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FW09042 Aflatoxins and Ochratoxin A Dried Fruits and Spices

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Scientific Interpretive Summary

This SIS is prepared by MPI risk assessors to provide context to the following report for MPI risk managers and external readers

The New Zealand Mycotoxin Surveillance Program 06-14 Report Series

FW09042 Aflatoxins and Ochratoxin A Dried Fruits and Spices

These reports are the outputs of MPIs ongoing mycotoxin surveillance programme. The nine reports form a series detailing the research undertaken over the last eight years to characterise and quantify the risk to the New Zealand public through the presence of mycotoxins in the food supply.

The nine reports are:

- Risk Profile: Mycotoxin in Foods 2006
- Aflatoxins in Maize Products 2008
- Aflatoxins and Ochratoxin A in Dried Fruits and Spices 2009
- Aflatoxins in Nuts and Nut Products 2010
- Dietary Exposure to Aflatoxins 2011
- Ochratoxin A in Cereal Products, Wine, Beer and Coffee 2011
- Trichothecene Mycotoxins in Cereal Products 2014
- Dietary Exposure to Ochratoxin A and Trichothecene Mycotoxins 2014
- Risk Profile: Mycotoxin in Foods 2014

<u>Aflatoxins and Ochratoxin A in Dried Fruits and Spices 2009</u>

Surveillance activities for Aflatoxins (AF) continued with the consideration of dried fruit and species. As the foods were also identified as likely contributors to Ochratoxin A (OTA) exposure this mycotoxin was also analysed for and reported.

The analytical methodology is well detailed and has sufficient validation to ensure the results presented are accurate for actual occurrence values.

Both mycotoxins were found to be frequently detected in dried fruits and spices. With the exception of consistently high levels of OTA in paprika only two results were deemed elevated above expected levels. The elevated levels were AF in curry powder and OTA in figs.

Generally the results were consistent with the profiles of AF and OTA reported previously in New Zealand and overseas.

ESR

MYCOTOXIN SURVEILLANCE PROGRAMME 2008-09 AFLATOXINS AND OCHRATOXIN A IN DRIED FRUITS AND SPICES

Prepared as part of a New Zealand Food Safety Authority contract for scientific services

by

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May 2009

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Client Report
FW09042

MYCOTOXIN SURVEILLANCE PROGRAMME 2008-09
AFLATOXINS AND OCHRATOXIN A IN DRIED FRUITS AND SPICES

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SUMMARY

The Mycotoxin Surveillance Programme (MSP) involves investigation of food safety issues associated with mycotoxins in the New Zealand food supply, as identified in a risk profiling exercise carried out in 2005-2006. During 2008-2009, the MSP continued analysis of the presence of aflatoxins in foods other than those currently covered by import Standard Management Rules (SMRs), peanuts and pistachio nuts. The selected foods (dried fruits and spices) are also commonly contaminated with ochratoxin A and the scope of the project was expanded to include this mycotoxin.

Aflatoxins and ochratoxin A were found to be frequently present in spices available on the New Zealand market. While occasional high concentrations were present, concentrations were generally consistent with previous New Zealand and overseas studies. However, one curry powder samples was found to contain 225 µg/kg of aflatoxins.

Paprika available in New Zealand was observed to contain consistently high concentrations of ochratoxin A (15-103 µg/kg), when compared to related products such as chilli powder (1.3-6.3 µg/kg) and cayenne pepper (1.8-7.3 µg/kg).

The majority of dried fruit types available in New Zealand contained a low prevalence of aflatoxins and ochratoxin A. More frequent detection of aflatoxins in figs and ochratoxin A in dried vine fruits (raisins, sultanas and currants) is consistent with previous New Zealand and/or overseas studies. With the exception of one elevated result for ochratoxin A in figs (73 µg/kg), the concentrations of mycotoxins detected in dried fruits were generally low (<10 µg/kg).

Dietary exposure estimates for aflatoxins and ochratoxin A, considering all potential food sources, would assist in placing the results of the current survey in context with respect to human health risks.

1 INTRODUCTION

The Mycotoxin Surveillance Programme (MSP) involves investigation of food safety issues associated with mycotoxins in the New Zealand food supply.

As with other activities of the New Zealand Food Safety Authority (NZFSA), activities in this area are directed on the basis of risk. The risk profile of mycotoxins in the New Zealand food supply (Cressey and Thomson, 2006) is viewed as a starting point for this process. The risk profile identified a number of issues to be investigated or clarified.

During 2008-2009, the MSP continued analysis of the presence of aflatoxins in foods other than those currently covered by Imported Food Requirements (IFRs) or Standard Management Rules (SMRs), peanuts and pistachio nuts. The selected foods (dried fruits and spices) are also commonly contaminated with ochratoxin A (OTA) and the scope of the project was expanded to include this mycotoxin.

1.1 Aflatoxins

1.1.1 Hazard identification

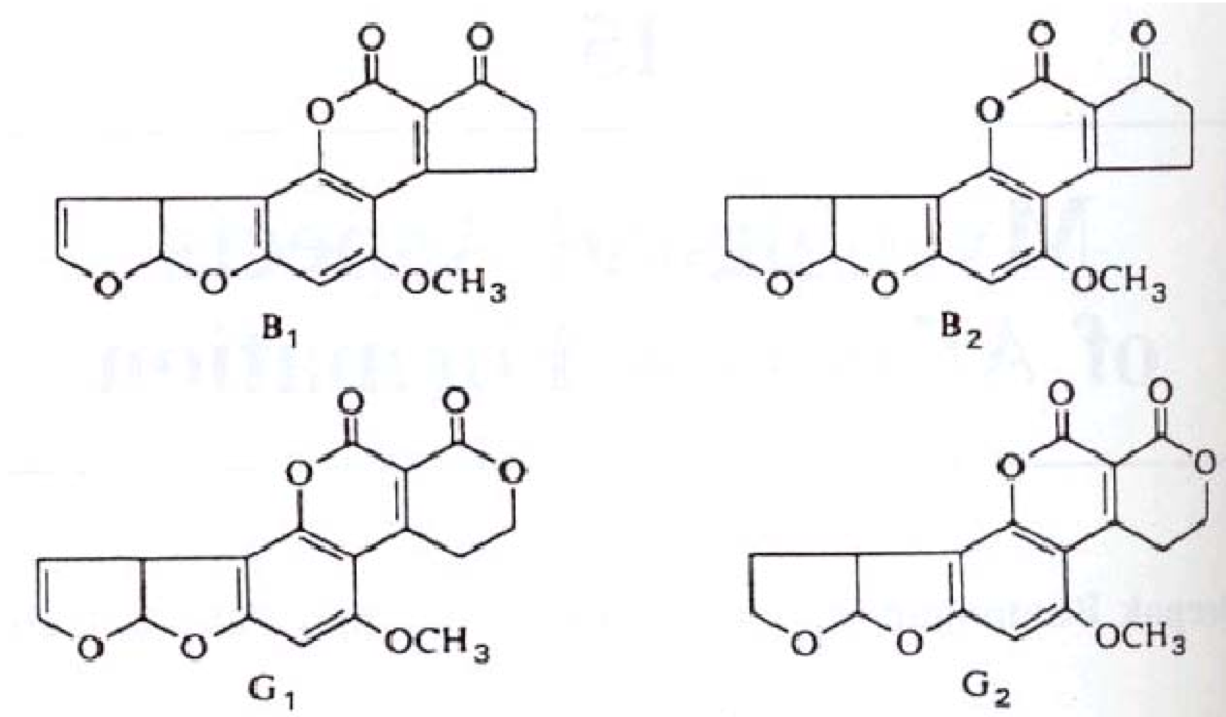
Aflatoxins are secondary metabolites produced by three species of *Aspergillus* mould: *A. flavus, A. parasiticus* and *A. nomius* (JECFA, 1998). *A. flavus* occurs in all tropical and subtropical regions and is particularly associated with peanuts and other nuts, maize and other oilseeds. *A. parasiticus* is less widely distributed and is usually only associated with peanuts (Pitt and Tomaska, 2001). *A. nomius* is closely related to *A. flavus*, but little information is available on its host range (Kurtzman *et al.*, 1987).

1.1.1.1 Structure and nomenclature

While the aflatoxins comprise a group of about 20 related compounds, the four major naturally-occurring compounds are aflatoxins B_1, B_2, G_1 and G_2. The ‘B’ and ‘G’ refer to the blue and green fluorescent colours produced by these compounds under UV light, while the subscripts ‘1’ and ‘2’ refer to major and minor components respectively (Pitt and Tomaska, 2001). The ‘2’ compounds are dihydro derivatives of the major (‘1’) metabolites. Chemical structures are shown in Figure 1. Aflatoxins M_1 and M_2 are hydroxylated metabolites of the respective ‘B’ aflatoxins produced when ruminant animals consume aflatoxin-contaminated feed. The ‘M’ aflatoxins may be excreted in milk (Pitt and Tomaska, 2001). Aflatoxins are fat soluble (lipophilic).

Reference to ‘aflatoxins’ or ‘total aflatoxins’ can be taken to refer to the sum of B and G aflatoxins.

Figure 1: Structure of aflatoxins



Reproduced from Eaton and Groopman (Eaton and Groopman, 1994)

1.1.1.2 Occurrence

A. flavus produces only 'B' aflatoxins (AFB_1 and AFB_2), with only about 40% of isolates producing toxins. *A. parasiticus* produces both 'B' (AFB_1 and AFB_2) and 'G' (AFG_1 and AFG_2) aflatoxins, with virtually all isolates producing toxins (Klich and Pitt, 1988). The situation for *A. nomius* appears to be similar to that for *A. parasiticus.*

Aflatoxin B_1 is the most commonly occurring aflatoxin in foods and is also the compound which has been most thoroughly studied in toxicological studies.

