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Title	Mycotoxins in spices and herbs - an update
Authors	Kabak, Bulent;Dobson, Alan D. W.
Publication date	2017-01
Original Citation	Kabak, B. and Dobson, A. D. W. (2017) 'Mycotoxins in spices and herbs - an update', Critical Reviews in Food Science and Nutrition, 57(1), pp. 18-34. doi:10.1080/10408398.2013.772891
Type of publication	Article (peer-reviewed)
Link to publisher's version	10.1080/10408398.2013.772891
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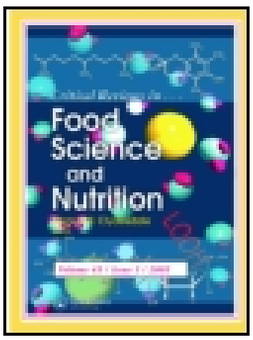

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Critical Reviews in Food Science and Nutrition

ISSN: 1040-8398 (Print) 1549-7852 (Online) Journal homepage: http://www.tandfonline.com/loi/bfsn20

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To cite this article: Bulent Kabak & Alan D. W. Dobson (2015): Mycotoxins in Spices and Herbs: An Update, Critical Reviews in Food Science and Nutrition, DOI: 10.1080/10408398.2013.772891

To link to this article: http://dx.doi.org/10.1080/10408398.2013.772891

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Mycotoxins in spices and herbs– An update

Bulent Kabak[1*] and Alan D. W. Dobson[2]

[1]Hitit University, Faculty of Engineering, Department of Food Engineering, TR-19030, Corum, Turkey

[2]Microbiology Department and Environmental Research Institute, University Colloge Cork, National University of Ireland, Cork, Ireland

*Corresponding author: Bulent Kabak, Hitit University, Faculty of Engineering, Department of Food Engineering, Corum, Turkey. E-mail: bulentkabak@hitit.edu.tr

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ABSTRACT

Spices and herbs have been used since ancient times as flavour and aroma enhancers, colourants, preservatives and traditional medicines. There are more than thirty spices and herbs of global economic and culinary importance. Among the spices, black pepper, capsicums, cumin, cinnamon, nutmeg, ginger, turmeric, saffron, coriander, cloves, dill, mint, thyme, sesame seed, mustard seed and curry powder are the most popular worldwide. In addition to their culinary uses, a number of functional properties of aromatic herbs and spices are also well described in the scientific literature. However, spices and herbs cultivated mainly in tropic and subtropic areas can be exposed to contamination with toxigenic fungi and subsequently mycotoxins. This review provides an overview on the mycotoxin risk in widely consumed spices and aromatic herbs.

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Keywords: spice, herbs, mycotoxins, aflatoxins, ochratoxin A

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INTRODUCTION

Spices are an important part of human nutrition and find utility in all the cultures of the world and have been used for flavour, colour, aroma and preservation of food or beverages for thousands of years. Spices are generally considered as the non-leafy parts of plants which are used for seasoning, colouring and flavouring food; while herbs are mainly referred to as the leafy parts being a sub-set of spices. Spices can be buds (clove), bark (cinnamon), root (ginger), berries (grains of pepper), seeds (cumin), leaf (e.g. bay leaf), or even stigma of the flower (saffron) (Viuda-Martos et al., 2011). Table 1 shows the botanical classification, part of plant used, classification, based on the degree of test and major-producing countries of spices and herbs.

It has been estimated that the value of the total world production of herbs and spices is around US$ 3 billion. The most important spices traditionally traded throught the world are products of tropical environments that have high ranges of temperature, humidity and rainfall. The major exceptions to this group are the capsicums (chilli peppers, paprika) and coriander which are grown over a much wider range of tropical and non-tropical environments. In terms of world trade value, the most important spice crops are black pepper (*Piper nigrum L.*), capsicums (*Capsicum annuum* L.), nutmeg (*Myristica fragrans* Houtt), cumin (*Cuminum cyminum* L.), cinnamon (*Cinnamomum*), ginger (*Zingiber officinale* Roscoe), turmeric (*Curcuma longa* L.), cloves (*Syzygium aromaticum* L.), coriander (*Coriandrum sativum* L.), thyme (*Thymus vulgaris* L.), mint (*Mentha piperita* L., *Mentha spicata* L.) mustard (*Sinapis alba* L.) and sesame seeds (*Sesame indicum* L.) (UNIDO/FAO, 2006).

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Because of the steps involved in their processing and the environmental conditions under which these steps are undertaken, spices have the potential to be heavily contaminated with toxigenic fungi and mycotoxins. For spices there are two groups of mycotoxins of concern, aflatoxins (AFs) and ochratoxin A (OTA). Aflatoxins are the most toxic group of mycotoxins that are produced by some *Aspergillus* species (*A. flavus*, *A. parasiticus* and more rarely by *A. nomius)* (Pitt, 2000). While several types of AFs are produced in nature belonging to a group called the difuranocoumarins, only four, aflatoxin B_1 (AFB_1), aflatoxin B_2 (AFB_2), aflatoxin G_1 (AFG_1) and aflatoxin G_2 (AFG_2) are naturally found in foodstuffs. *Aspergillus parasiticus* produces both B and G AFs and is well adapted to a soil environment, while *A. flavus* is more adapted to the aerial parts of plants and produces only B aflatoxins (EFSA, 2004).

AFs have several toxic effects in animals and humans, including carcinogenic, mutagenic, teratogenic and immunosuppressive activity (Eaton and Gallagher, 1994). AFB_1 is the most potent genotoxic and carcinogenic AF and amongst the most commonly found in agricultural products (Sweeney and Dobson, 1998). AFB_1 and naturally occurring mixtures of AFs have been classified by the International Agency for Research on Cancer as group I carcinogens (carcinogenic to humans) (IARC, 1993), with a role in the aetiology of liver cancer, notably among subjects who are carries of hepatitis B virus surface antigens (IARC, 2002).

Ochratoxin A is a kidney toxin, produced mainly by *Penicillium verrucosum* in temperate climates and by *Aspergillus ochraceus* and more rarely by *Aspergillus carbonarius* in warm and tropical countries; that can contaminate agricultural products prior to harvest or much more commonly during storage (EFSA, 2006). This compound has been shown to have nephrotoxic effects on all mammalian species and has been associated with fatal human kidney disease,

referred to as Balkan Endemic Nephropathy and with an increased incidence of tumours of the upper urinary effect (JECFA, 2001). The toxic effects of OTA against various experimental animals include carcinogenic, teratogenic, immunotoxic, genotoxic and possibly neurotoxic activity (European Commission, 1998). The IARC has classified OTA as a probable human carcinogen (Group 2B) based on sufficient evidence for carcinogenicity in animal studies and inadequate evidence in humans (IARC, 1993).

Both groups of mycotoxins can contaminate spices in the field, during drying and/or in storage. The SCOOP report emphasized that among different spices, nutmeg, paprika, coriander and pepper powder were the most highly and frequently contaminated. The overall mean level of OTA in spices (n=361) was 1.2 µg kg^{-1} and the maximum content reported was 24 µg kg^{-1} (European Commission, 2002b). This review focussed on mycotoxin risk in spices and herbs consumed widely throughout the world.

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LEGISLATION CONCERNING MYCOTOXINS IN SPICES

Many countries have established regulations for mycotoxins in foodstuffs, due to their health hazards for humans. The European Union has the most extensive regulations for mycotoxins in the world. The European Union has set maximum levels for certain contaminants in foodstuffs according to Commission Regulation (EC) No 1881/2006 (European Commission, 2006), which has been amended and replaced with new regulations to revise legal limits for contaminants in foodstuffs. With regard to AFs, the EU has set a legal limit of 5 µg kg^{-1} for AFB_1 and 10 µg kg^{-1} for the sum of AFB_1, AFB_2, AFG_1 and AFG_2 in spices including *Capsicum* spp. (dried fruits thereof, whole or ground, including chillies, chilli powder, cayenne and

paprika), *Piper* spp. (fruits thereof, including white and black pepper) nutmeg, ginger and turmeric and mixtures of species containing one or more of the mentioned spices (European Commision, 2010a). Moreover it has also set maximum limits for oilseeds such as mustard seeds, sesame seeds and poppy seeds.

In Indonesia, a limit of 20 μg kg^{-1} for total AFs has been set for the category ñcoconut, spices and traditional drugmedicines/herbsò. In Croatia, a legislative limit of 30 μg kg^{-1} for AFB_1 has been established for spices, while a limit of 5 and 20 μg kg^{-1} for AFB_1 and total AFs, respectively, for all food and spices has been established in Uruguay. However, many countries have established a general maximum limit for AFB_1 or total AFs for the category ñall foodsò. The legislative limit varies, from 2 μg kg^{-1} in Tunisia to 20 μg kg^{-1} in Nigeria for AFB_1, and from 5 μg kg^{-1} in Cuba and Chili to 35 μg kg^{-1} in Malaysia for total AFs in the category ñall foodsò. However, some countries such as Bangladesh, Ecuador, Ethiopia, Ghana, Iraq, Myanmar, Nicaragua, Pakistan, Panama, Uganda, Yemen and Zambia have as yet not established any regulatory limit for mycotoxins.

With regard to OTA, Commission Regulation (EC) No 1881/2006 has been recently amended by regulation (EU) No 105/2010 to revise the OTA levels in foodstuffs. The EU Commission established a limit of 30 μg kg^{-1} as from 1.7.2010 until 30.6.2012 and 15 μg kg^{-1} as from 1.7.2012 for the spices *Capsicum* spp., *Piper* spp., nutmeg, ginger, turmeric and mixtures of spices containing one or more of the mentioned spices (European Commission, 2010b). In addition, Turkey, Egypt and Bosnia and Herzegovina refer to the Commission Regulation in setting up their national maximum limits for OTA. However, no specific limits for OTA in spices have do date been established in other parts of the world.

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NOTIFICATIONS ON MYCOTOXINS IN SPICES

The Rapid Alert System for Food and Feed (RASFF) is a system, which was establised to provide the control authorities with the facility to exchange information on measures taken to ensure food and feed safety in Europe. This exchange of information helps Member States (EU and EFTA/EEA countries) to act more rapidly and in a coordinated manner in response to a potential health threat caused by food or feed. While the system has been in place since 1979, the legal basis of the RASFF is regulation (EC) No 178/2002, (European Commission, 2002a). In 2008, the number of countries which were part of the RASFF network increased to 31, an increase from the 18 countries which were part of the network in 2002. The RASFF notifications are classified as alert, and information or border rejection notification according to the seriousness of the risks identified and the distribution of the product on the market.

The European Commission publishes weekly overviews of alert and information notifications on its website. Between the years 2002-2011, the RASFF received a total of 451 notifications in the category ñherbs and spicesò on mycotoxins, of which 87 were alert (19.3%), 181 information (40.1%) and 183 border rejection (40.6%) notifications (Figure 1). Table 2 shows the number of RASFF notifications on herb and spices contaminated by mycotoxins during the period 2002-2011. The large majority of these notifications on herb and spices (371/451, 82%) dealt with AFs. During this time, there was a sharp increase in RASFF notifications concerning AFs contamination in herb and spices in 2010, while the notification level decreased by 43.8% in 2011. The rise in notifications in 2010 was mainly due to a higher reporting of chilli (mainly originating from India), curry powder (from India) and nutmeg

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(mainly from India and Indonesia) contaminated by AFs. From the notifications on aflatoxins in herb and spices during the 2002-2010 period, the main notifications were concerned with capsicums (58%), followed by nutmeg (15%), curry powder (12%) and ginger (5%) (Figure 2).

