

Review

Mycotoxin risks and toxigenic fungi in date, prune and dried apricot among Mediterranean crops

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Summary. Dried fruit is fruit that is preserved by removing the original water content naturally, through sun drying or artificially, by the use of specialized dryers or dehydrators. Dried fruit has a long tradition of use dating back to the fourth millennium BC in Mesopotamia and is prized because of its sweet taste, nutritive value and long shelf life. Traditional dried fruits such as raisins, figs, dates, apricots and prunes have been a staple of Mediterranean diets for millennia. The Mediterranean region is very favourable for production of dried fruits, not only with its climatic conditions, but also its exceptional fertile lands. Additionally, proximity to trade routes historically has allowed Mediterranean countries more access to dried fruits than landlocked countries. Today, dried fruit consumption is widespread. Nearly half of the dried fruits sold throughout the world are raisins, followed by dates, prunes (dried plums), figs, apricots, peaches, apples and pears. Dates, prunes, apricots, figs and raisins are the major dried fruits produced in the Mediterranean area. Dried fruits are not perishable but can support mold growth, some of which can produce mycotoxins. Occurrence of toxigenic molds and mycotoxins on these dried fruits can be a problem in the Mediterranean basin, as in the other parts of the world, being a health hazard to the population as well as a trade issue for the export of local products. Although the most important mycotoxins occurring in Mediterranean crops are aflatoxins (B₁, B₂, G₁ and G₂) and ochratoxin A, the type and level of mycotoxins and toxigenic molds vary by crop and also by country and in some cases geographic location within a country. In this review mycotoxin risks and toxigenic fungi in date, prune and dried apricot among Mediterranean crops are reported and discussed.

Key words: dried fruit, aflatoxin, ochratoxin A, *Aspergillus*, date, apricot, prune.

Introduction

Mycotoxins are a group of toxic fungal secondary metabolites which can contaminate agricultural products under pre- and postharvest conditions. They can cause acute or chronic toxic effects such as carcinogenic, mutagenic, teratogenic, atherogenic and oestrogenic effects in human and animals (Hussein and Brasel, 2001; Kuiper-Goodman, 2004). Mycotoxins affect food quality, resulting in huge economic losses in addition to being hazardous to consumer health for producing countries (Richard, 2007). Therefore, mycotoxins are considered an im-

portant problem throughout the world in terms of public health, agriculture and economics. Mycotoxins, mainly formed by certain filamentous fungi belonging to the genera *Aspergillus*, *Penicillium*, *Alternaria* and *Fusarium* species, may grow on a number of food commodities. Of these genera, the first three are the major contributors of fruit spoilage and mycotoxin production in fruits (Barkai-Golan, 2008). Although a large number of different mycotoxins exist, only a few of them, namely patulin, aflatoxins (AFs), ochratoxin A (OTA) and *Alternaria* toxins are frequently found in fruit and fruit products (Drusch and Ragab, 2003). Among mycotoxins, AFs and OTA are the major concern, given their high occurrence and toxicity.

AFs, produced by members of *Aspergillus* section *Flavi* (mainly *Aspergillus flavus* and *A. parasiticus*),

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are potent hepatotoxic, mutagenic and carcinogenic toxins causing serious health hazards to humans and animals. Aflatoxins B₁, B₂, G₁ and G₂ exist predominantly in grains, nuts, dried fruits, and foods whereas, M₁ and M₂ aflatoxins, hydroxylated metabolites are found primarily in animal tissues and fluids (milk and urine) as the metabolic products of aflatoxins B₁ and B₂ respectively (Richard, 2007). The most toxic aflatoxin, B₁, is noted as a human carcinogen (group 1) by the International Agency for Research on Cancer (IARC, 1993). Special interest is given to aflatoxins, due to their high occurrence and toxicity. Aflatoxigenic fungi are found in different food commodities including cereals, nuts, spices, figs and dried fruits (Pitt and Hocking, 2009). They may contaminate foods by colonizing them at several stages of the food chain; preharvesting, processing, transportation and storage (Manonmani *et al.*, 2005).