A. flavus occurs widely in the environment, but *A. parasiticus* is considerably less common. However, some regional specificities exist and *A. parasiticus* is commonly isolated from peanuts in the United States, South Africa and Australia.

Fungal infection and consequent aflatoxin contamination can occur in field crops prior to harvest or during post-harvest storage if the moisture content of the crop exceeds critical values for fungal growth (JECFA, 1998). Fungal growth and subsequent toxin production are favoured by factors which place the host plant under stress such as high temperature, drought, and high insect activity.

Aflatoxin contamination is most commonly associated with peanuts and peanut products, dried fruit, tree nuts, spices, figs, crude vegetable oils, cocoa beans, maize, rice, cottonseed and copra (JECFA, 1998). Consumption of aflatoxin-contaminated feed by animals can lead to occurrence of aflatoxins (mainly the hydroxylated metabolite AFM_1) in meat, eggs and milk.

Most of these crops are not grown in New Zealand. Surveillance of fungal infections of New Zealand grown grain found no *Aspergillus* species (Sayer and Lauren, 1991). This is consistent with expert opinion, that aflatoxigenic species of *Aspergillus* are unlikely to occur in New Zealand (Pitt JI, Mycologist, Food Science Australia, personal communication; 1999).

1.2 Ochratoxin A

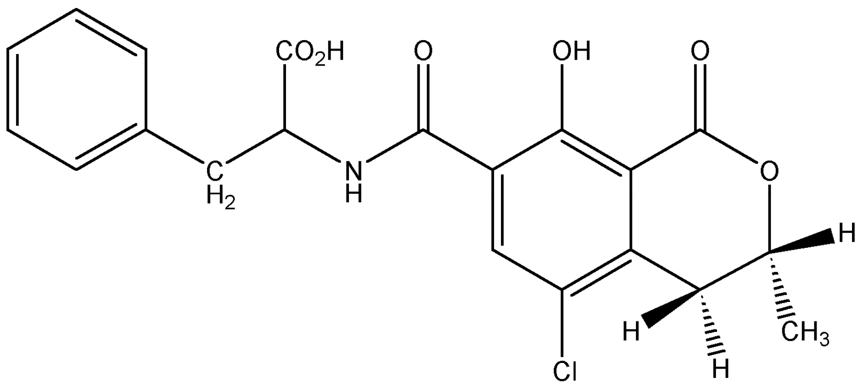
1.2.1 Hazard identification

Ochratoxin A (OTA) is produced by *Aspergillus ochraceus* and a related *Aspergillus* species, *A. carbonarius,* as well as some isolates of *A. niger*, and by *Penicillium verrucosum* (JECFA, 2001). These organisms differ in their geographical distribution and ecological niche, in the commodities affected, and the point at which they are likely to infect commodities.

1.2.1.1 Structure and nomenclature

OTA contains a chlorinated isocoumarin moiety linked via a carboxyl group to L-phenylalanine. Ochratoxin B (a dechlorinated analogue of OTA) and ochratoxin C (an ethyl ester of OTA) have also been detected, but OTA is by far the major contaminant found in crop plants (Walker, 1999).

Figure 2: Structure of OTA



1.2.1.2 Occurrence

P. verrucosum is a cool climate organism (0-31˚C, optimum 20˚C), occurring only in cool temperate regions, and is able to grow at water activities as low as 0.8 (Pitt and Hocking, 1997). It is the source of OTA formation in stored cereals and cereal products in European countries and Canada. Due to the high stability of OTA, this can also result in the presence of OTA in animals fed contaminated cereals. *P. verrucosum* does not occur in the tropics (JECFA, 2001).

A. ochraceus grows at moderate temperatures (8-37˚C, optimum 24-31˚C) and at water activities above 0.8 (optimum 0.95-0.99) (Pitt and Hocking, 1997). It occurs occasionally on a wide range of stored food products, but is seldom the cause of substantial concentrations of OTA (JECFA, 2001).

A. carbonarius grows at high temperatures (max 40˚C, optimum 32-35˚C) and is associated with maturing fruit, particularly grapes. It is the major source of OTA in fresh grapes, dried vine fruits and wine (JECFA, 2001).

OTA contamination is principally found in cereals, but can also occur in coffee, cocoa, spices, nuts, dried vine fruits, grape juice and wine, beer, and pork and pork products made from animals fed OTA contaminated feed (Walker, 1999).

Sayer and Lauren did not report isolation of any of these OTA-forming fungal species from New Zealand grain sampled at harvest (Sayer and Lauren, 1991). However, no information was found on occurrence of these fungal species on stored grain in New Zealand. Similarly, no information was found on *Aspergillus* infection of grapes or other fruits in New Zealand. However, it has been reported that bunch rot of vines due to *A. niger* probably occurs in New Zealand, but hasn't been officially reported (http://www.hortnet.co.nz/publications/hortfacts/hf905020.htm).

2 MATERIALS AND METHODS

2.1 Foods Sampled

An initial scoping exercise identified dried fruits and spices as foods commonly contaminated with aflatoxins and/or OTA.

2.1.1 Dried Fruits

The dried fruits most commonly imported into New Zealand are dried vine fruits (raisins, sultanas and currants)>dried apricots>dried dates>dried prunes>dried figs. However, due to the known association of aflatoxins with dried figs, it was agreed that the following numbers of samples be analysed for aflatoxins and OTA:

- Dried figs 10
- Dried vine fruits 10
- Dried apricots 10
- Dried dates 5
- Dried prunes 5

2.1.2 Spices

While aflatoxins and OTA have been detected in a range of spices, these mycotoxins appear to be most commonly associated with cayenne pepper, chilli powder, cumin, curry powder and other spice mixes, ginger, nutmeg, paprika, pepper. This is consistent with unpublished OTA analyses carried out by ESR of spices on the New Zealand market. It was agreed that the following numbers of samples be analysed for aflatoxins and OTA:

- Pepper (black, white) 5
- Chilli powder 5
- Cayenne pepper 5
- Paprika 5
- Ginger 5
- Curry powder 5

Details of samples included in the survey are included in Appendix 1.

2.2 Sampling Plan – Sampling Protocols

The UK Food Standard Agency recently updated their advice on the sampling of foodstuffs for mycotoxin analyses (Food Standards Agency, 2007). For sampling of retail packets of food it is recommended that sufficient retail units are purchased to obtain an aggregate sample weight of 1 kg, with all units coming from the same batch. This protocol has been employed in the UK for surveys of mycotoxins in retail products, including dried fruits (see http://www.food.gov.uk/multimedia/pdfs/nuts_q_a.pdf for a Q&A, including a discussion of this issue).

A UK Food Standards Agency survey of mycotoxins in retail spices specified a sample size of at least 400 g (see http://www.foodstandards.gov.uk/science/surveillance/fsis2005/fsis7305). This appears realistic given the small pack sizes and relatively high cost of retail spice packs.

A report of the European Commission Working Group on Agricultural Contaminants on Sampling and Analysis of Aflatoxins and Ochratoxins further discussed the issue of sampling retail packaged products, but did not further elaborate strategies for sampling at the retail levels (http://archive.food.gov.uk/pdf_files/ecreport.pdf).

For the current survey it was agreed that analytical samples be made up by blending individual purchase units to a combined weight of approximately one kilogram for dried fruit and at least 400 g for spices, with all samples coming from a single batch.

2.3 Analytical Methodology

2.3.1 Aflatoxins

2.3.1.1 Dried fruit

Samples were extracted with methanol-water (60:40), filtered and cleaned up using Aflatest immunoaffinity columns (Vicam, Watertown, USA) according to the method of Karaca and Nas (Karaca and Nas, 2006). Aflatoxins were eluted from the immunoaffinity column with acetonitrile.

Aflatoxin analyses were based on the method of Takahashi (Takahashi, 1977). Extracts were prepared for HPLC by removing acetonitrile under reduced pressure, then adding 100 µl of trifluoroacetic acid and dissolving in 900 µl of water-acetonitrile (9:1).

Aflatoxins (20 µl) were separated by HPLC on a C-18 reversed-phase column with acetonitrile-water (20:80) as the mobile phase at a flow rate of 1.5 ml/minute. Fluorescence detection was carried out with an excitation wavelength of 360 nm and an emission wavelength of 470 nm.

The method allows quantitation of the four principle aflatoxins (B_1, B_2, G_1 and G_2).

2.3.1.2 Spices

Spices were analysed by a modification of the method of Stroka *et al*. (Stroka *et al.*, 2000). This involved extraction with methanol-water (80:20) containing 2% w/v NaCl. Extracts were filtered (Whatman No. 4), then 10 ml of filtrate was diluted with 60 ml of phosphate buffered saline (PBS) containing 100 µL Tween 20. An aliquot of 66 ml of diluted filtrate was applied to an Aflatest immunoaffinity column, previously conditioned with 10 ml of PBS/Tween 20. The column was washed with 15 ml of water and allowed to dry. Aflatoxins were eluted from the column with 1.25 ml of methanol.

This method was modified for black and white pepper samples due to the presence of co-extractives. Extracts were prepared and filtered as above and 2 ml of extract was diluted with 68 ml of PBS containing 100 µL Tween 20. Immunoaffinity chromatography was carried out as for other spice samples.