There were 80 notifications on unacceptable level of OTA in herbs and spices during the period 2002-2011 and in 22 of these notifications AFs occurred simultaneously at unacceptable levels. Around 88% of these notifications on OTA concerned capsicums originating mainly from Peru, Spain and India (Figure 3).

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MYCOTOXINS IN SPICES AND HERBS

Black pepper

Black pepper (*Piper nigrum* L.), kown as the ñKingò of spices, a perennial crop of the tropics; is economically the most important and the most widely used spice crop in the world (Nair, 2011). The fruit, known as black peppercorns, are the green unripe berries, which become black and shriveled when dried in the sun. Black pepper, an Indian native spice, is valued for its characteristics sharp and stinging qualities attributed to alkoloid piperine (Srinivasan, 2009). Black pepper is used not only in processed foods such as savory dishes, meat products, soups, vegetables and marinades as a spice, but also for a variety of other purposes such as medicinal, as a preservative, and in perfumery (Srinivasan, 2007).

An earlier study showed that black pepper supported profuse growth and conidiation of *A. parasiticus* (Seenappa and Kempton, 1980). However, it has been shown that growth of toxigenic strains of *A. flavus* is quite weak on both black pepper and white pepper and that no

aflatoxin could be detected in black or white pepper following 10 days growth at 25°C (Bartine and Tantaoui-Elaraki, 1997). In a similar study, Tantoui-Elaraki and Beraoud (1994) while monitoring the effects of 13 chemically different essential oils of spices, including black pepper, found that they inhibited both mycelial growth and aflatoxin synthesis in *A. parasiticus*.

Despite the fact that black pepper appears to contain some substances which are active against several fungi, previous studies have shown that black pepper can be contaminated with a wide variety of fungi and mycotoxins. *A. flavus* and *Aspergillus niger* were found to be the most dominant fungi in black pepper marketed in Bahrain (Mandeel, 2005), Brazil (Freire et al., 2000), Malaysia (Reddy et al., 2011) and Turkey (Vural et al., 2004), while *Penicillium* strains were isolated less frequently in black pepper and white pepper samples in Brazil (Freire et al., 2000). In another study, Gatti et al. (2003) isolated a total of 497 fungi belonging mainly to the *Aspergillus* (53.5%), *Eurotium* (24.5%), *Rhizopus* (12.3%), and *Penicillium* (3.2%) genera, from black pepper grown in Brazil. They also reported that aflatoxin-producing *A. flavus* was more frequent than *A. parasiticus* and OTA-producing *A. ochraceus* in black pepper.

With respect to AFs, Bircan (2005) examined 15 black pepper samples from Turkey and found AFs in 27% of samples at levels ranging from 0.3 to 1.2 µg kg^{-1} for AFB_1 and from 0.3 to 2.3 µg kg^{-1} for total AFs. Colak et al. (2006) revealed that AFs occurred in 8 out of 24 black pepper samples in Turkey with concentrations ranging from 0.3 to 16.7 µg kg^{-1}, while Kursun and Mutlu (2010) found AFs at levels ranging from 0.67 ï 6.15 µg kg^{-1} in black pepper powder samples marketed in Turkey. While in a recent study in Turkey, AFB_1 was found in 7 out of 23 black pepper powder samples (30.4%) at levels ranging from 0.13 to 0.42 µg kg^{-1} (Ozbey and Kabak, 2012).

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Studies in other countries have also reported on the presence of AFB_1 in black pepper. For example in Hungary, Fazekas et al. (2005) found AFB_1 in only one of 6 black pepper samples tested at a level of 0.46 µg kg^{-1}. In Morocco, Zinedine et al. (2006) reported that the incidence of AFB_1 and total AFs in black pepper was between 47 and 93%, with an average values of 0.09 and 0.21 µg kg^{-1}, respectively. In Saudi Arabia, AFs were detected in 3 out of 5 black pepper samples tested at levels ranging from 25 to 40 µg kg^{-1} (Bokhari, 2007). In Potugal, Ferreira et al. (2007) found AFs in 3 of 4 black pepper samples at levels varying from 0.35 to 6.6 µg kg^{-1}. In Bahrain, Musaiger et al. (2008) found AFs in all samples of black pepper powder analysed at a level up to 27.7 µg kg^{-1}, while Ramognoli et al. (2007) did not detect any AFs in 11 samples of whole or smashed black pepper commercialised in Italy. In Egypt, 3 out of 5 black pepper samples analysed contained aflatoxins (AFB_1+AFG_1) at concentrations ranging from 28 to 35 µg kg^{-1} (El-Kady et al., 1995). While in a recent survey in Malaysia, Reddy et al. (2011) reported that all black pepper samples analysed contained AFB_1 at levels ranging from 0.65 to 2.1 µg kg^{-1}.

There are fewer studies focusing on the incidence of OTA in black pepper in the literature. Thirumala-Devi et al. (2001) found 14 OTA positive black pepper samples (54%) from India in the range of 10 ï 51 µg kg^{-1}. Zaied et al. (2010) found OTA in 13 out of 25 black pepper samples in Tunusia with levels ranging from 26 to 643 µg kg^{-1}. In Malaysia, Jalili et al. (2010) observed that 17 out of 30 black pepper powder analysed contained OTA at levels ranging from 0.23 to 12.64 µg kg^{-1}, while only 4 out of 23 black pepper samples from Turkey were found to be contaminated with OTA in the range of 0.87-3.48 µg kg^{-1} (Ozbey and Kabak, 2012). Recently, a border rejection notification was sent by Poland concerning unacceptable level (42.84 µg kg^{-1}) of OTA in black pepper originating from Vietnam (http://webgate.ec.europa.eu/rasff-

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window/portal). In contrast however, OTA could not be detected in black pepper marketed in other countries including Hungary (Fazekas et al., 2005), Belgium, The Netherlands and Russia (Goryacheva et al., 2006).

Capsicum

Chilli also called red pepper belongs to the genus *Capsicum*, under the nightshade family, *Solanaceae*. Chillies are referred to as chillis, Chile, hot peppers, bell peppers, red peppers, pod peppers, cayenne peppers, paprika, pimento and *Capsicum* in different parts of the world (SBI, 2010). Capsaicin is the substance that makes chilli peppers hot, while paprika is a type of red chilli that has little or no heat and which is grown primarily for its colour (Hall and Skaggs, 2003). Traditionally, after harvesting, fresh red chillies are washed and after drying, can be left as whole chilli pods, processed into small flakes or processed into powder.

Chilli (the dried form of *Capsicum annum* L.) is the the second largest consumed spice throughout the world, after black pepper. Turkey is the third largest producer of chilli and pepper with a production of 1.84 million metric tonnes, followed by China and Mexico (FAO, 2010). In 2010, the total EU imports of capsicums (dried, whole, crushed, and ground, sweet and hot) was about 75 000 tons, with a value of 128 million euros. The main suppliers of capsicums to the EU are China, Peru, India and Brazil (ESA, 2011).

Chilli is highly susceptible to fungal contamination and subsequently mycotoxin formation due to their environmental (high humidity and high temperature) and processing conditions. Red chilli can be contaminated with toxigenic fungi in the field during crop production, but also during drying process and in storage. The inadequate cleaning process for freshly harvested red

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chilli pods and improper drying techniques are likely to increase the risk of fungal contamination and subsequently mycotoxin production (Duman, 2010). For this reason, fresh fruits must be washed after harvesting and injured and diseased fruits must be removed (Almela et al., 2007). In addition it is recommended that the moisture content of red chillies (65-80%) on harvesting should be immediately reduced to about 10% by a drying process to avoid mould growth and mycotoxin accumulation (Iqbal et al., 2010).

While different drying methods are available, traditional sun drying of fruit by spreading the crop in a dry open area exposed to the sun is the most commonly used method (UNIDO/FAO, 2006). In a recent study, Ahn et al. (2010) indicated that mechanically dried powder had slightly lower levels of OTA than their sun-dried counterparts, even though this difference was not statistically significant. Marín et al. (2009) determined that the minimum water activity (a_w) for aflatoxigenic *A. flavus* growth on red chilli powder varied from 0.82 to 0.88 depending on the isolate, while an estimation of optimum a_w for growth was consistently around 0.97 ï 0.99.

The RASFF received 66 notifications relating to the unacceptable presence of mycotoxins in spices in 2011. With 66 notifications in 2011 compared to 123 in 2010, the notification level for spices decreased by 54%. Most of these notifications in 2011 were for capsicums (36 cases, 55%), followed by nutmeg (13 cases, 20%). Of the 36 notifications concerned mycotoxins in capsicums, 28 notifications were classified as rejections at the border, 6 as alert and 2 as information notification. The main issue notified was AFs in capsicums originating from India with 23 notifications (only 1 of which is from Turkey), followed by OTA (11 notifications) mainly from China and Peru and co-occurrence of AFs and OTA (2 notifications) originating

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from India. According to the RASFF notifications in 2011, the contamination levels in capsicums were from 6 (from Turkey) to 82 µg kg^{-1} (from India) for AFB_1 and from 42.4 (from Spain) to 137.9 µg kg^{-1} (from China) for OTA (http://webgate.ec.europa.eu/rasff-window/portal).

During the period 2002-2011, there were 226 notifications in total on the presence of AFs in capsicums, of which 174 were in chilli, 35 in paprika and 17 in other capsicums including red pepper, hot pepper and cayenne pepper. The 174 notifications on AFs in chilli were mainly from India (80.5%), while notifications on paprika originated mainly from Spain (28.6%), Turkey (17.1%) and Peru (11.4%).

In contrast to AFs, the large majority of notifications on OTA in capsicums during the period 2002-2011 concerned paprika (39 notifications), followed by chilli (15 notifications) and other capsicums (16 notifications) including cayenne pepper, dried pepper, red pepper, sweet pepper, whole pepper and bell pepper. For paprika, most notifications on OTA concerned products from Peru (17 notifications, 43.6%) and Spain (14 notifications, 35.9%), while the imported chilli originating mainly from India (8/15, 53.3%), Thailand (2/15, 13.3%) and Spain (2/15, 13.3%). Moreover, 23.1% of these notifications on paprika and 53.3% of the notifications on chilli simultaneoulsy contained AFs.

Moreover, a large number of studies have been performed over the last two decades to assess the occurrence and levels of mycotoxins in capsicums. The results of these studies are summarised in Table 3. Most of the available contamination data have been obtained from Turkey and Pakistan, and the occurence of mycotoxins in capsicums refers to AFs. As can be seen in Table 3, there are large differences in mycotoxin levels, ranging from 0.025 to 525 µg kg^{-}

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[1] for AFs and from <0.2 to 528 µg kg^{-1} for OTA, depending on the origin. The highest concentrations of AFs and OTA were found in capsicums from Ethiopia and Tunisia, respectively. Not surprisingly perhaps the high incidence and levels of AFs and OTA contamination in red chilli samples were frequently reported by countries located in tropical and subtropical areas (Cho et al., 2008; Jalili and Jinap, 2012). It has also been shown that high levels of OTA in red chillies originating from Peru and China could be related to their high humidity and special climatology conditions when compared to red chillies from Hungary and Spain with dry climatic conditions (ESA, 2011). The ecolological conditions in the red pepper producing areas of Peru appear to be suited to the growth of mesophilic/xerophilic moulds (Almela et al., 2007).