OTA is a mycotoxin produced by several fungal species belonging in *Aspergillus* sections *Circumdati*, *Flavi* and *Nigri* and by *Penicillium verrucosum* and *P. nordicum*. These species can frequently be found in a variety of foods and beverages, therefore OTA contamination may occur in diverse foodstuffs including cereals, coffee, cocoa, spices, malt, beer, wine, grape juice, dried fruits and meat as well as their products (Desphande, 2002). OTA is a potent nephrotoxic and hepatocarcinogenic mycotoxin that primarily affects the kidneys in animals and has been associated with Balkan Endemic Nephropathy and urethelial tumors in humans. OTA is classified as a possible human carcinogen (group 2B) by the International Agency for Research on Cancer (IARC, 1993).

Agriculture provides the main income for the economy in mediterranean countries. Most of these crops are cereals, fruits, vegetables and oil seeds. Export crops especially make a great contribution to the economy. Among these export crops, dried fruits are susceptible to mold contamination and growth, and consequent mycotoxin production. Various reports revealed high incidences/levels of contamination of these products with mycotoxins with possible high economic losses (Karaca *et al.*, 2010).

Dried fruit moisture contents vary from 2 to 22% depending on the kind of fruit (Vinson *et al.*, 2005). These products are thought to be resistant to microbial spoilage because of their low water activity, high acidity and sugar content, as a consequence of drying process. In general most dried fruits have sufficiently low water activity to inhibit bacterial growth. How-

ever molds are the most important microorganisms in dried fruits in terms of spoilage. There are many studies on microflora of dried fruits which indicate growth of microorganisms occurs mostly on the outer surfaces with a load of a few hundreds to thousands per gram of fruits. Even if a small part of surface is infected by mold, they may grow quickly in a short time. Furthermore, the numbers of infected fruit may increased rapidly if the drying process is not performed properly (Montville and Matthews, 2008).

Food drying is one of the oldest methods for preserving foods and solar drying of fruits has been used for centuries. Fruit may be dried whole (e.g., grapes, various berries, apricot, plum, etc.), in sliced form (e.g., banana, mango, papaya, kiwi, etc.), in puree form (e.g., mango, apricot, etc.), as leather, or as a powder by spray or drum drying (Ratti and Mujumdar, 2004). The drying of fruits allows for their better preservation by reducing water content, thus inhibiting microbial growth and enzymatic modifications.

Fruits with high sugar and acid content are suitable to dry under the sun. Sun drying is limited to climates with a hot sun and a dry atmosphere and to certain fruits, such as raisins, prunes, figs, apricots, pears and peaches. Because of proper climatic conditions, sun drying is one of the most common food preservation methods in mediterranean countries. The fruits are spread out on a layer such as trays, concretes, sheets and turned during drying (Bircan, 2009). Although drying is one of the best preservation techniques for fruits, if it is not used properly, molds and bacteria can grow and spoil the fruits. Besides fruit spoilage, mycotoxin formation is the most important problem related with dried fruits.

Natural occurrence of mycotoxins and fungal contamination of dried fruits have been investigated in many parts of the world by different authors (Herry and Lemetayer, 1992; Zohri and Abdel-Gawad, 1993; Ozay *et al.*, 1995; Abdel-Sater and Saber, 1999; MacDonald *et al.*, 1999; Bayman *et al.*, 2002; Aksoy *et al.*, 2003; Battilani *et al.*, 2003; Möller and Nyberg, 2003; Meyvacı *et al.*, 2005; Aksoy *et al.*, 2007; Juan *et al.*, 2007; Zinedine *et al.*, 2007; Musaiger *et al.*, 2008; Ozay and Özer, 2008; Bircan, 2009). The most studied mycotoxins in dried fruits are mainly AFs in dried figs and OTA in dried grapes due to their economic importance throughout the world. Available data on mycotoxin occurrence in dried fruits except dried figs, dried vine grapes and raisins, not only in mediterranean countries but also in the rest of the world,

are limited. The purpose of this review is to summarize the data available for toxigenic fungi and mycotoxins mainly occurring in prune, date and apricots cultivated in mediterranean countries.

Toxigenic fungi in dried fruits in Mediterranean crops

Molds, as natural inhabitants of soil and contaminants of air, water, foods and feeds, can be found widespread throughout world. Environmental factors which effect mold growth and mycotoxin production are temperature, pH, moisture content, oxygen levels, nutritional components, the mold strains and microbial competition (Jackson and Al-Taher, 2008).