Analysis was subsequently carried out as described for dried fruit, except that for black and white peppers an injection volume of 100 µL was used.

2.3.2 Ochratoxin A

2.3.2.1 All samples, except pepper

Extraction and clean up was based on AOAC Standard Method 49.6.02A (2005) and the method of Lobeau *et al*. (Lobeau *et al.*, 2007).

Samples (15 g) were blended with 150 ml of methanol-3% sodium bicarbonate (80:20) for one minute, then filtered (Whatman No. 4). Filtrate (10 ml) was diluted with 40 ml of phosphate buffered saline (PBS) containing Tween 20 (0.01%) and applied to an Ochratest immunoaffinity column (Vicam, Watertown, USA). The column was washed with water (2 x 5 ml) and allowed to dry before ochratoxin A was eluted with methanol (4 x 1 ml). Solvent was removed under reduced pressure and the extract was redissolved in 1 ml 60% acetonitrile-39% water-1% acetic acid (Mobile phase B).

HPLC was carried out on a C18 reversed-phase column at a flow rate of 1.5 ml/min using an isocratic mixture of 65% mobile phase A (20% acetonitrile-15% methanol-64% water-1% acetic acid) and 35% mobile phase B. Injection volume was 50 µL. Detection was by fluorescence with excitation wavelength 333 nm and emission wavelength of 460 nm.

2.3.2.2 Pepper

Analysis of black or white pepper for ochratoxin A was carried out according to the method of Fazekas *et al*. (Fazekas *et al.*, 2005). Samples (25 g) were extracted with 1 M phosphoric acid (12.5 ml) and chloroform (125 ml) for 3 minutes, then filtered (Whatman No. 4). Sodium bicarbonate (4%, 17ml) was added to 50 ml of filtrate in a separating funnel and shaken for one minute. The aqueous layer was removed after separation and the process repeated with a further 35 ml 4% sodium bicarbonate. The pH of combined sodium bicarbonate extracts was adjusted to 3.5 with 2M sulphuric acid. The solution was returned to the separating funnel and extracted twice with 50 ml aliquots of chloroform. Chloroform extracts were combined and sodium sulphate added to dry. Chloroform was carefully poured into a round-bottomed flask and solvent removed under reduced pressure.

Extract was redissolved in 20 ml of methanol-PBS (2:18) and applied to an Ochratest immunoaffinity column preconditioned with 10 ml of PBS. The column was washed with 5 ml PBS, followed by 5 ml water. OTA was eluted from the column with 4 ml methanol, evaporated to dryness, and dissolved in 1 ml mobile phase B and analysed as previous described for other spices and dried fruits.

2.3.3 Analytical quality control

Four quality control materials (FAPAS – Food Analysis Performance Assessment Scheme, operated by the Food and Environment Research Agency, Sand Hutton, York, United Kingdom) were analysed. The materials were:

- T0483 Dried figs (for Aflatoxins)
- T0475 Spice – chilli (for Aflatoxins)
- T1760 Dried vine fruit (for OTA)
- T1753 Paprika (for OTA)

Results of the analyses are shown in Table 1.

Table 1: Analysis of quality control materials

Analyte	Assigned value (µg/kg)	Satisfactory range (µg/kg)	ESR analytical results (µg/kg)
T0483 Dried figs			
Aflatoxin B1	4.36	2.44-6.28	3.17
Aflatoxin B2	1.11	0.91-2.33	1.11
Aflatoxin G1	3.09	1.73-4.44	2.10
Aflatoxin G2	0.88	0.49-1.27	0.66
Total Aflatoxins	10.0	5.6-14.4	7.04
T0475 Spice – chilli			
Aflatoxin B1	16.7	9.4-24.1	13.43
Aflatoxin B2	0.72	0.4-1.04	0.49
T1760 Dried vine fruit			
Ochratoxin A	9.49	5.31-13.66	11.18
T1753 Paprika			
Ochratoxin A	18.3	10.3-26.4	15.08

Aflatoxins and ochratoxin A were spiked into samples of each of the matrices examined. Mean recoveries are reported in Table 2.

Table 2: Spike recoveries for aflatoxins and ochratoxin A in dried fruit and spice matrices

Food	Percentage spike recovery				
	AFB1	AFB2	AFG1	AFG2	OTA
Dried figs	83	78	89	81	95
Dried vine fruit	93	95	97	94	101
Dried apricots	87	86	90	88	88
Dates	70	73	75	76	91
Prunes	64	70	76	69	95
Pepper	67	81	67	70	85
Chilli powder	90	87	92	83	77
Cayenne pepper	75	74	74	72	95
Paprika	78	75	81	72	120
Ginger	86	85	90	79	84

Food	Percentage spike recovery				
	AFB1	AFB2	AFG1	AFG2	OTA
Curry powder	67	88	81	89	103

It should be noted that some of these matrices presented significant analytical challenges. The spike recoveries were generally within the range considered to be acceptable (70-120%). While some results were marginally outside this range, they were considered to be acceptable given the analytical challenges associated with these matrices. All analytical results were reported without correction for recovery.

Coefficients of variation (CV) were in the range 4.9-6.2% for the individual aflatoxins and 6.3% for ochratoxin A. These CVs are very good for trace organic analyses.

Limits of detection and quantitation were calculated as three and ten times the signal to noise (S/N) ratio respectively:

Analyte	**LOD (µg/kg)**	**LOQ (µg/kg)**
Aflatoxin B1	0.08	0.25
Aflatoxin B2	0.08	0.27
Aflatoxin G1	0.07	0.23
Aflatoxin G2	0.06	0.22
Ochratoxin A	0.24	0.81

Results falling between the limit of detection and the limit of quantitation were termed ‘indicative’. These appear in this report as quantitative values in brackets.

3 RESULTS AND DISCUSSION

3.1 Summary of Results

Results for the 70 dried fruits and spices analysed in the current study are summarised in Table 3 and Table 4. Full details of results are given in Appendix 1.

Table 3: Aflatoxin content of dried fruits and spices available on the New Zealand market

Food type	Number of samples	Number positive for aflatoxins (%)	Total aflatoxins in positive samples (μg/kg)*	Aflatoxins detected
Dried figs	10	3 (30)	(0.1)-6.7	B1, B2, G1, G2
Dried vine fruits#	10	0 (0)		
Dried apricots	10	1 (10)	(0.9)	B1, B2, G1, G2
Dates	5	0 (0)		
Prunes	5	1 (20)	(0.5)	B1, B2, G1, G2
Pepper (black, white)	5	0 (0)		
Chilli powder	5	4 (80)	3.5-8.5	B1, B2, G1, G2
Cayenne pepper	5	4 (80)	2.9-5.0	B1, B2
Paprika	5	5 (100)	(0.2)-3.5	B1, G1
Ginger, ground	5	4 (80)	0.3-3.6	B1, B2, G1, G2
Curry powder	5	5 (100)	(0.2)-225	B1, B2, G1

* Concentration figures in brackets are indicative and relate to analytical results that were above the limit of detection, but below the limit of quantitation
# Raisins, sultanas and currants

Dried fruit samples containing aflatoxins mostly contained detectable levels of B and G aflatoxins, suggesting that the contamination was due to infection of the plants by *A. parasiticus*. In spice samples the G aflatoxins were often not detected and it is probable that the dominant fungal species infecting the parent plants was *A. flavus*.

Table 4: Ochratoxin A content of dried fruits and spices available on the New Zealand market

Food type	Number of samples	Number positive for ochratoxin A (%)	Ochratoxin A in positive samples (μg/kg) *
Dried figs	10	1 (10)	73
Dried vine fruits#	10	5 (50)	(0.2)-(0.6)
Dried apricots	10	0 (0)	
Dates	5	0 (0)	
Prunes	5	0 (0)	
Pepper (black, white)	5	4 (80)	(0.7)-8.3
Chilli powder	5	4 (80)	1.3-6.3
Cayenne pepper	5	5 (100)	1.8-7.3
Paprika	5	5 (100)	15-103
Ginger, ground	5	4 (80)	(0.5)-2.1

Food type	Number of samples	Number positive for ochratoxin A (%)	Ochratoxin A in positive samples (µg/kg) *
Curry powder	5	5 (100)	(0.2)-3.5

* Concentration figures in brackets are indicative and relate to analytical results that were above the limit of detection, but below the limit of quantitation
# Raisins, sultanas and currants

3.2 Aflatoxins

3.2.1 Dried figs

Aflatoxins were detected in 30% (3/10) of dried fig samples examined, with the highest total aflatoxin concentration detected being 6.7 µg/kg. Aflatoxin B1 was the toxin detected at the highest concentrations of the component aflatoxins, although generally all four major aflatoxins were present. Previous New Zealand surveys did not detect aflatoxins in fig samples analysed (Lake *et al.*, 1991; Stanton, 2000a).

Data obtained from Statistics New Zealand indicates that the majority of dried figs imported into New Zealand are from Turkey (>85%). Two of the three positive fig samples listed Turkey as the country of origin, while no country of origin was listed on the third sample.

The prevalence and concentration of aflatoxin contamination of figs found in the current study are within the range observed in overseas studies (see Appendix 2, Table 6). However, the occasional very high concentrations of aflatoxins (>100 µg/kg) reported in some overseas studies (Boyacioglu and Gonul, 1990; Iamanaka *et al.*, 2007; Karaca and Nas, 2006; Senyuva *et al.*, 2007) were not detected in the current survey.