In general, AFB_1 and AFB_2 have been detected more frequently than AFG_1 and AFG_2 in capsicums. This could be explained by both occurrence and invasion of capsicums by *A. flavus* rather than by *A. parasiticus*. In a study by Vural et al. (2004), *A. flavus*, *Aspergillus fumigatus* and *A. niger* were frequently recorded in red chilli flake and red chilli powder samples purchased randomly in retail stores in southeastern Anatolia, Turkey. In a similar study, red-scaled pepper samples from southeastern Anatolia of Turkey were found to be contaminated with *A. niger*, *A. flavus*, *Aspergillus versicolor*, *A. ochraceus* and *Penicillium* spp. (Erdogan, 2004). Mandeel (2005) demonstrated that *A. flavus* and *A. niger* were the most dominants fungi in red chilli samples imported from various countries. The mycobiota of paprika samples from the region of Murcia in Spain have been shown to be composed of species of *Alternaria*, *Cladosporium*, *Rhizopus*, *Penicillium* and *Aspergillus* section *Nigri*, while *Aspergillus* section *Circumdati*, black *Aspergilli* and *Aspergillus* section *Nigri* were mainly isolated from five paprika samples from

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Peru with relatively high OTA levels (Almela et al., 2007). Recently, Reddy et al. (2011) reported that *A. flavus*, *A. niger* and *Aspergillus tamarii* were isolated in all chilli samples that they analysed from Malaysia.

It is also important to note that several toxins may be present simultaneously in contaminated red chillies. A combined intake of different type of mycotoxins is believed to lead to a possibly higher risk for adverse health effects than the intake of one of these mycotoxins alone (Speijers and Speijers, 2004). In this respect, Sedmikova et al. (2001) demonstrated that OTA can increase the mutagenicity of AFB_1 in the case of their simultaneous occurrence in the same substrate.

In a recent study conducted in the Kabak laboratory, 62.5% (15/24) of red chilli flakes were found to be simultaneously contaminated by AFs and OTA, while co-occurrence of AFs and OTA was observed in 40.9% (9/23) of red chilli powder samples. It is also important to note that red chilli flake and red chilli powder containing the highest levels of OTA (53.04 and 98.24 µg OTA kg^{-1}, respectively) were simultaneously contaminated by AFB_1 with the highest concentrations (11.45 and 35.77 µg AFB_1 kg^{-1}) respectively (Ozbey and Kabak, 2012). This is the first data on the natural co-occurrence of AFs and OTA in chillies from Turkey, while there are few studies reporting the incidence of two or more mycotoxins in chillies from various other countries. Some of these include the work of Hierro and co-workers who observed that the co-occurence of AFs and OTA in paprika samples marketed in Spain was 61.9% (Hierro et al. (2008), while 5 of 70 ground red pepper (7.1%) samples were found to simultaneously contain both AFB_1 and OTA at levels higher than the maximum permissible limit of the Hungarian Ministry (Fazekas et al., 2005). In another study, the co-occurence of AFs and OTA were

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detected in 50% of spices including red pepper, black pepper and cumin marketed in Tunusia (Ghali et al., 2008). While more recently, Santos et al. (2010) examined 64 paprika and 35 chilli samples available in the Spanish market for the co-occurence of AFs, OTA and zearalenone (ZEA). They found that 75% of paprika and 65% of chilli samples contained more than one mycotoxin and the incidence of OTA was correlated with the presence of AFB_1 and total AFs.

Cinnamon and cassia

Cinnamon and cassia spices are the prepared dried bark of the trees belonging to the genus *Cinnamomum* (UNIDO/FAO, 2006). The most important *Cinnamomum* species are *C. cassia* (Chinese cinnamon), *C. verum* (syn. *C. zeylanicum*, Ceylon cinnamon), *C. burmanni* (Indonesian cassia), *C. loureirii* (Vietnamese cassia) and *C. tamala* (Indian cassia) (Jayaprakasha and Rao, 2011).

Cinnamon and cassia spices have for centuries been used in several cultures both for their aroma and taste properties (Gruenwald et al., 2010). Indonesia, China, Sri Lanka and Vietnam are the major producers and exporters of cinnamon in international markets (FAO, 2010). In Turkey, cinnamon is widely used traditionally in the preparation of Turkish rice pudding (*sütlaç*), Turkish hot drink (*salep*) and cookies. In addition to its culinary uses, cinnamon bark has also been used as an antiemetic, antidiarrheal, antiflatulent, stimulant, antipyretic, antiseptic, astringent and as a fungicidal (Kunnumakkara et al., 2010; Jayaprakasha and Rao, 2011).

Cinnamon is likely not to be a good substrate for the growth of mycotoxin-producing fungi and mycotoxin accumulation. For example AFs were not detected in cinnamon powder samples marketed in a number of countries including Bahrain (Musaiger et al., 2008), Egypt (El-Kady et

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al., 1995; Aziz et al., 1998), India (Saxena and Mehrotra, 1989), Ireland (O'Riordan and Wilkinson, 2008), Japan (Hitokoto et al., 1978), Korea (Cho et al., 2008) and Turkey (Ozbey and Kabak, 2012).

Several reports have also highlighted that cinnamon compounds such as cinnamic aldehyde and eugenol can inhibit the growth of aflatoxin-producing fungi and aflatoxin formation (Bullerman et al., 1977; Mabrouk and El-Shayeb, 1980; Tantaoui-Elaraki and Beraoud, 1994). *C. zeylanicum* bark oil has shown fungitoxic properties against fungi such as *A. niger*, *A. fumigatus*, *Aspergillus nidulans* and *A. flavus* (Montes-Belmont and Carvajal, 1998). More recently, Simic et al. (2004) reported that the main component of *C. zeylanicum* (trans-cinnamaldehyde) has an inhibitory effect against 17 fungi including *A. niger*, *A. ochraceus*, *A. flavus*, *Aspergillus* terreus, *Alternaria alternata*, *Fusarium tricinctum* and *Fusarium sporotrichioides*. The volatile oils of cinnamon have also been found to have inhibitory effect against OTA-producing fungi (Morozumi, 1978), and essential oils in cinnamon are known to inhibited the synthesis of OTA starting at concentrations of 3% (Pereira et al. 2006).

Cladosporium (53.2%) and *Syncephalostrum* (27.1%) were found to be the most dominants genera encountered in cinnamon marketed in Serbia, while *Eurotium* (11.5%), *Aspergillus* (5.5.%) and *Penicillium spp.* (1.4%) were detected less frequently (Dimic et al., 2008). In a similar study, Hitokoto et al. (1978) indicated that *Mucor* were the dominant fungi in cinnamon from Japan, while no *Aspergillus* species was detected. However, in another study cinnamon was found to be contaminated by a number of fungi including potentially mycotoxin producing fungi such as *A. flavus* and *A. ochraceus* (Elshafie et al., 2002). Hashem and Alamri (2010) found that *A. niger* and *A. flavus* were most frequently isolated from cinnamon purchased from Saudi

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Arabian supermarkets. Recently, Al-Juraifani (2011) detected AFB_1 contamination in 31 of 50 cinnamon samples marketed in Saudi Arabia, over the range 0.13 ï 4.67 µg kg^{-1}, while Ramagnoli et al. (2007) reported that one cinnamon powder sample marketed in Italy contained AFB_1 at a level of 0.98 µg kg^{-1}. In Egypt, Selim et al. (1996) found AFB_1 in 2 cinnamon samples at levels of 10 and 42 µg kg^{-1}.

Cloves

Cloves (*Szygium aromaticum*) are the aromatic unopened dried flower buds of clove tree, which belongs to the genus *Szygium*, family Myrtaceae. Cloves are native to Indonesia and used either whole or ground as a spice in many parts of the world. They are also used as a food preservative and for therapeutic purposes especially in dental medicine (Kunnumakkara et al., 2009). Indonesia is the single largest cloves producing country in the world, with a production of about 57 000 metric tonnes annually (FAO, 2010).

There are several reports on the inhibitory effect of clove on *A. flavus* and *A. parasiticus* as well as on other fungi (Bullerman et al., 1977; Mabrouk and Shayeb, 1980; Hasan and Mahmoud, 1993; Chalfoun et al., 2004; Bokhari, 2007). While the main components of clove essential oil are eugenol (2-methoxy-4-(2-propenyl-phenol), eugenol acetate, and β-caryophyllene (Mandrioli et al., 2005; Osman et al., 2012), eugenol is known to be most inhibitory to the growth of *A. parasiticus* and *Fusarium moniliforme* among the nine different oils of spices (Juglal et al., 2002).

Several studies have shown that there is no discernible mycotoxin risk in cloves. For example AFs were not detected in any of the clove samples which were being marketed in the

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following countries: Egypt (El-Kady et al., 1995), India (Moorthy et al., 2011), Portugal (Martins et al., 2001), Saudi Arabia (Bokhari, 2007) and Sultanate of Oman (Elshafie et al., 2002). Moreover, clove marketed in India were found not to contain any detectable amounts of AFs, rubratoxin, OTA, citrinin, ZEA and sterigmatocystin (ST) (Saxena and Mehrotra, 1989). However, RASFF notifications for high levels of AFs in clove powder between the years 2002-2011 are rare with one from India in 2009 (29 µg kg^{-1}), and one for OTA (160 µg kg^{-1}) in clove powder from Comoros.

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Coriander

Coriander (*Coriandrum sativum* L.) is an annual herb native to the Mediterranean region and which is extensively grown in many climates throughout the world (UNIDO/FAO, 2006). The name ñcorianderò is given to the seeds of the plant, while its leaves are referred to as cilantro, Chinese parsley or Mexican parsley. All parts of the plant are edible, but the fresh leaves and the dried seeds are the parts most commonly used in cooking (Kunnumakkara et al., 2009). The green leaves of coriander are commonly consumed as fresh herb, whilst dried coriander fruits (seeds) are extensively used as condiments, in the preparation of curry powder, pickling spices, sausages and seasonings. Corainder seeds are also used for flavoring pastry, cookies, buns and cakes (Bhuiyan et al., 2009).

The mycoflora of coriander from India has been extensively studied by Rani et al. (1995), who reported the incidence of *A. flavus*, *A. niger*, *A. nidulans*, *Curvularia lunata*, *Rhizopus* spp., *Penicillium* sp. and *Mucor* sp. While coriander showed one of the narrowest species diversity

among the spice samples, *P. verrucosum* was found to be the dominant fungus in coriander marketed in Bahrain (Mandeel, 2005).

In Egypt, two coriander samples were found to contain AFs at levels of 2 and 8 µg kg^{-1} (Aziz and Youssef, 1991). In a screening study in Andhra Pradesh, India, AFs were detected in 6 out of 50 (12%) coriander samples analysed at levels ranging from non detectable to 3.2 µg kg^{-1} (Mayi, 1999). In Bahrain, AFs were found in 50% of coriander samples at a mean level of 1.7 µg kg^{-1} (Musaiger et al., 2008), while only one of 9 coriander samples marketed in Ireland was found to be contaminated with AFs at a level of 0.31 µg kg^{-1} (OôRiordan and Wilkinson, 2008). Similarily AFB_1 was found in only one (8 µg kg^{-1}) of 5 coriander samples analysed in Egypt (El-Kady et al., 1995). However, coriander samples commercialised in Italy were found to be AFs-free (Ramagnoli et al., 2007) and coriander from India which which was tested for type A trichothecenes (T-2 toxin and DAS) was also shown to be mycotoxin free (Lincy et al., 2008).