Dried fruits are susceptible to mold growth and mycotoxin formation because of their high sugar content, method of harvest and drying conditions (Trucksess and Scott, 2008). The main problems related to sun drying of fruits are contact with the soil and infection risk by attack of insects and pathogens during outside drying longer than necessary (Flaishman *et al.*, 2008). Moreover, mold growth is related directly with the moisture content of dried fruits (Piga *et al.*, 2004).

Species belonging to the genera *Aspergillus*, *Penicillium* and *Alternaria* are major causative agents of fruit spoilage; in addition, these fungi can produce mycotoxins and, in this way, can cause significant economic losses for any process of the food industry, including drying (Jackson and Al-Taher, 2008).

Within the genus *Aspergillus*, *A. flavus* and *A. parasiticus* are the most important contaminants of certain foods and animal feeds because of their ability to produce AFs. When these species contaminate and grow in commodities such as cereals, nuts, spices and dried fruits, the resulting contamination with aflatoxins often makes the commodities inconsumable. Those two aflatoxigenic species are widely known and distributed around the world and may grow to form AFs under many conditions, especially hot, humid, subtropical and tropical climates as in Mediterranean countries (Pitt, 2004).

Surveys carried out in Mediterranean countries have revealed that toxigenic fungi, especially *Aspergillus* species, are the main contaminants in dried fruits. Among *Aspergillus* species, the ones belonging to section *Nigri* and *Flavi* are the most frequently identified species in dried apricot, dates and prunes as in other dried fruits (Zohri and Abdel-Gawad,

1993; Aziz and Moussa, 2002; Heperkan, 2006; Benlioğlu *et al.*, 2008). It is well known that some species of these two *Aspergillus* sections are considered the most significant toxigenic fungi.

Studies carried out in Mediterranean countries showed that *A. flavus* is the major species responsible for AFs contamination in dried dates and prunes (Abdel-Sater and Saber, 1999; Ragab *et al.*, 2001; Shenasi *et al.*, 2002). Aflatoxigenic *Aspergilli* have been associated mainly with dates and date products. In a study performed in United Arabian Emirates, although only 12% of date samples were contaminated with aflatoxins, potentially aflatoxigenic *Aspergillus* species were detected in 40% of the date samples examined (Shenasi *et al.*, 2002).

Another toxigenic group of fungi which commonly are found in dried apricots, dates and prunes is *Aspergillus* section *Nigri* (called black *Aspergilli*) which includes *Aspergillus carbonarius* and the members of *Aspergillus niger* aggregate. The *A. niger* aggregate is a group of closely related species which are very difficult to distinguish morphologically. The division of *A. niger* aggregate with molecular techniques has resulted in description of a number of species, namely *A. niger*, *A. tubingensis*, *A. vadensis*, *A. costaricensis*, *A. piperis*, *A. lacticoffeatus*, *A. sclerotium*, *A. ibericus*, *A. brasiliensis* and *A. uvarum* (Samson *et al.*, 2004; de Vries *et al.*, 2005; Serra *et al.*, 2006; Varga *et al.*, 2007; Perrone *et al.*, 2008). The black *Aspergilli* are not only most common fungi responsible for food spoilage and biodeterioration of materials, but are also extensively used for various biotechnological processes including production of various enzymes and organic acids. In addition, some black *aspergilli* can produce OTA in various food commodities (Schuster *et al.*, 2002).

Studies carried out in Mediterranean countries revealed the presence of ochratoxigenic fungi members of the *Aspergillus* section *Nigri*, especially *A. niger* and *A. carbonarius* in dried fruits. OTA contamination of dried fruits was found to be due to the action of black *aspergilli* in Mediterranean countries including Spain (Abarca *et al.*, 2003), Turkey (Özay *et al.*, 1995), Greece (Tjamos *et al.*, 2004) and Egypt (Zohri and Abdel-Gawad, 1993). These species are common soil inhabitants in Mediterranean, tropical and subtropical regions (Magan and Aldred, 2005). In addition, during the process of fruit drying, moisture content decreases and sugar content increases, resulting in a favourable medium for xerotoler-

ant molds such as *Aspergillus* section *Nigri* species (Iamanaka *et al.*, 2005).

Studies on molds in dried apricots, dates and prunes are very limited in Mediterranean countries. Table 1 indicates the presence of toxigenic molds in dried apricots, dates and prunes.