3.2.2 Dried vine fruits

Aflatoxins were not detected in any sample of dried vine fruit (raisins, sultanas, currants) analysed in the current survey. This is consistent with a previous New Zealand study that did not detect aflatoxins in 23 samples of dried vine fruit (Stanton, 2000a).

Dried vine fruit imported into New Zealand comes mainly from Turkey (sultanas 80%, raisins 14%), USA (raisins 55%), South Africa (currants 58%, raisins 26%), China (sultanas 11%), Australia (sultanas 8%) and Greece (currants 35%).

Results from the overseas studies summarised in Appendix 2, Table 6 suggest that dried vine fruit is infrequently contaminated with aflatoxins.

3.2.3 Dried apricots

The current survey detected aflatoxins in one sample (10%) of dried apricots. However, the levels detected were very low (total aflatoxins less than 1 µg/kg). A previous New Zealand study did not detect aflatoxins in any of three samples of dried apricots (Stanton, 2000a). The limit of detection for this earlier survey (1 µg/kg) would not have allowed detection of the low aflatoxin concentrations observed in the current study.

While there is some domestic production of dried apricots, this product is mainly imported from Turkey (80%), with smaller quantities imported from USA, South Africa and Australia. The country of origin was not specified on the positive sample from the current survey.

The overseas studies summarised in Appendix 2, Table 6 confirm that significant contamination of dried apricots with aflatoxins is a rare occurrence.

3.2.4 Dates

Aflatoxins were not detected in any samples of dates analysed in the current survey. This is consistent with an earlier New Zealand study that did not detect aflatoxins in any of four date samples (Stanton, 2000a).

Dates are primarily imported into New Zealand from Iran (82%).

The overseas studies summarised in Appendix 2, Table 6 confirm that aflatoxins are infrequently detected in dates.

3.2.5 Prunes

Aflatoxins were detected in one sample (20%) of prunes analysed in the current survey. The levels of aflatoxins detected were very low (estimated at 0.5 μg/kg, but values for individual aflatoxins were below the limit of quantitation). This is consistent with an earlier New Zealand study that did not detect aflatoxins in any of three prune samples at a detection limit of 1 μg/kg (Stanton, 2000a).

New Zealand mainly imports prunes from the USA (80%) and this was the country of origin of the single positive sample.

Only one other study was found that had analysed prunes for aflatoxins (Food Standards Agency, 2002), which found a comparable prevalence (12.5%) and concentration (0.4-0.6 g/kg) of aflatoxins in prunes.

3.2.6 Pepper (black, white)

Aflatoxins were not detected in any pepper samples analysed in the current survey. No previous analyses of spices for aflatoxins have been carried out in New Zealand.

Pepper is imported into New Zealand from Malaysia (37%), India (23%) and Australia (10%).

Overseas studies summarised in Appendix 2, Table 6 show high variability in the prevalence of aflatoxins in black and white pepper, with prevalence estimates ranging from zero to more than 90%. Most studies that detected aflatoxins in pepper reported relatively low concentrations (<5 μg/kg), although concentrations as high as 16.7 μg/kg have been reported for black pepper from Turkey (Colak *et al.*, 2006).

3.2.7 Chilli powder

Aflatoxins were detected in 80% (4/5) of chilli powder samples analysed with total aflatoxin concentrations in the range 3.5-8.5 µg/kg.

Chilli powder, cayenne pepper and paprika are all derived from varieties of *Capsicum annuum*. These products are described collectively under the Harmonised System used for categorisation of imported materials. New Zealand imports of products in this category come mainly from India (35%), Spain (23%), China (21%) and Australia (6%).

Overseas studies summarized in Appendix 2, Table 6 confirm that chilli powder is frequently contaminated with aflatoxins, with prevalence estimates of 100% not being uncommon. Similarly, the concentrations of aflatoxins in chilli powder in the current study appear typical of those reported overseas.

3.2.8 Cayenne pepper

As mentioned previously, chilli powder and cayenne pepper are closely related products and the prevalence (80%) and concentration range (2.9-5.0 µg/kg) for aflatoxins observed in cayenne pepper was similar to observations for chilli powder. Results reported for aflatoxins in cayenne pepper in overseas studies (Appendix 2, Table 6) are also similar to those in the current study.

3.2.9 Paprika

As mentioned previously, paprika, chilli powder and cayenne pepper are closely related products and the prevalence (100%) and concentration range (0.2-3.5 µg/kg) for aflatoxins observed in paprika was similar to observations for chilli powder and cayenne pepper. Results reported for aflatoxins in paprika in overseas studies (Appendix 2, Table 6) are also similar to those in the current study.

3.2.10 Ginger, ground

Aflatoxins were detected in 80% (4/5) of ground ginger samples analysed in the current study, with concentrations of total aflatoxins in the range 0.3-3.6 µg/kg.

Ground ginger is mainly imported into New Zealand from China (65%) and India (29%).

The prevalence of aflatoxins in ginger in the current survey is towards the upper end of estimates from overseas studies (Appendix 2, Table 6), although concentrations observed are generally consistent with overseas studies.

3.2.11 Curry powder

Curry powders are mixtures of spices and the composition of the mixture can vary considerably from one formulation to the next. Aflatoxins were detected in all curry powders analysed in the current study. While four of the five samples analysed contained modest amounts of aflatoxin (0.2-4.4 µg/kg), the remaining sample contained more than 200 µg/kg total aflatoxins.

Overseas studies that have analysed curry powders have generally reported lower prevalence of aflatoxins than observed in the current study and none have reported such high levels of contamination as the sample containing 225 µg/kg in the current study (Appendix 2, Table 6).

3.3 Ochratoxin A (OTA)

3.3.1 Dried figs

OTA was detected in one sample (10%) of figs analysed in the current study at a concentration of 73 µg/kg. The fig sample was the only sample with Australia declared as the country of origin. No aflatoxins were detected in this sample. A previous New Zealand study detected OTA in one of two (50%) fig samples analysed, but at a much lower concentration (0.2 µg/kg) (Stanton, 2000b).

Overseas studies have reported estimates of the prevalence of OTA in figs in the range 0-100% (Appendix 2, Table 7). The concentration of OTA found in the current study is towards the high end, but not outside the range, of results that have been reported overseas.

3.3.2 Dried vine fruits

OTA was detected in 50% (5/10) of samples of dried vine fruit (raisins, sultanas, currants) analysed in the current study. However, concentrations were generally very low (estimated 0.2-0.6 µg/kg, but all results were below the limit of quantitation). The prevalence of OTA in dried vine fruits is consistent with other New Zealand studies which found OTA in 65% (Stanton, 2000b) and 66% (D. Saunders, ESR, personal communication) of dried vine fruits analysed. The concentrations of OTA observed in the current study are consistent with a recent unpublished New Zealand study (0.3-0.7 µg/kg; D. Saunders, ESR, personal communication), but are generally lower than an earlier New Zealand study (0.3-22 µg/kg) (Stanton, 2000b).

A number of overseas studies have shown a similar prevalence of OTA in dried vine fruits (50-60%), although the maximum concentrations reported are generally higher than the current survey (Appendix 2, Table 7).

3.3.3 Other dried fruits (apricots, dates and prunes)

OTA was not detected in any samples of dried apricots, dates or prunes in the current survey. A recent unpublished New Zealand study also did not detect OTA in dried apricot or prune samples, but did detect OTA in one date sample at a concentration of 1 µg/kg (D. Saunders, ESR, personal communication). An earlier New Zealand study did not detect OTA in any dried apricot, prune or date samples (Stanton, 2000b).

Overseas studies are mostly in good agreement with these findings, with OTA detected in, at most, 10% of samples of these fruit types (Appendix 2, Table 7). The exception is an Egyptian study which detected OTA in all apricot samples analysed, at concentrations up to 110 µg/kg (Zohri and Abdel-Gawad, 1993).

3.3.4 Pepper (black, white)

OTA was detected in 80% (4/5) of pepper samples analysed in the current study, with concentrations in the range 0.7-8.3 μg/kg. No previous New Zealand studies have examined the OTA content of pepper.

Only one overseas study was found to compare these results against (Fazekas *et al.*, 2005), in which OTA was not detected in any of eleven black and white pepper samples.

3.3.5 Chilli powder

OTA was detected in 80% (4/5) of chilli powder samples analysed in the current study, with concentrations in the range 1.3-6.3 μg/kg. A recent unpublished New Zealand study found a comparable prevalence of OTA, with all of four chilli powder samples containing OTA at concentrations of 0.2-40 μg/kg (D. Saunders, ESR, personal communication).

Overseas studies have reported the prevalence of OTA in chilli powder in the range 33-100%, with maximum concentrations as high as 152 μg/kg (see Appendix 2, Table 7).

3.3.6 Cayenne pepper

OTA was detected in 100% (5/5) of cayenne pepper samples in the current study, with concentrations in the range 1.8-7.3 μg/kg. A recent unpublished New Zealand study found comparable results, with both of two cayenne pepper samples containing OTA at concentration of 0.8-2.7 μg/kg (D. Saunders, ESR, personal communication).

A single comparative overseas study was found, which also observed OTA in 100% of samples, but with a higher maximum concentration of 16.5 μg/kg (Food Standards Agency, 2005).

3.3.7 Paprika

OTA was detected in 100% (5/5) of paprika samples in the current study, with concentrations in the range 15-103 μg/kg. A recent unpublished New Zealand study found comparable results, with four of four paprika samples containing OTA at concentrations of 13-51 μg/kg (D. Saunders, ESR, personal communication).