With respect to OTA, it has previously been reported that essential oils of coriander do not produce any inhibitory effect on the mycelial growth or on OTA production in *A. carbonarius* (Basílico and Basílico, 1999). While, Thirumala-Devi et al. (2001) showed that 20 out of 50 coriander samples from India contained OTA in the range of 10 ï 51 µg kg^{-1}. In a recent study in Tunisia, OTA was detected in 50% (10/20) of coriander samples at levels ranging from 74 to 576 µg kg^{-1} (Zaied et al., 2010).

Cumin

Cumin is the dried seed of the *Cuminum cyminum* L., belonging to the family of Apiaceae (Umbelliferae). Cumin is native to the Mediterranean region, and is valued for its aroma,

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medicinal and therapeutic properties (UNIDO/FAO, 2006). Turkey is one of the larger producer and exporter of cumin with a production of 12.587 tonnes in 2010 (TUIK, 2010).

Cumin appears to be a harsh substrate and may contain inhibitory agents which are active against aflatoxin production (Llewellyn et al., 1981b). It has been reported that cumin significantly suppressed aflatoxin formation and completely inhibited ST production (Hasan and Mahmoud, 1993). In another study, Bokhari (2007) showed that cumin retarded citrinin production, while ST production by *A. versicolor* was not affected by cumin. The major components of cumin essential oils includes α-pinene (29.2%), limonene (21.7%), 1,8-cineole (18.1%), linalool (10.5%), linalyl acetate (4.8%) and α-terpineole (3.2%) (Mohammodpour et al., 2012).

The fungi, *A. niger*, *A. flavus*, *A. ochraceus, A. fumigatus, A. ustus, A. clavatus*, *A. sydowii, Penicillium dunkii*, *Penicillium oxalicum*, *Penicillium brevicompactum*, *Penicillium waksmani, Fusarium oxysporum, Alternaria alternata*, *Cladosporium cladosporioides*, *Rhizopus stolonifer*, *Rhizoctonia solani, Eurotium repens, Stemphylium botryosum*, *Gliocladium roseum*, *Acremonium strictum* and *Mucor racemosus* have previously been isolated from the green cumin collected from Saudi Arabian supermarkets (Hashem and Alamri, 2010), while *A. flavus*, A. *fumigatus* and *A. niger* were found to be dominant in cumin samples from Turkey.

Cumin has intermittently been reported to be contaminated with mycotoxins. AFs were detected in 18 of 57 cumin samples commercialised in Turkey at levels ranging from <1 to 12 µg kg^{-1} (Dincoglu and Karacal, 2006). In another study, Kursun and Mutlu (2010) reported that AFs contamination varied from 4.55 to 8.57 µg kg^{-1} in cumin from Turkey, while Bircan (2005) did not found AFs at detecable levels in 15 cumin samples marketed in Turkey. In recent work

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conducted by the Kabak group, 21.1% (4/19) and 5.3% (1/19) of cumin contained AFB_1 and OTA, at mean values of 0.14 and 0.06 µg kg^{-1}, respectively (Ozbey and Kabak, 2012).

In Portugal, Martins et al. (2001) have reported AFB_1 in 3 out of 7 cumin samples, ranging from 1 to 2.8 µg kg^{-1}. In Morocco, 57% of cumin samples were found to contain AFs at levels up to 0.18 µg kg^{-1} (Zinedine et al., 2006). In Malaysia, AFB_1 was found in 2 out of 3 samples analysed in the range of 1.89 ï 4.64 µg kg^{-1} (Reddy et al., 2011), while no AFs were detected in 6 cumin samples marketed in Ireland (OôRiordan and Wilinson, 2008) and one cumin sample from Italy (Ramagnoli et al., 2007).

With regard to other mycotoxins, ST was reported in 3 out of 5 cumin samples from Egypt (El-Kady et al., 1995) and Saudi Arabia (Bokhari, 2007), with mean levels of 11 and 17.5 µg kg^{-1}, respectively.

Ginger

Ginger (*Zingiber officinale*), a member of the tropical and sub-tropical Zingiberaceae, is one of the oldest known spices used as a flavourant in foods. It has also been documented to be of used in treating headaches, nausea and colds (Zhao et al., 2009). Ginger is marketed in several forms such as fresh or dried products, liquid or solid extracts, tablets or capsules, bulk powder and in tea bags (Whitaker et al., 2009). India, China, Nepal, Thailand and Nigeria are the worldôs largest producers and exporters of ginger.

Ginger rhizome is reported to contain 3-6% fatty oil, 9% protein, 60-70% carbohydrates, 3-8% crude fiber, 8% ash, 9-12% water and 2-3% volatile oil (Baliga et al., 2011). The gingerols and shogaols are the two main biologically active constituents of ginger (Zhao et al., 2009).

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Wang and Ng (2005) found an antifungal protein in ginger rhizomes, and this protein had a strong antifungal activity toward various fungi.

On the other hand, AFs and OTA have been reported in ginger products in several studies. In Morocco, AFs were found in 10 out of 12 ginger samples up to a level of 9.1 µg kg^{-1} (Zinedine et al., 2006). In Korea, Cho et al. (2008) reported that only one of 7 ginger samples analysed contained AFs (0.18 µg kg^{-1}). In India, Thirumala-Devi et al. (2001) found that only 2 of 25 ginger samples contained OTA at levels of 23 and 80 µg kg^{-1}. In another study, all 25 bottles of ginger capsules (60 capsules/bottle, 625 mg/capsule) contained AFs and OTA at levels of 6.2-12.3 and 1.8-2.9 µg kg^{-1}, with mean values of 8.7 and 2.2 µg kg^{-1}, respectively. The authors also revealed that AFG_1 level was about 10% higher than that of the AFB_1, which was unexpected since AFB_1 is usually the major aflatoxin found in agricultural commodities (Trucksess and Scott, 2008). Iha and Trucksess (2010) investigated the migration of AFs and OTA from naturally contaminated powdered ginger to surrounding liquid (tea). They observed that at 100°C, approximately 30-40% of AFB_1 and total AFs and 20-30% of OTA in the contaminated ginger were found in the ginger tea, while at 50°C, about 10% of AFs and OTA were found in tea.

Moreover, the RASFF received a total of 19 notifications dealing with AFs in ginger during the period 2002-2011, of which 13 originated from India (68.4%), 5 from Nigeria (26.3%) and 1 from China (5.3%), while there was no notification for OTA.

However, in contrast AFs were not detected in ginger samples marketed in Portugal (Martins et al. 2001) and Saudi Arabia (Bokhari, 2007). While ginger marketed in Belgium, the Netherlands and Russia have been reported not to contain OTA at detectable levels (Goryacheva

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et al., 2006). With respect to other mycotoxins, type A trichothecenes (T-2 toxin and DAS) were not found in ginger samples from India (Lincy et al., 2008).

Nutmeg

Nutmeg (*Myristica fragrans*) is the kernel of the seed, removed from its husk and seed covering (aril), of the cultivated evergreen nutmeg tree of the *Myristica* genus, which is native to the Moluccas of Indonesia. The tissue of the seed kernel is yellowish in colour, with dark strands passing through it which contain the essential oil. Nutmeg is one of the most important spices used domestically on a worldwide basis. It is typically used for a variety of applications including (for seasoning soups, sauces, vegetables, meat and fish dishes), for sausage products, in baking, for liqueur production, in the food industry and for the production of essential oils (http://www.tis-gdv.de/tis_e/ware/gewuerze/muskatnu/muskatnu.htm). Indonesia and Grenada are worldôs major producers and exporters of nutmeg.

Inadequate drying and insect infestation of nutmegs can make the product susceptible to fungal attack and subsequently mycotoxin formation. *A. flavus* has been detected in nutmeg from Bahrain as the predominant fungal contaminant, followed by *Rhizopus stolonifer* (Mandeel, 2005). AFs were detected in 30 of 32 ground nutmeg samples commercialised in The Netherlands at concentrations ranging from 2.7 to 36.5 µg kg^{-1}, while no AFs were detected in 8 whole nutmeg kernels (Belijaars et al., 1975). In a study which monitored 67 nutmeg samples in Japan between 1986 and 1991, 29 (43%) were found to contain AFB_1 (Takahashi, 1993). According to information on the occurrence of AFs in imported spices in the European Union, among the 828 nutmeg, 282 samples contained AFs (European Commission, 1997). In Portugal,

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8 of 10 nutmeg samples analysed contained AFB_1 at levels ranging from 1.25 to 58 µg kg^{-1} (Martins et al., 2001), while AFB_1 was detected in only one of 3 nutmeg commercialised in Italy at a level of 2.27 µg kg^{-1} (Ramagnoli et al., 2007). However, El-Kady et al. (1995) did not detect AFs in 5 nutmeg samples from Egypt. Similarily, OTA was not found in nutmeg purchased from retail shops in Belgium, The Netherlands or Russia (Goryacheva et al., 2006).

In recent years, many rapid alerts on AFs in nutmegs have been issued by the European Commission. Between the years 2002-2011, the RASFF received a total of 61 notifications of mycotoxins in nutmeg of which 60 notifications concerned AFs particularly originating from Indonesia (25/60, 41.7%) and India (22/60, 36.7%). A large majority of these notifications have been received in the last two years (22 notifications in 2010 and 13 notifications in 2011). In marked contrast there have only been 2 notifications of OTA (in one notification OTA was simultaneously found with AFs) in nutmeg originating from India.

Saffron

The saffron spice is the dried stigma of *Crocus sativus* L. and belongs to the family Iridaceae. It is mainly cultivated in Iran, Mediterranean countries (Spain, France, Italy, Greece, Turkey, Libya) and India (Giaccio, 2004). Saffron gives a golden colour to food but due to its powerful and distinctive flavour, it is routinely used in soups, stews, bread and rice dishes in cusines in many countries (Peter, 2006). The composition of saffron is 14-16% water, 11-13% nitrogenous matters, 12-15% sugars, 41-44% extract soluble, 0.6-0.9% volatile oil, 4-5% fibres, and 4-6% total ashes. The major pharmacological activity of saffron appears to be due to its

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biologically active substances including picrocrocin, safranal, crocin and crocetin (Giaccio, 2004).

It has been reported that the biological active compound of saffron, crocetin protects against oxidation damage in rats primary hepatocytes, in particular a suppression of AFB_1-induced hepatotoxic lesions and has protective effects on the bladder toxicity induced by cyclophosphamide. The toxicity reduction seems to be due to the property of crocetin to stimulate defence mechanisms from the liver cells with an increase in glutathione-S-transferase activity (Giaccio, 2004).

A. flavus, *A. parasiticus* and *A. niger* were found to be the most frequent fungi in saffron samples imported from India (Aziz et al., 1998). In Egypt, Donia (2008) isolated *A. flavus*, *A. niger*, *A. terreus*, *A. fumigatus*, *A. candidus*, *A. ochraceus*, *A. crothecium*, *Penicillium* spp., *Fusarium* spp. and *Mucor* spp. from saffron samples. No mycotoxins including AFB_1, OTA, penicillic acid, ZEA and T-2 toxin were detected in saffron imported from India (Aziz et al., 1998), whereas AFB_1 was detected in 2 out of 5 saffron marketed in Portugal at levels of 2 and 2.8 µg kg^{-1} (Martins et al., 2001).