In Egypt, 40 date samples of mycoflora collected from the different production line stages of a date packing factory were analyzed. *A. niger*, *A. flavus* and *A. ochraceus*, and *Penicillium chrysogenum* were isolated with highest occurrence. *A. niger* (58.1–100% of total fungi) and *A. flavus* (1.5–7.0% of total fungi) were the dominant species in date samples while incidence of *A. ochraceus* was significantly lower (Ragab *et al.*, 2001).

Similar to these results, in another study in Egypt, Abdel-Sater and Saber (1999) found that *Aspergillus* was the most frequently isolated genus with contamination of 100% of the date samples while *Penicillium* was less frequently isolated with contamination of only 30% of the date samples. On the other hand, Zohri and Abdel-Gawad (1993) found that *Penicillium* was the most predominant genus isolated from dried apricots and prunes in a survey performed also in Egypt. It was represented by four species of which *P. chrysogenum* was the most common spe-

cies in the three dried fruits. *P. chrysogenum* is one of the most famous and important species under the *Penicillium* subgenus *Penicillium*, producing the well known extrolites, penicillins (Frisvad *et al.*, 2004a). In Morocco, ten important varieties of date were investigated for biochemical and microbiological composition. The most abundant species found was *A. niger* (Hasnaoui *et al.*, 2010).

Iamanaka *et al.* (2005) analyzed 14 dried apricots, 22 dates and 21 prunes for the presence of the toxigenic fungi. Dried fruit samples originated from Turkey, Spain, Mexico, Tunisia, USA, Argentina and Chile. While none of the apricot samples were contaminated by any fungi, 1.5% of date samples originated mostly from mediterranean countries were mainly contaminated with *A. niger*. On the other hand, 8% and 0.5% of the prune samples were contaminated with *A. niger* and *A. ochraceus* respectively. 15% of *A. niger* strains were found to be ochratoxigenic while 87% of *A. ochraceus* strains have the capacity of ochratoxin production among all samples. However, it was reported that most of the strains identified previously as *A. ochraceus* should be *A. westerdijkiae*, a new species recently described as very similar and morphologically indistinguishable from *A. ochraceus*. So most ochratoxigenic isolates which have been previously

Table 1. Mycotoxigenic fungi in dried apricots, prunes and dates in Mediterranean crops.

Sample	No. of samples	Fungi	Contaminated samples ^a (%)	Reference
Dried apricot	14	None	0	Iamanaka <i>et al.</i> , 2005
Dried apricot	1	<i>P. chrysogenum</i>	100	Zohri and Abdel-Gawad, 1993
Date	22	<i>A. niger</i>	1.5	Iamanaka <i>et al.</i> , 2005
Date	25	<i>A. flavus</i>	50	Shenasi <i>et al.</i> , 2002
Date	10	<i>A. niger</i>	NI	Hasnaoui <i>et al.</i> , 2010
Date (from different production stage of packing)	40	<i>Aspergillus</i> spp. (<i>A. niger</i> , <i>A. flavus</i> , <i>A. ochraceus</i>)	100	Ragab <i>et al.</i> , 2001
		<i>P. chrysogenum</i>	NI	
Date	60 ^b	<i>Aspergillus</i> spp. (<i>A. niger</i> , <i>A. flavus</i>)	100	Abdel-Sater and Saber, 1999
Prune	21	<i>A. niger</i>	8	Iamanaka <i>et al.</i> , 2005
		<i>A. ochraceus</i>	0.5	
Prune	1	<i>P. chrysogenum</i>	100	Zohri and Abdel-Gawad, 1993

^a NI, No information.

^b Total number of dried fruits.

identified as *A. ochraceus* are now recognized as *A. westerdijkiae* (Frisvad *et al.*, 2004b).

The predominance of black Aspergilli in dried fruits can be explained the protection from sunlight and ultraviolet light provided by their black spores, giving them a competitive advantage in this habitat. Moreover, high sugar concentration and low water activity in dried fruits also assist the development of these fungi because they are xerophilic (Iamanaka *et al.*, 2005).

Mycotoxins in dried fruits in Mediterranean crops

Production of mycotoxins occurs in the field, transportation, processing, and storage of foods depending on environmental factors and storage conditions.