While chilli powder, cayenne pepper and paprika are all derived from varieties of *Capsicum annuum*, paprika available in New Zealand appears to have consistently higher concentrations of OTA than chilli powder or cayenne pepper. These differences were not apparent in a study carried out for the UK Food Standards Agency, in which the mean OTA concentrations in chilli powder, cayenne pepper and paprika were 9.3, 7.0 and 9.6 μg/kg respectively (Food Standards Agency, 2005). The mean concentration of ochratoxin A in the five samples of paprika analysed in the current study was 43 μg/kg.

3.3.8 Ginger, ground

OTA was detected in 80% (4/5) of ground ginger samples in the current study, with concentrations in the range 0.5-2.1 µg/kg. A recent unpublished New Zealand study found comparable results, with both of two ginger samples containing OTA at concentrations of 0.6-4.5 µg/kg (D. Saunders, ESR, personal communication).

No overseas data were found on OTA in ginger.

3.3.9 Curry powder

OTA was found in 100% (5/5) of curry powder samples in the current study, at concentrations in the rang 0.2-3.5 µg/kg. It is interesting to note that the same sample that contained 225 µg/kg of total aflatoxins also contained 3.0 µg/kg of OTA.

No comparative New Zealand or overseas data were found.

3.4 Regulatory Limits for Aflatoxins and Ochratoxin A

The Joint Australia New Zealand Food Standards Code does not include any limits for aflatoxins in dried fruit or spices or limits for OTA in any food.

In 2003, worldwide regulations for mycotoxins were reviewed (Van Egmond and Jonker, 2004). While a number of countries reported 'catch all' limits for aflatoxins in any food, a limited number of countries reported limits relevant to the foods and mycotoxins included in the current survey. These are summarised in Table 5.

Table 5: International regulatory limits for aflatoxins and ochratoxin A in dried fruits and spices

Food description	Country	Mycotoxin description	Limit (µg/kg)
Aflatoxins			
Dried fruits for direct human consumption	Bulgaria	AFB1	2
		Total	4
Dried fruit to be processed before human consumption		AFB1	5
		Total	10
Dried fruit for direct consumption	Czech Republic	AFB1	2
		Total	4
Dried fruit as raw material		AFB1	5
		Total	10
Dried fruits for direct human consumption	Estonia	AFB1	2
		Total	4
Dried fruit to be processed before human consumption		AFB1	5
		Total	10
Dried fruits for direct human consumption	European Union	AFB1	2
		Total	4
Dried fruit to be processed before human consumption		AFB1	5
		Total	10

Food description	Country	Mycotoxin description	Limit (µg/kg)
Dried fruits for direct human consumption Dried fruit to be processed before human consumption	Hungary	AFB1 Total AFB1 Total	2 4 5 10
All dried fruits	Iran	AFB1 Total	5 15
Figs and their products	Israel	AFB1 Total	5 15
Dried fruit	Malta	AFB1 Total	2 4
Dried fruits	Turkey	AFB1 Total	5 10
Dried fruits	Uruguay	Total	30
Spices	Bulgaria	AFB1 Total	2 5
Spices	Croatia	AFB1	30
Spices	Czech Republic	AFB1	20
Spices	European Union	AFB1 Total	5 10
All spices	Finland	Total	10
Spices	Hungary	AFB1 Total	5 10
Spices	Indonesia	Total	20
Spices	Serbia and Montenegro	AFB1	30
Spices Nutmeg	Switzerland	AFB1 Total AFB1 Total	5 10 10 20
Spices	Turkey	AFB1 Total	5 10
Spices	Uruguay	AFB1 Total	5 20
Ochratoxin A			
Dried vine fruit	Bulgaria	OTA	5
Dried vine fruit	European Union	OTA	10
Dried vine fruit	Hungary	OTA	10
All dried fruits	Iran	OTA	10
Dried fruit	Switzerland	OTA	20
Dried raisins	Turkey	OTA	10
Spices	Bulgaria	OTA	10
Spices	Switzerland	OTA	20

AFB1 = aflatoxin B1 Total = total aflatoxins (B1+B2+G1+G2) OTA = ochratoxin A

In summary, regulatory limits cover a significant range of values for the same product type, including:

- Total aflatoxins in dried fruit - 4-30 µg/kg

- Total aflatoxins in spices- 5-30 (AFB1) µg/kg
- Ochratoxin A in dried fruit- 5-20 µg/kg
- Ochratoxin A in spices- 10-20 µg/kg

4 CONCLUSIONS

Aflatoxins and ochratoxin A were found to be frequently present in spices available on the New Zealand market. While occasional high concentrations are present, concentrations observed were generally low and are consistent with previous New Zealand and overseas studies. However, one curry powder was found to contain very high concentrations of aflatoxins (225 µg/kg).

Paprika available in New Zealand was observed to contain consistently high concentrations of ochratoxin A (mean 43 µg/kg, range 15-103 µg/kg), when compared to related products such as chilli powder and cayenne pepper. A similar study carried out in the UK did not show a marked difference between the ochratoxin A content of paprika and other spices derived from *Capsicum annuum* (chilli powder and cayenne pepper) (Food Standards Agency, 2005).

The majority of dried fruits types available in New Zealand were found to contain a low prevalence of aflatoxins and ochratoxin A or no detectable levels of these mycotoxins at all. More frequent detection of aflatoxins in figs and ochratoxin A in dried vine fruits is consistent with previous New Zealand and/or overseas studies. With the exception of one elevated result for ochratoxin A in figs (73 µg/kg), the concentrations of mycotoxins detected in dried fruits were generally low (<10 µg/kg).

Dietary exposure estimates for aflatoxins and ochratoxin A, considering all potential food sources, would assist in placing the results of the current survey in context with respect to human health risks.

REFERENCES

Abdulkadar AHW, Al-Ali AA, Al-Kildi AM, Al-Jedah JH. (2004) Mycotoxins in food products available in Qatar. Food Control; 15(7): 543-548.

Aksoy U, Eltem R, Meyvaci KB, Altindisli A, Karabat S. (2007) Five-year survey of ochratoxin A in processed sultanas from Turkey. Food Additives & Contaminants: Part A; 24(3): 292 - 296.

Anonymous. (2004) West Australian Food Monitoring Program. Aflatoxins in WA Foods 1995-2000. Perth: Food Safety Branch, Environmental Health Directorate, Department of Health, Government of Western Australia.

Ardic M, Karakaya Y, Atasever M, Durmaz H. (2008) Determination of aflatoxin B1 levels in deep-red ground pepper (isot) using immunoaffinity column combined with ELISA. Food and Chemical Toxicology; 46(5): 1596-1599.

Aydin A, Emin Erkan M, Baskaya R, Ciftcioglu G. (2007) Determination of Aflatoxin B1 levels in powdered red pepper. Food Control; 18(9): 1015-1018.

Boyacioglu D, Gonul M. (1990) Survey of aflatoxin contamination of dried figs grown in Turkey in 1986. Food Additives and Contaminants; 7(2): 235-237.

Cho S-H, Lee C-H, Jang M-R, Son Y-W, Lee S-M, Choi I-S, Kim S-H, Kim D-B. (2008) Aflatoxins contamination in spices and processed spice products commercialized in Korea. Food Chemistry; 107(3): 1283-1288.

Colak H, Bingol EB, Hampikyan H, Nazli B. (2006) Determination of aflatoxin contamination in red-scaled, red and black pepper by ELISA and HPLC. Journal of Food and Drug Analysis; 14(3): 292-296.

Cressey P, Thomson B. (2006) Risk Profile: Mycotoxins in the New Zealand food supply. ESR Client Report FW0617 for the New Zealand Food Safety Authority. Christchurch: Institute of Environmental Science and Research (ESR).

Eaton DL, Groopman JD. (1994) The toxicology of aflatoxins: Human health, veterinary and agricultural significance. San Diego: Academic Press.

El-Kady IA, El-Maraghy SSM, Emam Mostafa M. (1995) Natural occurrence of mycotoxins in different spices in Egypt. Folia Microbiologica; 40(3): 297-300.

Erdogan A. (2004) The aflatoxin contamination of some pepper types sold in Turkey. Chemosphere; 56(4): 321-325.

European Commission. (1997) Assessment of dietary intake of ochratoxin A by the population of EU Member States. Reports on tasks for scientific cooperation. Report of experts participating in Task 3.2.2. EUR 17523 EN. Luxembourg: Office for Official Publications of the European Communities.

Fazekas B, Tar A, Kovacs M. (2005) Aflatoxin and ochratoxin A content of spices in Hungary. Food Additives and Contaminants; 22(9): 856-863.

Food Standards Agency. (2002) Survey of nuts, nut products and dried tree fruits for mycotoxins. Food Survey Information Sheet 21/02. Accessed at: http://www.foodstandards.gov.uk/multimedia/pdfs/21nuts.pdf. Accessed: 17 March 2009.

Food Standards Agency. (2005) Survey of spices for aflatoxins and ochratoxin A. FSIS 73/05. London: Food Standards Agency.

Food Standards Agency. (2007) Sampling Advice: Mycotoxins in Foodstuffs. London: Food Standards Agency.

Ghali R, Hmaissia-khlifa K, Ghorbel H, Maaroufi K, Hedili A. (2008) Incidence of aflatoxins, ochratoxin A and zearalenone in Tunisian foods. Food Control; 19(9): 921-924.

Iamanaka BT, de Menezes HC, Vicente E, Leite RSF, Taniwaki MH. (2007) Aflatoxigenic fungi and aflatoxins occurrence in sultanas and dried figs commercialized in Brazil. Food Control; 18(5): 454-457.

