolated from dried figs has been reported recently (Daskaya and Heperkan, 2010).

Fumonisins have a negative impact on human and animal health, since they are related to several diseases such as leukoencephalamomacia in horses, pulmonary edema and hydrothorax in pigs, cancer in experimental animals, neural tube defects and esophoegal cancer in humans (Desjardin, 2006). Due to its toxicity, IARC has classified FUM as a potential carcinogenic agent (group 2B) (IARC, 1993). Therefore occurrence of FUM can make dried figs hazardous in terms of mycotoxins. European Commission Scientific Committee on Food has determined the tolerable daily intake for fumonisins as 2 μg kg^{-1} body weight (EC, 2005). However, the limits of FUM contamination in food commodities have been established by the European Commission Scientific Committee on Food (EC, 2007) only for maize and maize by-products, since very little information is available on other commodities, including fruits.

Other mycotoxins and related fungi

Fig fruits may also contain other mycotoxins such as citrinin (CIT), patulin (PAT) and CPA at different levels. Studies on natural mycotoxin contamination in dried figs are shown in Table 4. There are limited studies on mycotoxins present in dried figs apart from AFs, OTA, and fumonisins.

Natural PAT contamination has been reported in dried figs from Turkey. Patulin contamination was observed in physically damaged cull figs only. The mean level of PAT contamination was 80 μg kg^{-1} which was above the legislated limit by the European Commission for fruit juices (50 μg kg^{-1}) (EC, 2006). However, in another study on figs from Egypt, PAT contamination was not detected. Citrinin was found only at low incidence rates (Aziz and Moussa, 2002). Aflatoxin and for the first time, CPA, contamination were investigated in dried fig samples contaminated by *Aspergillus* section *Flavi*. Higher incidence of CPA than AF was reported (Heperkan *et al*., 2012a). All aflatoxin-producing *A. flavus* strains produced CPA in figs with an average occurrence of 75% (Heperkan and Karbancioglu-Güler, 2009). Therefore the origin of CPA in Turkish figs has been considered to be *A. flavus,* not *Penicillium* spp. or *A. tamarii*.

Prevention of mycotoxin contamination in dried figs

Several methods have been developed in order to control growth of mycotoxigenic fungi and prevent mycotoxin contamination in agricultural products. However, studies on fig are limited and summarized below. Using sodium bisulphate or sulphur dioxide alone or in combination with hydrogen peroxide degrades AF in dried figs (Altug *et al*., 1990). However, the toxicological aspects of these agents should not be overlooked. The influence of ozone treatment on dried fig microflora has been investigated. Ozone treatment in gaseous phase for 3 hours at 5 μg kg^{-1} reduced yeast and mould contamination approximately 72% (Oztekin *et al*., 2006). In another study both gaseous ozone (13.8 μg L^{-1}) and ozonated water (1.7 μg L^{-1}) treatment of dried figs for 15 min. inactivated molds completely and caused 95.21% and 88.62% reductions in AFB_1 level, respectively (Zorlugenç *et al*., 2008). Alkalinization (pH=10) combined with heat treatment of dried figs also has been reported as an effective degradation method. Degradation of AFB_1 and AFG_1 were 97 and 100% at 98°C and 50°C, respectively by this method. However, the breakdown products were not identified (Karaca and Nas, 2009). UV irradiation (365 nm wavelength) has been reported as another way to reduce AF contamination in dried figs, depending on the time of exposure to the UV treatment (60, 90, 120 min). Ninety min of UV irradiation caused a decrease of 25% in the AF in dried figs (Isman and Bıyık, 2009).

Aflatoxin, CIT, CPA, FUM, PAT and OTA have been found in dried figs. Some of them, such as fumonisins, are mainly produced on the tree in the orchards and may increase in the initial stages of drying. *Fusarium* needs high water activity to grow and produce fumonisins (a_w>0.93), therefore FUM levels could not be expected to increase after the drying stage. The levels of other mycotoxins are low in the drying stage, but they can increase during the following stages: transportation, storage and processing if the conditions are favorable. Therefore mycotoxins can be controlled by utilizing effective measures in the orchards and during transportation, storage and processing. Although the presence of mould does not always indicate the presence of mycotoxins,

it indicates a mycotoxin hazard. We would also like to emphasize that the mould flora and the presence of mycotoxigenic moulds should be determined in samples collected from the orchards, to control mycotoxins. Control of mycotoxin contamination can be achieved by intensive work among different disciplines. In addition to technological methods, good agricultural practices (GAP), good hygiene practices (GHP) and hazard analysis critical control points (HACCP) systems must be implemented.

The highest total mold count was observed in Iranian fig samples obtained from collection sites and sun-drying locations with poor hygienic conditions (Javanmard, 2010). The lowest total mold count was observed in manually harvested samples. This emphasizes the importance of good agricultural practices. According to Codex Alimentarus Report (2008), as the fig fruits fall from the trees onto the ground, they must be collected daily to decrease AF contamination.

Some processing plants have been removing the figs that show BGYF under UV light, along with mouldy and defective figs. This method is especially effective to remove AF-and CPA-contaminated figs having BGYF . Many moulds do not show BGYF under UV light, therefore this application can not be effective to eliminate figs contaminated with OTA, FUM and other mycotoxins.

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