Natural occurrence of AFs in dried fruits such as figs and dates has only been found in tropical and subtropical regions with high temperature and humidity (as in Mediterranean countries) which are suitable climatic conditions for growth of aflatoxigenic fungi (Shenasi *et al.*, 2002; Drusch and Ragab, 2003; Karaca and Nas, 2006). Besides AFs, OTA has been detected in many different food products including cereals, nuts, cocoa, spices and dried fruits from different geographical origins. This is due to the wide distribution of ochratoxigenic members of *Aspergillus* section *Nigri* throughout the world. It is generally assumed that *Aspergillus* species, both AFs and OTA producers, are more commonly associated with commodities in warmer and tropical climates such as Mediterranean countries (Pitt and Hocking, 2009). The presence of AFs and OTA in dried fruits has been studied by some authors in different countries (Zohri and Abdel-Gawad, 1993; MacDonald *et al.*, 1999; Stefanaki *et al.*, 2003; Iamanaka *et al.*, 2006; Juan *et al.*, 2007; Bircan, 2009; Zinedine and Manes, 2009).

Investigations on the occurrence of mycotoxins in dried fruits have been mostly on AFs in dried figs and OTA in dried vine fruits, such as raisins, due to their economic importance throughout the world (Romero *et al.*, 2005; Aksoy *et al.*, 2007; Iamanaka *et al.*, 2007; Heperkan *et al.*, 2012). Data available on occurrence of mycotoxins in dried fruits except dried figs, dried vine grapes and raisins in Mediterranean countries are limited. Table 2 indicates the studies on mycotoxin contamination in dried apricots, dates and prunes.

Apricot

There are few reports regarding to natural occurrence of mycotoxins in dried apricots in Mediterranean countries. Morton *et al.* (1979) studied the aflatoxin risk for dried figs, apricots, pineapples and raisins and demonstrated that dried apricots have highest potential for aflatoxin, along with dried figs. A number of studies have been performed on the natural occurrence of mycotoxins in apricots in Turkey, one of the world's greatest apricot producer and exporter. Aksoy *et al.* (1995) conducted a survey on the natural occurrence of OTA and aflatoxins in 35 sulphur-treated and 35 naturally dried apricot samples which were collected in 1993 from different processing plants in Turkey. All collected samples were analyzed for aflatoxins but only 30 of the samples (half of them naturally dried) were analyzed for OTA presence and no mycotoxin contamination was found. On the other hand there are other studies that report aflatoxin presence in dried apricot (Apergi and Panagiotopoulou, 1998; Celik and Ozturk, 2000; Gunsen and Buyukyoruk, 2002). Celik and Ozturk (2000) studied the aflatoxin level of dried apricot samples dried on soil and tarp, sulphur-treated and non-sulphur-treated. They showed that samples were contaminated with aflatoxin B₁ (AFB₁) and aflatoxin G₁ (AFG₁) in the range of 0.10–1.47 µg kg⁻¹ and 0.35–1.27 µg kg⁻¹ respectively. Similar to this study, Gunsen and Buyukyoruk (2002) analyzed AFB₁ in 15 dried apricot samples using ELISA and three of them were contaminated with mean levels of 1.44 µg kg⁻¹ AFB₁.

In addition to aflatoxins, OTA contamination has been reported in dried apricots in the range of 50–110 µg kg⁻¹. Three dried apricot samples were analyzed for OTA, AFs, citrinin, patulin, sterigmatocystin, T-2 and zearalanone presence by thin layer chromatography. Though a small number of samples was analyzed, all of them were found to be contaminated, only with OTA (Zohri and Abdel-Gawad, 1993). Bircan (2009) also tested 20 dried apricot samples from Turkey for OTA contamination and only one of them was contaminated, with 0.97 µg kg⁻¹ OTA. On the other hand, Iamanaka *et al.* (2005) analyzed 14 samples of dried apricots and none of them was contaminated with OTA. These studies imply that low incidence of fungi and mycotoxin contamination in apricot could be due to the sulfur dioxide treatment (Karaca *et al.*, 2010).

Table 2. Mycotoxins in dried apricots, prunes and dates in Mediterranean crops.