Iamanaka BT, Taniwaki MH, Menezes HC, Vicente E, Fungaro MHP. (2005) Incidence of toxigenic fungi and ochratoxin A in dried fruits sold in Brazil. Food Additives and Contaminants: Part A; 22(12): 1258 - 1263.

Ioannou-Kakouri E, Aletrari M, Christou E, Hadjioannou-Ralli A, Koliou A, Akkelidou D. (1999) Surveillance and control of aflatoxins B1, B2, G1, G2, and M1 in foodstuffs in the Republic of Cyprus: 1992-1996. Journal of AOAC International; 82(4): 883-892.

JECFA. (1998) Aflatoxins. Safety Evaluation of Certain Food Additives and Contaminants. WHO Food Additive Series 40. Geneva: World Health Organization.

JECFA. (2001) Ochratoxin A. Safety Evaluation of Certain Food Additives and Contaminants. WHO Food Additive Series 47. Geneva: World Health Organization.

Juan C, Zinedine A, Molto JC, Idrissi L, Manes J. (2008) Aflatoxin levels in dried fruits and nuts from Rabat-Sale area, Morocco. Food Control; 19: 849-853.

Karaca H, Nas S. (2006) Aflatoxins, patulin and ergosterol contents of dried figs in Turkey. Food Additives and Contaminants; 23(5): 502-508.

Karbancioglu-Güler F, Heperkan D. (2008) Natural occurrence of ochratoxin A in dried figs. Analytica Chimica Acta; 617(1-2): 32-36.

Klich MA, Pitt JI. (1988) Differentiation of *Aspergillus flavus* from *A.parasiticus* and closely related species. Transactions of the British Mycological Society; 91: 99-108.

Klieber A. (2001) Aflatoxin contamination and its management in chilli and paprika products in Australia. Food Australia; 53(3): 90-92.

Kurtzman CP, Horn BW, Hesseltine CW. (1987) *Aspergillus nomius*, a new aflatoxin-producing species related to *Aspergillus flavus* and *Aspergillus tamarii*. Antonie van Leeuwenhoek; 53(3): 147-158.

Lake RJ, Jamieson EJ, North MT, Stanton DW. (1991) Aflatoxins in food: A review and survey. DSIR Chemistry Paper No. CD 9029. Christchurch: Department of Scientific and Industrial Research.

Lobeau M, De Saeger S, Sibanda L, Barna-Vetro I, Van Peteghem C. (2007) Application and validation of a clean-up tandem assay column for screening ochratoxin A in cocoa powder. Food Additives and Contaminants; 24(4): 398-405.

Lombaert GA, Pellaers P, Neumann G, Kitchen D, Huzel V, Trelka R, Kotello S, Scott PM. (2004) Ochratoxin A in dried vine fruits on the Canadian retail market. Food Additives and Contaminants: Part A; 21(6): 578 - 585.

MacDonald S, Castle L. (1996) A UK retail survey of aflatoxins in herbs and spices and their fate during cooking. Food Additives and Contaminants; 13(1): 121-128.

MAFF. (1996) Aflatoxin surveillance of retail and imported nuts, nut products, dried figs and fig products. Food Surveillance Information Sheet No. 81. London: MAFF.

Magnoli CE, Astoreca A, Ponsone L, Combina M, Palacio G, Rosa CAR, Dalcero AM. (2004) Survey of the mycoflora and ochratoxin A in dried vine fruits from Argentina markets. Letters in Applied Microbiology; 39: 326-331.

Martins ML, Martins HM, Bernardo F. (2001) Aflatoxins in spices marketed in Portugal. Food Additives and Contaminants; 18(4): 315-319.

O' Riordan MJ, Wilkinson MG. (2008) A survey of the incidence and level of aflatoxin contamination in a range of imported spice preparations on the Irish retail market. Food Chemistry; 107(4): 1429-1435.

Paterson RRM. (2007) Aflatoxins contamination in chilli samples from Pakistan. Food Control; 18(7): 817-820.

Pitt JI, Hocking AD. (1997) Fungi and Food Spoilage. London: Blackie Academic and Professional.

Pitt JI, Tomaska L. (2001) Are mycotoxins a health hazard in Australia? 1. Aflatoxins and *Fusarium* toxins. Food Australia; 53(12): 535-539.

Reddy SV, Mayi DK, Reddy MU, Thirumala-Devi K, Reddy DVR. (2001) Aflatoxins B1 in different grades of chillies (*Capsicum annum* L.) in India as determined by indirect competitive-ELISA. Food Additives and Contaminants; 18(6): 553-558.

Romagnoli B, Menna V, Gruppioni N, Bergamini C. (2007) Aflatoxins in spices, aromatic herbs, herb-teas and medicinal plants marketed in Italy. Food Control; 18(6): 697-701.

Sayer ST, Lauren DR. (1991) *Fusarium* infection in New Zealand grain. New Zealand Journal of Crop and Horticultural Science; 19: 143-148.

Selim MI, Popendorf W, Ibrahim MS, El Sharkawy S, El Kashory ES. (1996) Aflatoxin B1 in common Egyptian foods. Journal of the AOAC International; 79(5): 1124-1129.

Senyuva HZ, Gilbert J, Ozcan S, Ulken U. (2005) Survey for co-occurrence of ochratoxin A and aflatoxin B1 in dried figs in Turkey by using a single laboratory-validated alkaline extraction method for ochratoxin A. Journal of Food Protection; 68(7): 1512-1515.

Senyuva HZ, Gilbert J, Ulken U. (2007) Aflatoxins in Turkish dried figs intended for export to the European Union. Journal of Food Protection; 70(4): 1029-1032.

Stanton DW. (2000a) Aflatoxins in foods. ESR Client Report FW0031. Auckland: ESR.

Stanton DW. (2000b) Survey of susceptible foods for ochratoxin A. ESR Client Report FW0030. Auckland: ESR.

Stefanaki I, Foufa E, Tsatsou-Dritsa A, Dais P. (2003) Ochratoxin A concentrations in Greek domestic wines and dried vine fruits. Food Additives and Contaminants: Part A; 20(1): 74 - 83.

Stroka J, Anklam E, Jorissen U, Gilbert J. (2000) Immunoaffinity column cleanup with liquid chromatography using post-column bromination for determination of aflatoxins in peanut butter, pistachio paste, fig paste, and paprika powder: collaborative study. Journal of the AOAC International; 83(2): 320-40.

Tabata S, Kamimura H, Ibe A, Hashimoto H, Iida M, Tamura Y, Nishima T. (1993) Aflatoxin contamination in foods and foodstuffs in Tokyo: 1986-1990. Journal of the AOAC International; 76(1): 32-35.

Taguchi S, Fukushima S, Sumimoto T, Yoshida S, Nishimune T. (1995) Aflatoxins in foods collected in Osaka, Japan, from 1988 to 1992 Journal of the AOAC International; 78(2): 325-327.

Takahashi DM. (1977) Reversed-phase high-performance liquid chromatographic analytical system for aflatoxins in wines with fluorescence detection. Journal of Chromatography A; 131: 147-156.

Van Egmond HP, Jonker MA. (2004) Worldwide regulation of mycotoxins in food and feed in 2003. FAO Food and Nutrition Paper 81. Rome: Food and Agriculture Organization of the United Nations.

Walker R. (1999) Mycotoxins of growing interest. Ochratoxins. Proceedings of the Third Joint FAO/WHO/UNEP International Conference on Mycotoxins, Tunis. Accessed at: ftp://ftp.fao.org/es/esn/food/myco5b.pdf. Accessed: 17 March 2009.

Zinedine A, Brera C, Elakhdari S, Catano C, Debegnach F, Angelini S, De Santis B, Faid M, Benlemlih M, Minardi V, Miraglia M. (2006) Natural occurrence of mycotoxins in cereals and spices commercialized in Morocco. Food Control; 17(11): 868-874.

Zinedine A, Soriano JM, Juan C, Mojemmi B, Molto JC, Bouklouze A, Cherrah Y, Idrissi L, Aouad RE, Manes J. (2007) Incidence of ochratoxin A in rice and dried fruits from Rabat and Sale area, Morocco. Food Additives and Contaminants: Part A; 24(3): 285 - 291.

Zohri AA, Abdel-Gawad KM. (1993) Survey of mycoflora and mycotoxins of some dried fruit in Egypt. Journal of Basic Microbiology; 33(4): 279-288.