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Turmeric

Turmeric (also known as Indian saffron in Europe), derived from the rhizome of the plant *Curcuma longa* L., is a yellow coloured spice commonly used in the Indian subcontinent. Turmeric is used to preserve food through its antioxidant mechanism, to give colour and flavour to food. It has also been extensively used as a folk medicine for treating various disorders

including gas, colic, toothaches, chest pains, menstrual difficulties, stomach and liver problems, and to heal wounds (Aggarwal et al., 2007).

Turmeric contains a wide variety of phytochemicals including curcumin, demethoxycurcumin, bisdemethoxycurcumin, zingiberene, curcumenol, curcumol, eugenol, tetrahydrocurcumin, triethylcurcumin, turmerin, turmerones and turmeronols (Aggarwal et al., 2007). Turmeric extract has been reported to effectively inhibit the growth of *A. flavus* (68%) and AFB_1 production (72.2%) at 5 g kg^{-1} concentration (Reddy et al., 2009).

Curcumin an extract of turmeric, is the most active compound and plays an important role in ameliorating aflatoxin-induced hemolysis (Mathuria and Verma, 2007). Curcumin has been shown to inhibit AFs production more than 90% at concentrations of 5-10 mg ml^{-1}. Turmeric and curcumin were also found to reverse the aflatoxin induced liver damage produced by feeding AFB_1 (5 µg/day per 14 days) to ducklings (Soni et al., 1992). In another study, dietary administration of turmeric (0.05%) and curcumin (0.005%) to rats significantly reduced the number of gammaglutamyl transpeptidase-positive foci induced by AFB_1 which is considered as the precursor of hepatocellular neoplasm (Soni et al, 1997). In a recent study, Yarru et al. (2009) demonstrated partial protective effects of curcumin on changes in expression of antioxidant, biotransformation and immune system genes in the livers of chicks fed AFB_1. In a similar study, turmeric powder (100-200 mg kg^{-1} b.w.) and curcumin (50-100 mg kg^{-1} b.w.) were shown to display protective effects against AFB_1 (2 µg kg^{-1} b.w.) induced toxicity by modulating lipid peroxidation and augmenting defense system (Sharma et al., 2011).

While it contains some active substances which are active against toxigenic fungi, several reports show that turmeric may be contaminated with various mycotoxins. AFB_1 was detected in

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one of 3 turmeric samples from Pakistan at a level of 6.54 µg kg^{-1} (Hussain et al., 2012). In Ireland, 4 out of 10 turmeric samples were found to be contaminated with AFs at a mean level of 1.9 µg kg^{-1} (OôRiordan et al., 2008), while turmeric samples were AFs-free in Italy (Ramognoli et al., 2007) and Bahrain (Musaiger et al., 2008).

There has been only one report of finding OTA in turmeric, with 9 out of 25 samples from India being positive; at levels ranging from 11 to 102 µg kg^{-1} (Thirumala-Devi et al., 2001). In the USA, FB_1 was detected in only one of three turmeric powder samples at a level of 150 µg kg^{-1} (Trucksess et al., 2006), while type A trichothecenes were not found in one turmeric sample from India (Lincy et al., 2008).

With regard to RASFF notification, a total of 14 notifications were received on mycotoxins in turmeric samples since 2002, of which 13 notifications concerned AFs and only one notification concerned OTA; all of which originated from India.

Black cumin

Black cumin (*Nigella sativa* L.), is an annual plant from the Ranunculaceae family, which originates in the Mediterranean region but which is indigenous to the countries of the Middle East, North Africa and Southeastern Europe. Black cumin is used principally to flavour food, either as whole seeds, in powdered form or as an oleoresin extract. It also possesses a high value as a herbal medicine (Luetjohann, 1998).

It has been reported that *A. flavu*s, *A. parasiticus*, *Penicillium variable*, *Rhizopus stolonifer* and *Mucor pusillus* are the main fungi which have been isolated from black cumin imported from India (Aziz et al., 1998). In another study, the lowest abundance of *A. flavus* was

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observed in black cumin among 16 various types of spices from three different districts of India (Moorthy et al., 2011).

An Egyptian study has shown that black cumins can be naturally contaminated with mycotoxins, with 2 out of 5 black cumin samples being found to be contaminated with mycotoxins at levels 25 and 31 µg kg^{-1} for AFs and 8 and 12 µg kg^{-1} for citrinin (El-Kady et al., 1995). Similarily AFs (20-30 µg kg^{-1}) and OTA (35 µg kg^{-1}) have been detected in black cumins imported from India (Aziz et al., 1998). More recently, Bokhari (2007) found AFs contamination (40% incidence) in black cumin from Saudi Arabia in the ranging from 24 to 35 µg kg^{-1}.

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Dill

Anethum graveolens L., commonly known as dill is an annual herb, which is native to the Mediterranean region and to southeastern Europe (Heamalatha et al., 2011). The genus name *Anethum* is derived from the Greek word *aneeson* or *aneeton*, which means strong smelling. Its fresh and dried aromatic leaves are used for flavouring and seasoning in various foods such as salads, soups, pickles and sauce. Its leaves are also used for the preparation of tea. The aromatic dill seeds are often used as a spice, and are also known to display carminative, mildly diuretic, galactogogue, stimulant and stomachic properties (Jana and Shekhawat, 2010).

Dill oil is extracted from seeds, leaves and stems, which contains an essential oil (EO) used as flavoring in the food industry (Jana and Shekhawat, 2010). The major components detected in dill oil are carvone (41.5-55.2%), limonene (16.6-32.6%), apiole (14.4-16.8%), linalool (3.7%), trans-dihydrocarvone (2.8%), cis-dihydrocarvone (2.6%), trans-isocroweacin (0.8%), together with several other components in minor percentages (Singh et al., 2005; Tian et al., 2012). The

major components in dill extract are dill apiole (43.2%), linoleic acid (23.1%), trans-anethole (11.0%), 2-propanone, 1-(4-methoxyphenyl) (4.6%), carvone (3.1%), p-anisaldehyde (2.7%), myristicin (1.5%), palmitic acid (1.3%) and foeniculin (0.9%) (Singh et al., 2005).

It has been shown that EOs of dill have antifungal activity against *A. flavus* and AFB_1 production *in vitro* (El-Habib, 2012) as well as other Aspergilli (Singh et al., 2005; Tian et al., 2011; Isopencu and Ferdes, 2012). The EO of dill has been observed to disrupt the permeability barrier of the plasma membrane and inhibit the mitochondrial ATPase of *A. flavus* (Tian et al., 2012). In another study, the EO of dill, dillapiol inhibited AFG_1 production by *A. parasiticus* with an IC50 value of 0.15 μM without inhibiting either AFB_1 production or fungal growth (Razzaghi-Abyaneh et al., 2007).

While there is no much data on the natural occurrence of mycotoxins in dill, two studies have been performed; neither of which detected AFs in dill samples in Canada (Scott and Kennedy, 1975) and Egypt (Donia, 2008).

Mentha

Mentha (also known as mint) is a genus of about 18 species of flowering plants in the family Lamiaceae, which is widely distributed across all continents (except in South America and Antartica). The centers of variety of this genus are Europe, Australia, Central Asia, North Africa and the Mediterranean region (Mkaddem et al., 2009). *M. piperita* (peppermint), *M. pulegium*, *M. spicata* (spearmint) and *M. longifolia* is the most common species in Turkey. Mint leaves, fresh or dried, are used in teas, beverages, salad, chewing gum and candies. It is also freqeuntly used in Turkish cuisine in the preparation of many foods for flavour and aroma.

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The EOs of mint contain varying levels of monoterpenoids like carvone, limonene, menthone, menthol, pulegone and dihydrocarveol (Mkaddem et al., 2009), which have been shown to possess antioxidant (Elmasta et al., 2006; Gulluce et al., 2007; Dhifi et al., 2012) and antimicrobial activity (Gulluce et al., 2007; Mkaddem et al., 2009). Mint EOs inhibited both mycelial growth and AFs formation in *A. flavus* on rice powdercorn steep medium (Mabrouk and El-Shayeb, 1980), yeast extract-sucrose medium (El-Habib, 2012) and stored corn (Gibriel et al., 2011). The minimum inhibition concentration of mentha EO against *A. flavus* was recorded as 400 μl L^{-1} (Kumar et al., 2009).

Mint leaves marketed in Egypt have been reported not to contain AFB_1, OTA, penicillic acid, ZEA and T-2 toxin (Aziz et al., 1998; Donia, 2008), while El Kady et al. (1995) found AFs in only one of 5 peppermint from Egypt. In a recent work, AFs were not detected in any of 30 samples of mint from the Vayk region of Armenia (Grigoryan et al., 2011).

Thyme

Thyme (*Thymus vulgaris* L., also known as garden thyme), belongs to the Lamiaceae family and is an aromatic and medicinal herb which is native to the Western Mediterranean region. It has been used for many years as an aromatic ingredient in cuisine and as a folk medicine in many countries. Fresh and dried forms of the herb are used for seasoning fish, poultry, soups, vegetables, flavoring liqueur, as well as in herbal teas (Ozcan and Chalchat, 2004).

The EO in thyme possesses a wide spectrum of fungicidal activity (Segvic Klaric et al., 2007). The chemical composition of the volatile oil of thyme is very different, primarily in terms

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of the quantities of the two basic components, thymol and carvacrol (Isopencu and Ferdes, 2012). It has been shown that thymol isolated from thyme leaves can inhibit both mycelial growth and AFs production (Llewellyn et al., 1992; Montes-Belmont and Carvajal, 1998; Rasooli and Abyaneh, 2004; Razzaghi-Abyaneh et al., 2009; Da Silva et al., 2012). Soliman and Badeaa (2002) have shown that thyme EO was inhibitory at a concentration of 500 mg kg^{-1} against *A. flavus*, *A. parasiticus*, *A. ochraceus* and *Fusarium moniliforme*. The same effect was demonstrated by Nguefack et al. (2004), who reported that thyme EO at a concentration of 200 mg kg^{-1} reduced the radial growth of *A. flavus* by 81%, while complete inhibition of conidial germination of *A. flavus* was achieved at a concentration of 1000 mg kg^{-1}. It has also been reported that thyme oils at doses between 250 and 500 mg day^{-1}, for 28 days, were able to modify rumen fermentation in sheep by changing protozoal activity and motility and could approximately normalized the adverse effects of aflatoxin (Abdel-Fattah et al., 2010).

AFs and other toxins have not been reported to be present in thyme (El-Kady et al., 1995; Ramagnoli et al., 2007), while *A. niger*, *Penicillium arenicola* and *Rhizopus stolonifer* were most frequently isolated species on thyme from Saudi Arabia (Hashem and Alamri, 2010).

Mustard seed

Mustard, which belongs to the genera *Brassica* and *Sinapis* are cultivated for their dried ripe seeds, with colours ranging from white (*Sinapis alba* L.) to brown Indian mustard (*Brassica juncea* L.) and black mustard (*Brassica nigra* L.) (Tomar-Balhara et al., 2006; UNIDO/FAO, 2006). Canada and Nepal are the major mustard seed producers in the world. Mustard seeds are used as a spice in the cuisine of various countries including India, Asia, Northern Europe,

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Mediterranean, North America and Africa or prepared mustard (condiment). Mustard seeds are also an important source of edible oil in several countries.

