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 intrinsic 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, patulin, 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 intrinsic 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...
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).

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 aw, 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 aw values. Furthermore, it has been reported that the mycotoxin production begins on the tree (Heperkan, 2006). Even if the aw 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 (Karakaya 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 1. Fig producing countries in the world (FAO, 2008).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Area</th>
<th>Production (Int 1000$)</th>
<th>Production (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Egypt</td>
<td>133885</td>
<td>304110</td>
</tr>
<tr>
<td>2</td>
<td>Turkey</td>
<td>91630</td>
<td>205067</td>
</tr>
<tr>
<td>3</td>
<td>Algeria</td>
<td>35181</td>
<td>78735</td>
</tr>
<tr>
<td>4</td>
<td>Morocco</td>
<td>31154</td>
<td>69723</td>
</tr>
<tr>
<td>5</td>
<td>Iran (Islamic Rep.of)</td>
<td>25494</td>
<td>57037</td>
</tr>
<tr>
<td>6</td>
<td>Syrian Arab Republic</td>
<td>17990</td>
<td>40262</td>
</tr>
<tr>
<td>7</td>
<td>United States of America</td>
<td>17551</td>
<td>39281</td>
</tr>
<tr>
<td>8</td>
<td>Spain</td>
<td>11575</td>
<td>25906</td>
</tr>
<tr>
<td>9</td>
<td>Tunisia</td>
<td>11170</td>
<td>25000</td>
</tr>
<tr>
<td>10</td>
<td>Brazil</td>
<td>10082</td>
<td>22565</td>
</tr>
<tr>
<td>11</td>
<td>Afghanistan</td>
<td>8936</td>
<td>20000</td>
</tr>
<tr>
<td>12</td>
<td>Albania</td>
<td>8042</td>
<td>18000</td>
</tr>
<tr>
<td>13</td>
<td>Greece</td>
<td>7800</td>
<td>18000</td>
</tr>
<tr>
<td>14</td>
<td>Japan</td>
<td>7372</td>
<td>16500</td>
</tr>
<tr>
<td>15</td>
<td>Portugal</td>
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<td>16500</td>
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<td>16</td>
<td>Italy</td>
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<td>15900</td>
</tr>
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<td>17</td>
<td>Azerbaijan</td>
<td>4727</td>
<td>10579</td>
</tr>
<tr>
<td>18</td>
<td>India</td>
<td>4691</td>
<td>10500</td>
</tr>
<tr>
<td>19</td>
<td>Libyan Arab Jamahiriya</td>
<td>4468</td>
<td>10000</td>
</tr>
<tr>
<td>20</td>
<td>Iraq</td>
<td>4232</td>
<td>9473</td>
</tr>
</tbody>
</table>

Table 2. Fig exporting Mediterranean countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2002</td>
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<tr>
<td>Turkey</td>
<td>35052</td>
</tr>
<tr>
<td>Spain</td>
<td>5540</td>
</tr>
<tr>
<td>Greece</td>
<td>2934</td>
</tr>
<tr>
<td>France</td>
<td>1104</td>
</tr>
<tr>
<td>Syrian Arab Republic</td>
<td>3227</td>
</tr>
<tr>
<td>Italy</td>
<td>319</td>
</tr>
</tbody>
</table>
Toxigenic fungi and mycotoxin associated with figs

Acremonium, Byssoschlamys, Cladosporium, Trichoderma, Mucor and Scopulariopsis (Zorlugenc et al., 2008; Isman and Biyk, 2009).

Extensive contamination of dried figs and fruits in the field caused by species belonging to genus Fusarium has been reported in Turkey (Karbancio glu-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).

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 B₁ (AFB₁) and aflatoxin G₁ (AFG₁) 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 AFB₁ 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 AFB₁ (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.
sold in Brazil. Out of 19 samples, ten were contaminated with AFB1 and AFB2 with 0.3–2 μg kg\(^{-1}\) and one was contaminated with 1500 μg kg\(^{-1}\) AFB1. 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 AFB1, AFB2, AFG1, and AFG2 generally contaminate a wide variety of foods and feeds. Among them, AFB1 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 AFB1 and 4 μg kg\(^{-1}\) for total AFs in dried fruits and 5 μg kg\(^{-1}\) for AFB1 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 Commission, 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. flavus* isolates from figs produced AF and/or cyclopiazonic acid (CPA) and all of the *A.