APPENDIX 1 DETAILS OF SAMPLES ANALYSED IN THE CURRENT SURVEY

Food type	Sample	Country of Origin	B1	B2	G1	G2	Total*	OTA
Dried Figs	Orchard Choice Mission Figlets	USA	ND	ND	ND	ND		ND
Dried Figs	Tasti Ready to Eat Figs 250g	NS	1.8	1.5	1.8	1.6	6.7	ND
Dried Figs	Dessert Maid Dried Figs 375g	Australia	ND	ND	ND	ND		73
Dried Figs	Angas Park Figs	Turkey	3.2	0.4	1.9	0.2	5.7	ND
Dried Figs	Alison's Pantry Everyday Figs (Bulk Bins)	Turkey	ND	ND	ND	ND		ND
Dried Figs	Summer Harvest Figs (Bulk Bins)	Turkey	ND	ND	ND	ND		ND
Dried Figs	Turkish Dried Figs	Turkey	ND	ND	ND	ND		ND
Dried Figs	Balars Figs Turkish	Turkey	ND	ND	ND	ND		ND
Dried Figs	Sun Valley Foods Figs (Bulk Bins)	Turkey	(0.1)	ND	ND	ND	(0.1)	ND
Dried Figs	Homestead Health Figs Turkish	Turkey	ND	ND	ND	ND		ND
Dried Vine Fruits	Sun Valley Foods Seedless Raisins	NS	ND	ND	ND	ND		ND
Dried Vine Fruits	Cinderella Seedless Currants 400g	NS	ND	ND	ND	ND		(0.4)
Dried Vine Fruits	Cinderella Sultanas 400g	Turkey	ND	ND	ND	ND		(0.3)
Dried Vine Fruits	Sun-Maid Raisins 250g	USA	ND	ND	ND	ND		(0.4)
Dried Vine Fruits	Pam’s Raisins 1kg	NS	ND	ND	ND	ND		ND
Dried Vine Fruits	Pam’s Saultanas 1kg	Turkey	ND	ND	ND	ND		ND
Dried Vine Fruits	Pam’s Currants	NS	ND	ND	ND	ND		(0.6)
Dried Vine Fruits	Sunbeam Sultanas 1kg	NS	ND	ND	ND	ND		ND
Dried Vine Fruits	Home Brand Sultanas 1kg	Turkey	ND	ND	ND	ND		(0.2)
Dried Vine Fruits	Sunbeam Sundried Currents 300g	Australia	ND	ND	ND	ND		ND
Dried Apricots	Angas Park Large Dried Apricots 500g	Australia	ND	ND	ND	ND		ND
Dried Apricots	Sunsweet Dried Apricots 200g	NS	ND	ND	ND	ND		ND
Dried Apricots	Home Brand Dried Apricots 500g	Turkey	ND	ND	ND	ND		ND
Dried Apricots	True Value Apricots 200g	NS	ND	ND	ND	ND		ND
Dried Apricots	Tasti Ready To Eat Apricots 250g	NS	ND	ND	ND	ND		ND
Dried Apricots	Budget Dried Apricots 200g	Turkey	ND	ND	ND	ND		ND
Dried Apricots	Tasti Dried Apricots	NS	(0.2)	(0.2)	(0.2)	0.2	(0.9)	ND
Dried Apricots	Value Pack Choice Apricots 400g	NS	ND	ND	ND	ND		ND
Dried Apricots	Pam’s Large Dried Apricots 200g	Australia	ND	ND	ND	ND		ND

Food type	Sample	Country of Origin	B1	B2	G1	G2	Total*	OTA
Dried Apricots	Naytura Dried Apricots 375g	Australia	ND	ND	ND	ND		ND
Dates	Camel Dates 400g	Iran	ND	ND	ND	ND		ND
Dates	Home Brand Pitted Dated 500g	Iran	ND	ND	ND	ND		ND
Dates	Angas Park Pitted Dates 500g	Iran	ND	ND	ND	ND		ND
Dates	Cinderella Pitted Dates 400g	NS	ND	ND	ND	ND		ND
Dates	Redlotus Dried Red Date 227g	China	ND	ND	ND	ND		ND
Prunes	Naytura Pitted Prunes 250g	NS	ND	ND	ND	ND		ND
Prunes	Tasti Pitted Prunes 250g	NS	ND	ND	ND	ND		ND
Prunes	Pam’s California Pitted Prunes 500g	USA	ND	ND	ND	ND		ND
Prunes	Sunsweet Pitted Prunes Ready to Eat 340g	USA	(0.1)	(0.2)	(0.1)	(0.1)	(0.5)	ND
Prunes	Angas Park Pitted Prunes 500g	Australia	ND	ND	ND	ND		ND
Pepper (black, white)	Greggs Ground white pepper 100g	NS	ND	ND	ND	ND		1.7
Pepper (black, white)	Pam’s Ground White Pepper 50g	NS	ND	ND	ND	ND		1.4
Pepper (black, white)	Home Brand Ground Black Pepper 50g	NS	ND	ND	ND	ND		8.3
Pepper (black, white)	Empire Ground Black Pepper 100g	NS	ND	ND	ND	ND		(0.7)
Pepper (black, white)	King Ground White Pepper 50g	NS	ND	ND	ND	ND		ND
Chilli Powder	Greggs Ground Chilli 40g	NS	5.5	(0.2)	ND	0.2	5.9	3.5
Chilli Powder	Baba's Serbuk Ciki Baba's 250g	Malaysia	ND	ND	ND	ND		1.3
Chilli Powder	Cock Brand Chilli Powder Fine 100g	Thailand	7.7	0.3	0.5	ND	8.5	6.3
Chilli Powder	Furong Brand Red Chilli Powder 113g	China	3.5	ND	ND	ND	3.5	ND
Chilli Powder	Master Foods Ground Chilli Hot 27g	NS	3.7	(0.2)	ND	ND	3.9	3.7
Cayenne pepper	Greggs Cayenne Pepper 40g	NS	4.8	(0.2)	ND	ND	5.0	6.2
Cayenne pepper	Pam’s Cayenne Pepper 40g	NS	3.3	ND	ND	ND	3.3	2.3
Cayenne pepper	Masterfoods Cayenne Pepper Ground, 30g	NS	2.9	ND	ND	ND	2.9	7.3
Cayenne pepper	Pepper Cayenne	NS	3.6	0.4	ND	ND	4.0	5.3
Cayenne pepper	Homestead Cayenne	China	ND	ND	ND	ND		1.8
Paprika	Pam’s Ground Paprika 40g	NS	2.0	ND	0.7	ND	2.6	103
Paprika	Greggs Ground Paprika 40g	NS	3.5	ND	ND	ND	3.5	15
Paprika	Master Foods Ground Paprika 115g	NS	0.7	ND	ND	ND	0.7	41
Paprika	Paprika Premium Powder	NS	(0.2)	ND	ND	ND	(0.2)	24
Paprika	Homestead Health Paprika Standard	Spain	0.9	ND	0.7	ND	1.6	32

Food type	Sample	Country of Origin	B1	B2	G1	G2	Total*	OTA
Ginger, ground	Greggs Ground Ginger 85g	NS	2.7	(0.2)	0.6	ND	3.6	(0.7)
Ginger, ground	Furong Brand Dried Ginger Powder 113g	China	0.3	ND	ND	ND	0.3	(0.5)
Ginger, ground	Sun Yuen Hing Spice Condiments Ginger Powder 454g	China	ND	ND	ND	ND		(0.5)
Ginger, ground	Masterfoods Ginger Ground 25g	NS	1.4	(0.1)	1.0	(0.1)	2.6	2.1
Ginger, ground	Pam's Ground Ginger, 30g	NS	1.3	(0.1)	ND	ND	1.4	ND
Curry powder	Empire Hot Curry Powder 100g	NS	0.6	ND	ND	ND	0.6	(0.5)
Curry powder	Select Signature Range Curry Powder 120g	NS	0.2	ND	ND	ND	0.2	(0.3)
Curry powder	Pam's Hot Curry Powder 40g	NS	202	23.0	(0.1)	ND	225	3.0
Curry powder	Greggs Curry Powder 100g	NS	0.2	ND	ND	ND	0.2	(0.2)
Curry powder	Vencat Curry Powder 100g	India	4.0	0.4	ND	ND	4.4	3.5

Concentration figures in brackets are indicative only and relate to analytical results which lie between the limit of detection and the limit of quantitation of the analytical method.
B1 = aflatoxin B1, B2 = aflatoxin B2, G1 = aflatoxin G1, G2 = aflatoxin G2, OTA = ochratoxin A
ND = Not detected, at a limit of detection of 0.1 µg/kg
* For some samples the figure for total aflatoxins will differ from the sum of the individual aflatoxins as presented in this table. This is due to cumulative roundings.

APPENDIX 2 INTERNATIONAL CONTEXT

Results of some overseas studies of aflatoxins and/or ochratoxin A in food comparable to those analysed in the current study are summarised in Tables 6 and 7.

Table 6: Overseas studies on the aflatoxin content of dried fruits and spices

Country	Year	Food(s)	Number of samples (positive/total)	Range of positive results (µg/kg)*	Reference
Dried Fruits					
Brazil	2002-2003	Black sultanas White sultanas Figs	0/24 3/19 11/19	ND 0.3-2.0 0.3-1500	(Iamanaka *et al.*, 2007)
Cyprus	1992-1996	Figs/fig pie Raisins Dates	4/24 0/22 0/5	AFB1 1.4-6.0 ND ND	(Ioannou-Kakouri *et al.*, 1999)
Egypt	NS	Figs Apricots Plums Raisins	0/4 0/3 0/3 0/3	ND ND ND ND	(Zohri and Abdel-Gawad, 1993)
Morocco	2006	Figs Raisins	6/20 4/20	Mean (Max) 8.7 (32.9) 10.7 (13.9)	(Juan *et al.*, 2008)
Qatar	2002	Figs Raisins Apricots	2/6 0/7 0/4	0.7-11.8 ND ND	(Abdulkadar *et al.*, 2004)
Turkey	1986	Figs	8/284	3.6-473.8	(Boyacioglu and Gonul, 1990)
Turkey	2003-2004	Figs	26/119	0.1-35.1	(Senyuva *et al.*, 2005)
Turkey	2004	Figs -palatable -fluorescent -cull	 1/4 4/4 3/4	 0.2 18-472 0.8-8.3	(Karaca and Nas, 2006)
Turkey	2003-2006	Figs	2043/10396	0.1-316	(Senyuva *et al.*, 2007)
UK	1994-1995	Figs Fig paste	17/49 9/10	1.0-89 1.0-76	(MAFF, 1996)
UK	2000-2001	Figs Prunes Dates Apricots	5/21 2/16 1/12 0/12	0.8-1.2 0.4-0.6 0.7 ND	(Food Standards Agency, 2002)
Spices					
Australia	1999	Chilli powder Paprika	26/26 21/21	7-71 7-89	(Klieber, 2001)
Australia	1995-2000	Spices	29/73	1-144	(Anonymous, 2004)
Egypt	NS	Anise Black cumin	3/5 2/5	30-35 25-31	(El-Kady *et al.*, 1995)