Mustards have been reported to be sensitive to aflatoxin contamination under both field conditions and during storage, and various levels of AFs contamination have been detected in mustard seeds (Bilgrami et al., 1992). Aflatoxin contamination in mustard seeds may be ascribed to several environmental agronomic and biological factors among which the temperature and humudity of the storage site are most significant (Tomar-Balhara et al., 2006). Sahay and Prasad (1990) studied the presence of AFs in 100 samples each of seed, oil and cakes of mustard from India. The authors detected AFs in 44 mustard seed, 33 mustard oil and 80 mustard cakes up to levels of 750, 87 and 1420 µg kg^{-1}, respectively. Twenty-five percent of *A. flavus* isolates (286 out of 1143 isolates screened) from mustard products were also toxigenic, producing different components of aflatoxins in varying concentrations. In a similar study, 42 out of 135 samples of mustard collected and stored in traditional storage structures in India contained AFB_1 (Ranjan et al., 1992). In contrast however, Martins et al. (2001) did not detect AFB_1 in mustard seeds being marketed in Portugal.

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Sesame seed

Sesame (*Sesamum indicum* L.), an annual herb; is considered to be the oldest oilseed crop cultivated in several countries (Asadi et al., 2011). Sesame is grown for its seed in a wide range of environments from tropical to temperate climates and requires mean temperatures above 10°C up to a 40°C maximum (UNIDO/FAO, 2006). Mynmar is the largest producer of sesame seeds in the world with almost 500.000 metric tonnes, followed by India, China, Ethiopia, Sudan and

Uganda (FAO, 2010). Sesame seed is widely used in various cuisines. It is the main ingredient of traditional sweets such as *tahin, humus* and *helva*, which are very popular in Turkey and in various Middle Eastern countries. In Turkey, the seeds are also added to bakery products such as *simit* (a circular bread with sesame seeds), *pide* (flat bread), breadsticks, cookies etc.

It has been shown that sesame seeds are sensitive to *A. flavus* invasion and subsequently aflatoxin formation (Llewellyn et al., 1981a; Jonsyn, 1988; Habibi and Banihashemi, 2008; Mbah and Akueshi, 2009). Toxigenic species of *Aspergillus* and *Penicillium* have been isolated in sesame seeds from Sierra Leone. AFB_1, AFG_1, OTA and citrinin have also been detected in these seeds (Jonsyn, 1988). Tabata et al. (1993) found AFB_1 in 2 of 19 sesame seed samples with levels of 0.6 and 2.4 µg kg^{-1}. Surprisingly, no type B aflatoxins were detected in 20 sesame seed samples in a Turkish study; while AFG_1 occurred in all samples at a mean level of 0.75 µg kg^{-1} (Yentür et al., 2006). In another study conducted in the Khorasan province of Iran, sesame seeds contained AFB_1 in 33 out of 182 samples analysed ranging from 0.49 to 5.54 µg kg^{-1} (Asadi et al., 2011). In a similar recently conducted study in Malaysia, Reddy et al. (2011) found AFB_1 in 7 out of 8 sesame seed samples (87.5%) in the range of 0.54-1.82 µg kg^{-1}, with a mean level of 0.9 µg kg^{-1}. More recently, Ezekiel et al. (2012) investigated 17 sesame samples from Nigeria by LC/ESI-MS/MS for the presence of fungal and bacterial metabolites. They detected DON and ZEA in 15 out of 17 samples, but at levels 8-76 µg kg^{-1} and 0.7-38 µg kg^{-1}, respectively; while AFs and fumonisins (FB_1 and FB_2) were not found in all sesame seeds. Similarly, Ramagnoli et al. (2007) could not detect AFs in 27 sesame seed samples commercially available in Italy.

With regard to sesame-based products, Li et al. (2009) detected AFs in 37 out of 100 sesame paste samples from China, some of which containing high levels of (up to 20 µg kg^{-1})

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AFs. Even though the roasting process is used, AFB_1 can be detected in *tahin (tahini* in Arabic) samples. Nilüfer and Boyacœoî lu (2002) found total AFs in one of 14 *tahin* samples with high level (176 µg kg^{-1}). However, AFB_1 was not detected in any 34 plain *helva* samples consumed in Turkey (Var et al., 2007). Aflatoxin contamination was not observed in sesame oil (n = 20) in Japan (Kumagai et al., 2008), while all sesame oils in Khartoum State, Sudan contained AFs with levels higher than 20 µg kg^{-1} (Elzupir et al., 2010). In another study, trace levels of OTA have been reported in a sample of sesame oil (Patel et al., 1996).

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Curry powder

Curry powder is a mixture of a wide variety of spices of varying composition based on South Asian cuisine. Most receipts and producers of curry powder usually include turmeric, coriander, cumin, fenugreek, and red chilli in their blends. Depending on the receipe, additional ingredients such as ginger, garlic, fennel seed, caraway, cinnamon, clove, mustard seed, cardamom, nutmeg and black pepper may also be added.

AFs have been reported to occur in curry powder marketed in various countries. In Portugal, Martins et al. (2001) detected AFB_1 in 2 out of 5 curry powder samples at levels of 1 and 3 µg kg^{-1}. In Bahrain, 83% of mixed curry powder analysed contained AFs at mean level of 6.8 µg kg^{-1} (Musaiger et al., 2008). In Ireland, AFs were detected in 3 out of 20 curry powders, ranging from 0.5 to 9.1 µg kg^{-1} (OôRiordan and Wilkinson, 2008). In another screening study in Korea, Cho et al. (2008) found AFs in 2 out of 20 curry powder at levels of between 0.13 and 0.46 µg kg^{-1}. In another study, Menon and Zavaier (2010) observed that 12 of 20 retail samples of curry powder from India contained AFs up to a level of 48 µg kg^{-1}. In a recent screening study

conducted in Germany, AFs and OTA were simultaneously detected in all curry powder samples, with mean levels of 0.35 and 1.44 µg kg^{-1}, respectively (Reinhold and Reinhardt, 2011).

In the category ñherbs and spicesò, there have been many notifications of mycotoxins in curry powder, followed by capsicums and nutmeg. There were 48 notifications concerning detection of AFs in curry powder particularly from India (79.2%) and Pakistan (14.6%) in the years between 2002 and 2011. Of these notifications, OTA was however simultaneously found with AFs in only one notification which originated from India.

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Other spices

There are limited reports on the occurrence of mycotoxins in many other spices and herbs. In a large screening study in Egypt, AFs were detected in 3 out of 5 anise (30 ï 35 µg kg^{-1}), 3 out of 5 caraway (14 ï 18 µg kg^{-1}), 2 out of 5 fennel (20 ï 25 µg kg^{-1}) and one out of 5 marjoram (9 µg kg^{-1}) samples, while STC was detected in only one of marjoram (17 µg kg^{-1}) and 3 of the caraway samples (14 ï 18 µg kg^{-1}) (El-Kady et al., 1995). They also observed that cardamom, laurel, mastic, rosemary and safflower were mycotoxin-free. In another Egyptian study, AFB_1 was found in Karkadia (24 µg kg^{-1}), Halfa bar (camelôs hay, 64 µg kg^{-1}), rawind (48 µg kg^{-1}), khashab keena (cinchona bark, 49 µg kg^{-1}), misht ballot (26 µg kg^{-1}) kesher romman (pomegrenate peel, 105 µg kg^{-1}), somowa (cleme, 26 µg kg^{-1}) and salamakka (senna pods, 48 µg kg^{-1}) (Selim et al., 1996). Aziz et al. (1998) tested a total of 14 different medicinal plants and spices imported from India for the incidence of AFB_1, OTA, penicillic acid, ZEA and T-2 toxin. They detected AFB_1 in 33% of fennel, 14% of lime tree, 14% of absinthium, 40% of ginger, 25% of carob tree, 50% of chamomile and 50% of worm wood analysed up to and at a mean level of

160 µg kg^{-1}; while no AFB_1 was found in curcuma, rosse and lesser glangel. OTA was detected only in fennel and absinthium at levels of 80 and 20 µg kg^{-1}, respectively; while penicillic acid, ZEA and T-2 toxin were not detected in any of the medicinal plant and spices samples.

Rizzo et al. (2004) studied the incidence of toxigenic fungi and their mycotoxins in 152 dried medicinal and aromatic herbs, belonging to 56 species; which are used as raw materials for drugs. *A. flavus* and *A. parasiticus* (Flavi section) were reported to be the predominant species isolated. AFs concentrations ranged between 10 and 2000 µg kg^{-1}. The authors also revealed that only 26% of isolates from the Circumdati section (*A. alliaceus*, *A. ochraceus* and *A. sclerotium*) produced OTA ranging from 0.12 to 9 µg kg^{-1}. Moreover, from a total of 29 strains of *Fusarium* spp., 27.5% were *F. verticillioides* and *F. proliferatum*, which produced fumonisin B_1 and fumonisin B_2 ranged from 20 to 22000 µg g^{-1} and from 5 to 3000 µg g^{-1}, respectively. In another survey conducted in Tunusia, Zaied et al. (2010) reported that OTA was found in 54% (13/24) of caraway and 52% (13/25) of curcuma samples at levels ranging from 28 to 510 µg kg^{-1} and 39 to 925 µg kg^{-1}, respectively; while many of the aromatic herbs such as turmeric, coriander, fennel seeds, marjoram, thyme, basil leaves, garlic, laurel leaves, parsley, popy-seeds and rosemary commercialised in Italy were AFs-free (Ramognoli et al., 2007).

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CONCLUSIONS

While most dried foods are considered comparatively low-risk products from a of microbiological standpoint, herbs and particularly spices, are an exception and commonly contain high levels of fungi and other microorganisms that can potentially cause food poisoning. Herbs and spices can be contaminated with several toxigenic fungi during crop production,

harvesting, washing and sun-drying which can take place either ñon farmò, or also during subsequent processing and storage. Most of the spices traditionally traded throughout the world are products of tropical environments. The climatic conditions (high humidity and high temperature) in herbs and spices producing areas are particularly suited to mould growth and subsequently mycotoxin formation. It is well established that the risk of AFs contamination is higher in geographical regions with a tropical or sub-tropical climate. Among the herbs and spices, capsicums, nutmeg, curry powder, ginger, turmeric and black pepper tend to have a comparatively high risk of mycotoxin (especially AFs and OTA) contamination. The absence or low mycotoxin contamination in other spices and herbs indicates that they are likely not to be a good substrate for fungal growth or may result from inhibition of fungal proliferation and mycotoxin production by their EOs and aromatic substances. Good agricultural practices (GAP) coupled with good manufacturing practices (GMP), including removing injured and diseased fruits, avoiding contact with soil during drying, quickly reaching ñsafeò moisture levels, improved drying methods and storage conditions, increased hygienic practices and safer packaging procedures have resulted in much lower levels of mycotoxin contamination in spices and herbs. Furthermore, the use of ongoing training programs for farmers, manufacturers and traders about GAP and GMP by Food Safety Authorities in various countries, should be continued and further encouraged as this is also having a very beneficial effect in lowering the mycotoxin levels in these commodities.