### Table 3. Natural aflatoxin contamination in dried figs.

<table>
<thead>
<tr>
<th>Origin</th>
<th>Mycotoxin</th>
<th>No. of positive sample/ No. of total sample</th>
<th>Range of mycotoxin (μg kg(^{-1}))</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyprus</td>
<td>AF</td>
<td>16/110</td>
<td>&lt;5–337</td>
<td>Gelosa, 1990</td>
</tr>
<tr>
<td>Morocco</td>
<td>AFB1</td>
<td>1/20</td>
<td>0.28</td>
<td>Juan et al., 2008</td>
</tr>
<tr>
<td></td>
<td>AFG1</td>
<td>5/20</td>
<td>0.28–32.9</td>
<td></td>
</tr>
<tr>
<td>Syria</td>
<td>AFB1</td>
<td>2/4</td>
<td>2.5–11.8</td>
<td>Haydar et al., 1990</td>
</tr>
<tr>
<td>Turkey</td>
<td>AFB1</td>
<td>52/62</td>
<td>0.2–&gt;10000</td>
<td>Steiner et al., 1988</td>
</tr>
<tr>
<td></td>
<td>AFG1</td>
<td>21/62</td>
<td>0.2–&gt;10000</td>
<td></td>
</tr>
<tr>
<td>Turkey</td>
<td>AF</td>
<td>11/12</td>
<td>0.2–471.9</td>
<td>Karaca and Nas, 2006</td>
</tr>
<tr>
<td>Turkey</td>
<td>AF</td>
<td>313/2643</td>
<td>0.2–162.76</td>
<td>Bircan et al., 2008a</td>
</tr>
<tr>
<td>Turkey</td>
<td>AF</td>
<td>1575/4917</td>
<td>0.2–259.46</td>
<td>Bircan et al., 2008b</td>
</tr>
<tr>
<td>Turkey</td>
<td>AF</td>
<td>7/98</td>
<td>0.23–4.28</td>
<td>Bircan, 2009</td>
</tr>
<tr>
<td>USA</td>
<td>AF</td>
<td>12/31</td>
<td>1–77200</td>
<td>Doster et al., 1996</td>
</tr>
<tr>
<td>Yemen</td>
<td>AFB1</td>
<td>2/20</td>
<td>120–250</td>
<td>Alghalibi and Shater, 2004</td>
</tr>
<tr>
<td>Worldwide</td>
<td>AFB1</td>
<td>11/19</td>
<td>0.3–1500</td>
<td>Iamanaka et al., 2007</td>
</tr>
</tbody>
</table>
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, 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 (Vaanonde 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; Battiliani 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, occurring in grapes and grape products, including juices and wines (Leong et al., 2006). Aspergillus carbonarius and A. niger also were reported as sources of OTA in maturing and drying grapes in Italy (Battiliani 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. Karbancioğlu-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.

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

<table>
<thead>
<tr>
<th>Origin</th>
<th>Mycotoxin</th>
<th>No. of positive sample/No. of total sample</th>
<th>Range of Mycotoxin (μg kg⁻¹)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egypt</td>
<td>OTA</td>
<td>4/4</td>
<td>60–120</td>
<td>Zohri and Abdel-Gawad, 1993</td>
</tr>
<tr>
<td>Morocco</td>
<td>OTA</td>
<td>13/20</td>
<td>0.03–1.42</td>
<td>Zinedine et al., 2007</td>
</tr>
<tr>
<td>Turkey</td>
<td>OTA</td>
<td>3/103</td>
<td>5.2–8.3</td>
<td></td>
</tr>
<tr>
<td>Turkey</td>
<td>OTA</td>
<td>55/115</td>
<td>0.12–15.31</td>
<td>Karbancıoğlu-Güler and Heperkan, 2008</td>
</tr>
<tr>
<td>Turkey</td>
<td>OTA</td>
<td>18/98</td>
<td>0.87–24.37</td>
<td>Bircan, 2009</td>
</tr>
<tr>
<td>USA</td>
<td>OTA</td>
<td>11/15</td>
<td>&lt;10–9600</td>
<td>Doster et al., 1996</td>
</tr>
<tr>
<td>Yemen</td>
<td>OTA</td>
<td>2/20</td>
<td>70–160</td>
<td>Alghalibi and Shater, 2004</td>
</tr>
<tr>
<td>Worldwide</td>
<td>OTA</td>
<td>18/19</td>
<td>0.1–30</td>
<td>Imanaka et al., 2005</td>
</tr>
<tr>
<td>Egypt</td>
<td>CIT</td>
<td>1/10</td>
<td>60</td>
<td>Aziz and Moussa, 2002</td>
</tr>
<tr>
<td>Turkey</td>
<td>CPA</td>
<td>28/48</td>
<td>23–187</td>
<td>Heperkan et al., 2012a</td>
</tr>
<tr>
<td>Turkey</td>
<td>FB₁</td>
<td>86/115</td>
<td>46–3649</td>
<td>Karbancıoğlu-Güler and Heperkan, 2009</td>
</tr>
<tr>
<td>Turkey</td>
<td>PAT</td>
<td>12/12</td>
<td>4.8–151.6</td>
<td>Karaca and Nas, 2006</td>
</tr>
</tbody>
</table>

### 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
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 Aydin 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 Aydin province may provide a favorable environment for the growth of ochratoxigenic Aspergillus species and the production of OTA (Karbancioglu-Guler and Heperkan, 2008; Bircan, 2009).

In addition to OTA production, members of Aspergillus section Nigri can lead to decay in figs caused by 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**

Fumonisins (FUM) contamination is very common in grains and grain-based products including maize and sorghum (Weidenbörner, 2001; Jackson and Jablonski, 2004; Saff 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 incarparina (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 B1 (FB1) at levels up to 3.649 μg 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; Michaillides 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; Yildiz 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 Michaillides (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 B₁ (FB₁) is most abundant in agricultural commodities followed by FB₂ and FB₃. Fumonisin B₂ (Frisvad et al., 2007), FB₄ (Logrieco et al., 2009;
Noonim et al., 2009) and FBs (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, FBs 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 leukoencephalomalacia in horses, pulmonary edema and hydrothorax in pigs, cancer in experimental animals, neural tube defects and esophageal 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 callus 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 AFB1 level, respectively (Zorlugenç et al., 2008). Alkalization (pH=10) combined with heat treatment of dried figs also has been reported as an effective degradation method. Degradation of AFB1 and AFG1 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 (aw>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 Alimentarius 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.

Acknowledgements

We wish to thank to FP7 EU Project MycoRed (GA222690) for giving the opportunity to spending a short term visit in CNR-ISPA laboratory and to prepare this review article.

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*Accepted for publication: April 29, 2011*