Country	Year	Food(s)	Number of samples (positive/total)	Range of positive results (µg/kg)*	Reference
		Black pepper Peppermint Caraway Coriander Fennel Marjoram Cardamom, Cassia, Cinnamon, Clove, Cumin, Eucalyptus, Ginger, Laurel, Mastic, Nutmeg, White pepper, Cubeb pepper, Red pepper, Rosemary, Safflower, Thyme	3/5 1/5 3/5 1/5 2/5 1/5 0/80	28-35 15 12-14 8 20-25 9 ND	
Egypt	NS	Coriander Red pepper Black pepper Cinnamon	0/4 1/2 1/2 2/2	ND 10 33 10-46	(Selim *et al.*, 1996)
Hungary	2004	 Red pepper Black pepper White pepper Spice mixtures Chilli	 18/70 1/6 0/5 2/5 2/5	AFB1 0.14-15.7 0.46 ND 0.16-0.91 0.75-8.1	(Fazekas *et al.*, 2005)
India	1998-1999	Chilli, grade 1 Chilli, grade 2 Chilli, grade 3 Chilli, cold store Chilli powder	21/42 25/38 41/44 3/15 17/43		(Reddy *et al.*, 2001)
Ireland	NS	Cayenne pepper Chilli powder Cinnamon Coriander Cumin Curry powder Paprika Pepper Turmeric	2/8 10/30 0/7 1/9 0/6 3/20 2/10 4/30 4/10	0.72-18.50 0.35-27.50 ND 2.90 ND 0.50-9.10 0.40-6.40 0.42-3.24 0.81-16.40	(O' Riordan and Wilkinson, 2008)
Italy	2000-2005	Black pepper Spice mixtures Cinnamon Nutmeg Turmeric Hot pepper	0/11 0/1 1/1 1/3 0/1 5/11	ND ND 0.98 2.74 ND 0.57-6.39	(Romagnoli *et al.*, 2007)
Japan	1986-1990	 Black pepper White pepper Red pepper Paprika Nutmeg Curry powder	 0/46 11/84 2/10 5/12 84/108 0/11	AFB1 ND 0.1-1.8 2.6-9.1 0.2-1.3 0.2-13.4 ND	(Tabata *et al.*, 1993)

Country	Year	Food(s)	Number of samples (positive/total)	Range of positive results (µg/kg)*	Reference
		Spice mixtures Other spices	16/78 0/215	0.1-1.9 ND	
Japan	1988-1992	Black pepper White pepper Red pepper Garlic Ginger Mustard Nutmeg Other	0/4 1/13 1/2 0/1 0/1 0/3 2/3 0/4	ND 0.6 0.8 ND ND ND 0.4-1.0 ND	(Taguchi *et al.*, 1995)
Korea	2006	Red pepper flour Red pepper paste Curry Ginger products Black pepper Cinnamon	7/41 2/15 2/20 1/7 0/2 0/3	0.08-4.66 0.21-0.55 0.13-0.46 0.18 ND ND	(Cho *et al.*, 2008)
Morocco	NS	 Black pepper Ginger Paprika Cumin	 14/15 10/12 14/14 8/14	Mean (Max.) 0.21 (0.55) 1.47 (9.10) 5.23 (9.68) 0.05 (0.18)	(Zinedine *et al.*, 2006)
Pakistan	NS	Chilli, ground and whole	13/13	0.1-96.2	(Paterson, 2007)
Portugal	NS	 Cardamom Cayenne pepper Chilli Cloves Cumin Curry powder Ginger Mustard Nutmeg Paprika Saffron White pepper	 0/5 5/5 3/8 0/5 3/7 2/5 0/5 0/5 8/10 8/12 2/5 3/7	AFB1 ND 2.1-31.8 1.5-2.2 ND 1.3-2.3 1.8-2.5 ND ND 1.3-58.0 1.3-17.8 2.0-2.8 1.3-5.0	(Martins *et al.*, 2001)
Qatar	2002	Spice mixtures Chilli powder	5/6 4/6	0.16-5.12 5.6-69.3	(Abdulkadar *et al.*, 2004)
Tunisia	2004-2005	Various (Cumin, Red pepper, Black pepper)	12/14	3.6-87.4	(Ghali *et al.*, 2008)
Turkey	NS	Black pepper Red pepper Red scaled pepper	8/24 11/30 17/30	0.3-16.7 0.8-15.4 0.7-46.8	(Colak *et al.*, 2006)
Turkey	NS	Deep-red ground pepper (isot)	72/75	0.11-24.7	(Ardic *et al.*, 2008)
Turkey	NS	Red scaled pepper Red powder pepper Isot pepper	8/44 3/26 1/20	1.1-97.5 1.8-16.4 13.8	(Erdogan, 2004)
Turkey	2004	Red (chilli) pepper	68/100	AFB1 0.025-40.9	(Aydin *et al.*, 2007)
UK	NS	Chilli, cayenne	27/64	1.0-47.5	(MacDonald

Country	Year	Food(s)	Number of samples (positive/total)	Range of positive results (µg/kg)*	Reference
		pepper, paprika Curry powder Pepper Various herbs and spices	 10/29 0/37 5/41	 1.0-5.2 ND 1.0-8.4	and Castle, 1996)
UK	NS	Paprika Chilli powder Cayenne pepper	26/26 29/31 4/4	0.4-5.7 0.6-14.6 0.2-7.0	(Food Standards Agency, 2005)

* Total aflatoxins unless otherwise stated
AFB1 = Aflatoxin B_1 Total = total aflatoxins (B_1 + B_2 +G_1 + G_2)

Table 7: Overseas studies on the ochratoxin A content of dried fruits and spices

Country	Year	Food(s)	Number of samples (positive/total)	Range of positive results (µg/kg)*	Reference
Dried Fruits					
Argentina	NS	Vine fruits	37/50	1.4-14	(Magnoli *et al.*, 2004)
Brazil	2002-2003	Black sultanas White sultanas Dates Plums Apricots Figs	19/24 10/19 2/20 1/21 0/14 18/19	0.1-33.9 0.1-5.0 0.1-5.0 0.1-5.0 ND 0.1-23.4	(Iamanaka *et al.*, 2005)
Canada	1998-2000	 Raisins Sultanas Currants	 67/85 39/66 2/2	Mean (Max) 1.81 (26.6) 1.81 (26.0) 2.81 (4.85)	(Lombaert *et al.*, 2004)
Egypt	NS	Figs Apricots Plums Raisins	4/4 3/3 3/3 0/3	60-120 50-110 210-280 ND	(Zohri and Abdel-Gawad, 1993)
Germany	1990-1992	Figs Dates	1/39 3/30	0.6 0.1-3.3	(European Commission, 1997)
Greece	1998-2000	 Sultanas Currants	 17/27 43/54	Mean (Max) 2.8 (13.8) 2.1 (13.2)	(Stefanaki *et al.*, 2003)
Morocco	2005	Raisins Figs	6/20 13/20	0.05-4.95 0.03-1.42	(Zinedine *et al.*, 2007)
New Zealand	1999-2000	Figs Currants Sultanas Raisins Prunes Apricots Dates	1/2 7/7 5/10 3/6 0/3 0/3 0/4	0.2 0.4-8.5 0.3-22 0.5-1.1 ND ND ND	(Stanton, 2000b)
Qatar	2002	Figs	0/6	ND	(Abdulkadar *et*

Country	Year	Food(s)	Number of samples (positive/total)	Range of positive results (µg/kg)*	Reference
		Raisins Apricots	2/7 0/4	0.93-1.2 ND	*al.*, 2004)
Turkey	1999-2003	Sultanas	1713/1885	0.3-100 (mean = 1.36)	(Aksoy *et al.*, 2007)
Turkey	2003-2004	Figs	14/119	0.1-26.3	(Senyuva *et al.*, 2005)
Turkey	2003-2004	Figs	55/115	0.12-15.31	(Karbancioglu-Güler and Heperkan, 2008)
UK	2000-2001	Figs Prunes Dates Apricots	4/21 1/16 1/12 0/12	0.4-151 0.6 0.9 ND	(Food Standards Agency, 2002)
Spices					
Hungary	2004	Red pepper Black pepper White pepper Spice mixtures Chilli	32/70 0/6 0/5 0/5 1/5	0.4-66.2 ND ND ND 2.1	(Fazekas *et al.*, 2005)
Qatar	2002	Spice mixtures Chilli powder	1/6 2/6	0.86 2.3-4.9	(Abdulkadar *et al.*, 2004)
Tunisia	2004-2005	Various (Cumin, Red pepper, Black pepper)	8/14	1.7-7.2	(Ghali *et al.*, 2008)
UK	NS	Paprika Chilli powder Cayenne pepper	26/26 31/31 4/4	0.3-47.7 0.2-152.2 2.4-16.5	(Food Standards Agency, 2005)