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Tabel 1. Classifications, part of plant used and major-producing countries of spices and herbs.

Common name	Binomial name	Family	Used part	Classification, based on the degree of taste	Major-producing countries
Anise (aniseed)	*Pimpinella anisum* L.	Apiaceae (or Umbelliferae)	Fruits (seeds)	Aromatic spice	China, Turkey, Spain, Greece, Egypt, India
Basil	*Ocimum basilicum* L.	Lamiaceae	Fresh and dried leaves	Herb	France, Mediterranean region, USA
Bay leaf	*Laurus nobilis* L.	Lamiaceae	Fresh and dried leaves	Herb	Turkey, Algeria, Belgium, France, Greece
Black cardamom	*Amomum subulatum, Amomum costatum*	Zingiberaceae	Fruits (seeds)	Aromatic spice	Nepal, India, Bhutan
Black cumin	*Nigella sativa* L.	Ranunculaceae	Seeds	Aromatic spice	Egypt, Sudan, Ehiopia, Syria, Turkey, Iraq, Iran,

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					Pakistan, India
Black pepper	*Piper nigrum* L.	Piperaceae	Dried fruits	Hot spice	Vietnam, India, Brazil, Indonesia
Caraway	*Carum carvi* L.	Apiaceae	Fruits (seeds)	Aromatic spice	The Netherland, European countries, Russia
Celery	*Apium graveolens* L.	Apiaceae	Seeds	Aromatic vegetables	China, France, India, Italy, Pakistan, USA
Chilli, paprika	*Capsicum* spp.	Solanaceae	Fruits	Hot spice (chilli)/Mild spice/colourant (paprika)	India, China, Mexico, Turkey, Hungary
Cinnamon	*Cinnamomum zeylanicum* Blume (syn. *Cinnamomum verum* J. Presl)	Louraceae	Bark	Aromatic spice	Indonesia, China, Sri Lanka, Vietnam

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Clove	*Szygium aromaticum* (L.) Merrill & Perry	Myrtaceae	Dried flower buds	Aromatic spice	Indonesia, Madagaskar, United Republic of Tanzania
Coriander	*Coriandrum sativum* L.	Apiaceae	Dried fruits (seeds)	Mild spice	Morocco, Romania, Mexico, Argentina, Canada
Cumin	*Cuminum cyminum* L.	Apiaceae	Dried fruits (seeds)	Aromatic spice	Turkey, Iran, Mediterranean countries
Dill	*Anethum graveolens* L.	Apiaceae	Fresh and dried leaves/seeds	Herb/Aromatic spice	India, Pakistan, Mediterranean countries, The Netherland, Mexico
Fennel	*Foeniculum vulgare* Mill.	Apiaceae	Dried fruits (seeds)	Aromatic spice	India, China, Turkey, Egypt, France

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Fenugreek	*Trigonella foenum-graecum* L.	Fabaceae	Seeds/Leaves	Aromatic spice	India, Nepal, Pakistan, Bangladesh, Egypt
Garlic	*Allium sativum* L.	Amaryllidaceae (Liliaceae)	Bulbs	Aromatic vegetables	China, India, Republic of Korea, Egypt
Ginger	*Zingiber officinale* Roscoe	Zingiberaceae	Rhizome	Hot spice	India, China, Nepal, Thailand, Nigeria
Green cardamom	*Elettaria cardamomum* (L.) Maton	Zingiberaceae	Fruites (seeds)	Aromatic spice	India, Guatemala, Sri Lanka
Lime tree	*Tilia* spp.	Malvaceae (Tiliaceae)	Dried inflorescence	Tree herb	USA, Canada, Georgia, Turkey
Marjoram	*Origanum majorana* L.	Lamiaceae	Leaves	Herb	Egypt, Mediterranean

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					countries
Mustard seed	*Brassica nigra* L./*B. juncea* (L.) Czern /*Sinapis alba* L.	Brassicaceae	Seeds	Hot spice/Aromatic spice	Canada, Nepal, Mynmar, Ukraine
Nutmeg	*Myristica fragrans* Houtt.	Myristicaceae	Seeds	Aromatic spice	Indonesia, Grenada, India
Onion	*Allium cepa* L.	Amaryllidaceae	Bulbs/Fresh leaves	Aromatic vegetables	China, India, USA, Egypt, Iran, Turkey
Oregano (wild marjoram)	*Origanum vulgare* L.	Lamiaceae	Leaves	Herb	Mediterranean countries
Parsley	*Petroselinum crispum* (Mill.)	Apiaceae	Fresh and dried leaves	Herb	Most part of the world
Peppermint	*Mentha piperita* L.	Lamiaceae	Fresh and dried leaves	Herb	Most part of the world

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Poppy seed	*Papaver* spp.	Papaveraceae	Seeds	Aromatic spice/Oilseed	Turkey, Czech Republic, Spain, France, Croatia
Rosemary	*Rosmarinus officinalis* L.	Lamiaceae	Fresh and dried leaves	Herb	Mediterranean countries, Northern Africa, England, Mexico, USA
Saffron	*Crocus sativus* L.	Iridaceae	Dried stigma and styles	Aromatic/Colourant/Mild spice	Iran, Mediterranean countries
Sesame seed	*Sesamum indicum* L.	Pedaliaceae	Seeds	Aromatic spice/Oilseed	Mynmar, India, China, Ethiopia, sudan
Spearmint	*Mentha spicata* L.	Lamiaceae	Fresh and dried leaves	Herb	USA, Egypt
Sumac	*Rhus coriaria* L.	Anacardiaceae	Dried fruits	Aromatic spice	Middle East, North

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					Africa, USA
Thyme (Garden thyme)	*Thymus vulgaris* L.	Lamiaceae	Leaves and stems	Herb	Turkey, Greece, Israel, Albania, Morocco, Mexico
Turmeric (Indian saffron)	*Curcuma longa* L.	Zingiberaceae	Rhizome	Aromatic/Colourant/Mild spice	India, Bangladesh, China Taiwan, Indonesia, Pakistan
Vanilla	*Vanilla planifolia* Andr.	Orchidaceae	Fruits	Aromatic spice	Indonesia, Madagascar, China, Mexico, Turkey

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Table 2. The number of RASFF notifications for herb and spices contaminated by mycotoxins.

Mycotoxin	**Number of RASFF notifications**										
	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Total**
AFs	12	14	22	47	36	33	25	21	112	49	371
OTA	-	2	3	10	2	8	2	11	5	15	58
AFs-OTA	-	-	4	3	2	2	1	2	6	2	22

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Table 3. Content of mycotoxins in capsicums (chilli peppers, paprika etc.) commerialised in various countries.

Country	Product	No. of samples	Positive *n* (%)	Method	Mycotoxin	Mean (μg kg^{-1})	Range (μg kg^{-1})	Reference
Bahrain	Red chilli powder	6	6 (100)	HPLC-FD	AFs	30	n.r.	Musaiger et al. (2008)
Brazil	Paprika	70	43 (61)	HPLC-FD	AFB_1	3.4	0.5 ï 7.3	Shundo et al. (2009)
			60 (86)	HPLC-FD	OTA	7	0.24 ï 97.2	
Egypt	Red pepper	5	3 (60)	TLC	STC	n.r.	10 ï 23	El-Kady et al. (1995)
Ethiopia	Ground red pepper	60	8 (13)	TLC	AFs	n.r.	250 ï 525	Fufa and Urga (1996)

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Hungary	Ground red pepper	70	18 (26)	HPLC-FD	AFB_1	n.r.	0.14 ï 15.7	Fazekas et al. (2005)
			32 (46)	HPLC-FD	OTA	n.r.	0.4 ï 66.2	
India	Chilli	182	107 (59)	ELISA	AFB_1	n.r.	<10 ï 969	Reddy et al. (2001)
India	Chilli	16	2 (13)	ELISA	AFB_1	n.r.	1.8 ï 8.4	Saha et al. (2007)
Ireland	Chilli powder	30	10 (33)	HPLC-FD	AFs	n.r.	0.35 ï 27.5	Oô Riordan and Wilkinson (2008)
	Paprika	10	2 (20)	HPLC-FD	AFs	n.r.	0.4 ï 6.4	

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Italy	Chilli	11	5 (46)	ELISA	AFB_1	n.r.	5 ï 27	Ramagnoli et al. (2007)
Korea	Red pepper powder	41	7 (17)	HPLC-FD	AFB_1	n.r.	0.08 ï 4.45	Cho et al. (2008)
			7 (17)	HPLC-FD	AFs	0.87	0.08 ï 4.66	
Korea	*Capsicum* powder	192	42 (22)	HPLC-FD	OTA	0.27	<0.2 ï 35	Ahn et al. (2010)
Malaysia	Chilli	8	8 (100)	ELISA	AFB_1	2.62	0.58 ï 3.5	Reddy et al. (2011)
Malaysia	Dried chilli	80	52 (65)	HPLC-FD	AFB_1	3.37	0.2 ï 56.61	Jalili and Jinap (2012)
			52 (65)	HPLC-FD	AFs	4.56	0.2 ï 79.7	

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			65 (82)	HPLC-FD	OTA	7.15	0.2 ï 101	
Morocco	Paprika	14	14 (100)	HPLC-FD	AFB_1	2.88	<LOD ï 5.4	Zinedine et al. (2006)
			14 (100)	HPLC-FD	AFs	5.23	<LOD ï 9.68	
Pakistan	Red chilli	176	116 (66)	TLC	AFB_1	n.r.	n.d. ï 25>	Shamsuddin et al. (1995)
Pakistan	Dried chilli	13	13 (100)	HPLC-FD	AFs	33.4	0.1 ï 96.2	Paterson (2007)
Pakistan	Whole chilli	22	16 (73)	HPLC-FD	AFB_1	24.7	<LOD ï 96.3	Iqbal et al. (2010)
	Chilli powder	22	19 (86)	HPLC-	AFB_1	32.2	<LOD ï	

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				FD			89.6	
Pakistan	Chilli	85	61 (72)	HPLC-FD	AFs	n.r.	<0.05 ï 95.90	Iqbal et al. (2011)
Portugal	Paprika	12	8 (67)	HPLC-FD	AFB_1	n.r.	1 ï 18.2	Martins et al. (2001)
Saudi Arabia	Red pepper	5	3 (60)	TLC	STC	n.r.	11 ï 25	Bokhari (2007)
Spain	Paprika	21	19 (90)	HPLC-FD	AFB_1	1.1	0.7 ï 3.8	Hierro et al. (2008)
			15 (71)	HPLC-FD	OTA	11.9	0.7 ï 73.8	

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Spain	Paprika	64	38 (59)	HPLC-FD	AFs	n.r.	0.5 ï 7.25	Santos et al. (2010)
			62 (98)	HPLC-FD	OTA	n.r.	0.1 ï 281	
			25 (39)	HPLC-FD	ZEA	n.r.	10 ï 131	
	Chilli	35	14 (35)	HPLC-FD	AFs	n.r.	0.5 ï 2.49	
			35 (100)	HPLC-FD	OTA	n.r.	0.62 ï 44.6	
			16 (46)	HPLC-FD	ZEA	n.r.	10 ï 129	
Tunusia	Paprika	23	16 (70)	HPLC-FD	OTA	203	31 ï 528	Zaied et al. (2010)
Turkey	Red chilli flake	31	28 (90)	TLC	AFB_1	8.43	n.d. ï 28.5	Taydaк and Aккēn (1995)