Sample	No. of sample ^a	Type of mycotoxin	No. (and %) of contaminated samples ^a	Mycotoxin level ^b ($\mu\text{g kg}^{-1}$)	Reference
Dried apricot	3	Ochratoxin A	3 (100)	50–110	Zohri and Abdel-Gawad, 1993
Dried apricot (treated or untreated with SO ₂ before drying)	150	Aflatoxins, citrinin, patulin, sterigmatocystin, T-2 and zearelanone	0	ND	
Apricot dried on soil	NI	Ochratoxin A	0	ND	Aksoy <i>et al.</i> , 1995
Apricot dried on tarp	NI	Total aflatoxins	NI	1.47	Celik and Ozturk, 2000
Apricot untreated with SO ₂	NI	Aflatoxin B ₁	NI	1.11	
Apricot untreated with SO ₂ + stored for 1 year	NI	Aflatoxin G ₁	NI	0.85	
Dried apricot	15	Aflatoxin B ₁	0	1.27	
Dried apricot	14	Aflatoxin B ₁	3 (20)	0.16	
Dried apricot	2	Aflatoxin G ₁	0	0.35	
Dried apricot	20	Aflatoxin B ₁	NI	0.10	
Date	60	Aflatoxin G ₁	0	ND	
Dates (raw, fumigated, dried, paste, stuffed with peanut, stuffed with almond)	40	Aflatoxin B ₁	2 (out of 5 pitted date fruits stuffed with peanut)	4.8–6.2	Ragab <i>et al.</i> , 2001
Date	20	Aflatoxin B ₁	2 (10)	110–180	Alghalibi and Shater, 2004
Date	20	Ochratoxin A	2 (10)	0.1–5	Iamanaka <i>et al.</i> , 2005
Prune	3	Ochratoxin A	3 (100)	210–280	Zohri and Abdel-Gawad, 1993
Prune	31	Aflatoxins, citrinin, patulin, sterigmatocystin, T-2 and zearelanone	0	ND	
Prune	21	Ochratoxin A	26 (84)	max. 0.07	Engel, 2000
Prune	21	Ochratoxin A	1 (4.8)	0.1–5	Iamanaka <i>et al.</i> , 2005

^a NI, No information.^b ND, Not detected.^c Total number of dried fruits.

Date

Date fruits are grown in areas where the temperatures and humidity are relatively high, so they are especially exposed to aflatoxin contamination during their later stages of maturation (Ahmed and Ahmed, 1997; Shenasi *et al.*, 2002). In addition to climatic conditions, color, flavor and chemical changes during fruit ripening make date fruit more susceptible to fungal attack (Ahmed and Robinson, 1998).

Shenasi *et al.* (2002) investigated the microflora of date fruits and production of aflatoxins at three stages of maturation: inedible green fruit (Kimri), edible soft and brown colored fruit (Rutab) and dried, dark brown colored fruit (Tamr). In the study, microbial counts and aflatoxin levels of 25 samples of dates were examined in fresh and stored products kept 14 days at 30°C and 98% relative humidity (RH). AF contamination was not detected in any samples of fresh dates. However, after 14 days of storage, three out of the 25 varieties of dates showed detectable levels of AFB1, but only when dates were harvested in the inedible Kimri stage. AFs and aflatoxigenic *Aspergillus* spp. were undetectable in dates at the final edible Tamr stage of maturation. This finding suggests that storage of dates under high humidity does not adversely affect their safety as far as AFs are concerned. Insect, bird or harvest-related damage which exposes inner tissues of the fruits to toxigenic aspergilli may also result in AF contamination (Ahmed and Ahmed, 1997).

Date fruit may contain mycotoxins, particularly AFs and OTA (Abdel-Sater and Saber, 1999; Alghalibi and Shater, 2004; Iamanaka *et al.*, 2005). Iamanaka *et al.* (2005) investigated OTA contamination of 20 date samples sold in Brazil but of worldwide origin; only two samples were found to be contaminated with OTA in the range of 0.1–5 µg kg⁻¹. In Egypt, Abdel-Sater and Saber (1999) reported presence of AFB1, OTA and zearelenone in dates analyzed by TLC. While three of the date samples were contaminated with 500–1000 µg kg⁻¹ of zearelenone, two of the samples were contaminated with AFB1 and OTA at the levels of 300–390 µg kg⁻¹ and 360–450 µg kg⁻¹ respectively.