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	Red chilli powder	30	30 (100)	TLC	AFB_1	4	1.25 ï 15.99	
Turkey	Red chilli flake	40	40 (100)	TLC	AFB_1	8.66	1.1 ï 44	Aĵ aoĵ lu (1999)
Turkey	Red chilli powder	30	14 (46.7)	TLC	AFs	n.r.	5 ï 25	Dokuzlu (2001)
Turkey	Red pepper	26	17 (65)	HPLC-FD	AFB_1	n.r.	0.6 ï 56	Omurtag et al. (2002)
Turkey	Red-scaled pepper	44	8 (18)	TLC	AFs	n.r.	1.1 ï 97.5	Erdogan (2004)
	Red pepper powder	26	3 (11)	TLC	AFs	n.r.	1.8 ï 16.4	

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Turkey	Paprika	30	27 (90)	HPLC-FD	AFs	n.r.	0.5 ï 124.6	Bircan (2005)
	Chilli powder	15	15 (100)	HPLC-FD	AFs	n.r.	1.8 ï 85.9	
Turkey	Red pepper	50	50 (100)	ELISA	AFB_1	n.r.	1.48 ï 70.05	Kanbur et al. (2006)
Turkey	Red pepper	30	6 (20)	ELISA	AFB_1	n.r.	2.9 ï 11.2	Colak et al. (2006)
			11 (37)	ELISA	AFs	n.r.	0.8 ï 15.4	
	Red-scaled pepper	30	13 (43)	ELISA	AFB_1	n.r.	1.9 ï 35.5	
			17 (57)	ELISA	AFs	n.r.	0.7 ï 46.8	

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Turkey	Red pepper powder	100	68 (68)	ELISA	AFB_1	3.92	0.025 ï 40.9	Aydin et al. (2007)
Turkey	Paprika	23	19 (83)	HPLC-FD	AFs	n.r.	0.38 ï 14.71	Bircan et al. (2008)
Turkey	*Isot*	75	72 (96)	ELISA	AFB_1	1.9	0.11 ï 24.7	Ardic et al. (2008)
Turkey	Flaked red pepper	38	n.r.	ELISA	AFs	4.79	n.d. ï 9.46	Kursun and Mutlu (2010)
	Red pepper	34	34 (100)	ELISA	AFs	6.36	3.55 ï 9.55	
United Kingdom	Chilli powder	51	35 (69)	TLC	AFs	n.r.	LOD ï 48	Macdonald and Castle (1996)

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United Kingdom	Paprika	26	26 (100)	HPLC-FD	AFB_1	n.r.	0.2 ï 3.4	FSI (2005)
			26 (100)	HPLC-FD	OTA	n.r.	0.3 ï 47.7	
	Chilli powder	31	29 (94)	HPLC-FD	AFB_1	n.r.	<0.2 ï 13.9	
			31 (100)	HPLC-FD	OTA	n.r.	0.2 ï 152.2	
	Cayenner pepper	4	4 (100)	HPLC-FD	AFB_1	n.r.	0.2 ï 6.8	
			4 (100)	HPLC-FD	OTA	n.r.	2.4 ï 16.5	
West Africa	Dried chilli	30	1 (3)	HPLC-FD	AFs	n.r.	3.2	Hell et al. (2009)

HPLC-FD: High performance liquid chromatography-fluorescence detection; TLC: Thin-layer chromatography; ELISA: Enzyme-linked immunosorbent assay; AFB_1: Aflatoxin B_1; AFs: Sum of AFB_1, AFB_2, AFG_1 and AFG_2; OTA: Ochratoxin A;

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STC: Sterigmatocystin; ZEA: Zearalenone; *Isot*: Traditional deep-red ground pepper; n.r.: Not reported; n.d.: Not detected;

LOD: Limit of detection

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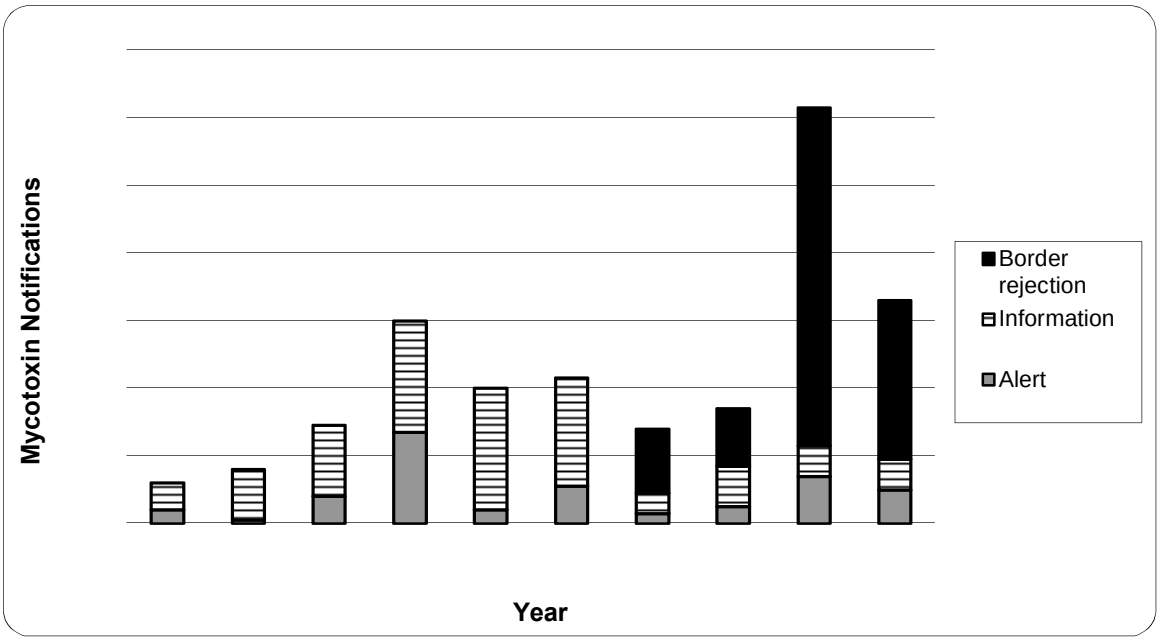

Figure 1. Evaluation of RASFF notifications on mycotoxins in the category ñspices and herbsò during the period 2002-2011.

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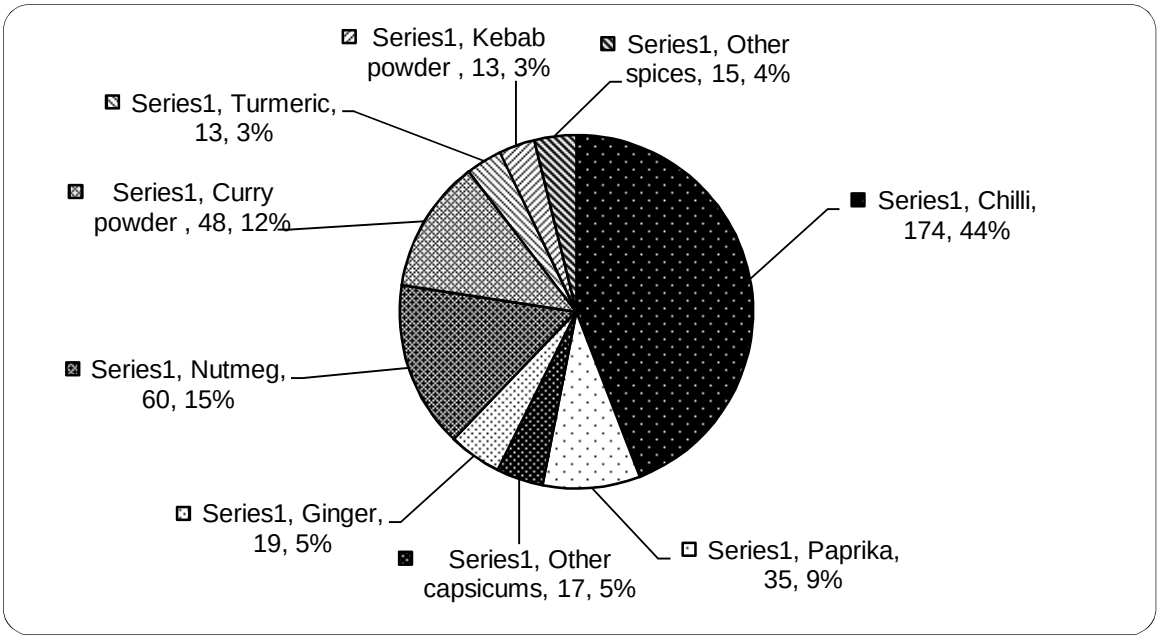

Figure 2. RASFF notifications on spices containing AFs during the period 2002-2011.

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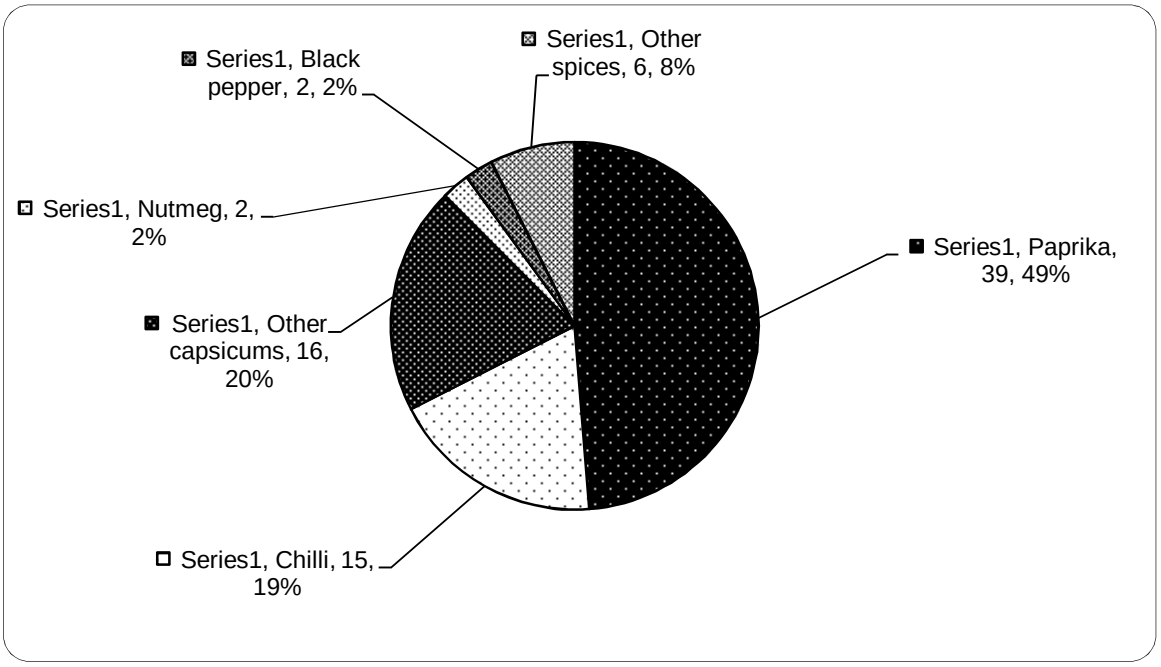

Figure 3. RASFF notifications of spices contaminated by OTA during the period 2002-2011.

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