The natural occurrence of AFB1 also has been reported in dates in another study. Ragab *et al.* (2001) investigated AF contamination in 40 date samples of different types (raw, fumigated, dried, paste, stuffed with peanut, stuffed with almond) using

TLC; only two out of the five samples of pitted date fruits stuffed with peanut were found to be contaminated by AFB1 with the concentration of 4.8 and 6.2 µg kg⁻¹. The authors of this study associated the presence of AF with previous contamination of the peanut kernels which had been used to produce the stuffed dates. In another study performed in Yemen, which is not one of the Mediterranean countries, Alghalibi and Shater (2004) determined AFB1 level of 20 date samples and only two of them were found to be contaminated with AFB1 in the range of 110–180 µg kg⁻¹.

In contrast to figs, mycotoxin contamination of dates is not associated with dried fruits. Removal of decayed or damaged dates before drying and packaging may reduce the incidence of aflatoxin contamination (Jackson and Al-Taher, 2008).

Prune (dried plums)

Studies performed on mycotoxin contamination of prunes indicate that OTA formation is the major mycotoxin problem in these fruits. OTA contamination of prunes has been examined in a few countries in the Mediterranean Region. Zohri and Abdel-Gawad (1993) performed a study on OTA, AFs, citrinin, patulin, sterigmatocystin, T-2 and zearelanone contamination of three samples of dried plums and only OTA was found in the range of 210–280 µg kg⁻¹ in all analyzed samples. On the other hand Iamanaka *et al.* (2005) analyzed 21 samples of dried plums and only one sample was contaminated with OTA in the range of 0.1–5 µg kg⁻¹. Similar to the previous study, Engel (2000) reported a maximum of 0.07 µg kg⁻¹ OTA content in 26 out of 31 prune samples. The natural occurrence of AFB1 has also been reported in prunes (Apergi and Panagiotopoulou, 1998).

Conclusions

Consumers mostly reject fresh fruit that is visibly moldy or rotten. However processed fruit products may contain significant levels of mycotoxins when the decayed or moldy fruit is used for producing dried fruits. Therefore sound fruits should be used, dried rapidly, and then stored under dry conditions for dried fruit production.

Although traditional dried fruits such as dates, apricots and prunes are not consumed as much as dried figs or raisins worldwide, these traditional

dried fruits are frequently consumed in the producing countries. Nowadays, due to their sweet taste and nutritive values, consumption of dried apricots, prunes and dates is increasing in countries outside the production areas, especially in European countries. Because dried fruits are usually consumed directly without any further processing, it is important to be aware of the quality and safety of these products.

This review, considering the consumption of dried apricots, dates and prunes especially in Mediterranean countries, demonstrates that studies on these dried fruits in terms of toxigenic molds and mycotoxins are very limited. The most important mycotoxins occurring in dried apricots, dates and prunes are AFs (B₁, B₂, G₁ and G₂) and OTA. Dominant species in these Mediterranean products are mainly from the genera *Aspergillus* and *Penicillium*. These results are in agreement with the studies on dried fruits from outside the Mediterranean countries. The type and level of contamination by mycotoxins and toxigenic molds vary by crop and by country.

Most investigations involving dried fruits deal with fruits grown in warm climates, such as figs and grapes. However available data related with dried dates, prunes, apricots are very limited. To ascertain the real mycotoxin risk in dried fruits other than figs and raisins, these crops should be better surveyed with increasing sample numbers and using standardized methodology. In addition, data in the literature are contradictory, indicating that a number of factors affect fungal growth and mycotoxins contamination of such fruits.

This review shows that further studies are needed to determine the fate of mycotoxins during processing of apricots, dates and prunes in addition to the necessity for more surveys on toxigenic molds and mycotoxins, especially AFs and OTA in these dried fruits.

In spite of inadequate data, we can conclude that occurrence of toxigenic molds and mycotoxin formation on dried apricots, dates and prunes could be a problem in the Mediterranean basin, as in the other parts of the world, for other kind of crops like dried figs, raisins and nuts.

Acknowledgements

The authors are grateful to reviewers for serving as pre-submission reviewers. The authors also wish to thank to FP7 EU project MycoRed (GA 222690) for giving the opportunity to prepare this review article.

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Accepted for publication: November 10, 2011