Author’s copy
provided for non-commercial and educational use only

No material published in World Mycotoxin Journal may be reproduced without first obtaining written permission from the publisher.

The author may send or transmit individual copies of this PDF of the article, to colleagues upon their specific request provided no fee is charged, and further-provided that there is no systematic distribution of the manuscript, e.g. posting on a listserv, website or automated delivery. However posting the article on a secure network, not accessible to the public, is permitted.

For other purposes, e.g. publication on his/her own website, the author must use an author-created version of his/her article, provided acknowledgement is given to the original source of publication and a link is inserted to the published article on the World Mycotoxin Journal website by referring to the DOI of the article.

For additional information please visit www.WorldMycotoxinJournal.org.
Editor-in-chief: Hans P. van Egmond, RIKILT Wageningen UR, Business unit Contaminants & Toxins, the Netherlands

Section editors
- omics: Deepak Bhatnagar, USDA, USA
- feed, toxicology: Johanna Fink-Gremmels, Utrecht University, the Netherlands
- toxicology: Isabelle P. Oswald, INRA, France
- pre-harvest: Alain Pittet, Nestlé Research Center, Switzerland
- post-harvest: Naresh Magan, Cranfield University, United Kingdom
- analysis: Paola Battilani, Università Cattolica del Sacro Cuore, Italy
- food, human health, analysis: Gordon S. Shephard, University of Stellenbosch, South Africa
- economy, regulatory issues: Felicia Wu, Michigan State University, USA
- industrial challenges and solutions: Michele Suman, Barilla, Italy

Editors
Paula Alvito, National Institute of Health, Portugal; Diána Bánáti, ILSI Europe, Belgium; Lei Bao, ACSIQ, China P.R.; Franz Berthiller, BOKU, Austria; Catherine Bessy, FAO, Italy; Wayne L. Bryden, University of Queensland, Australia; Pedro A. Burdaspal, Centro Nacional de Alimentación, Spain; Jeffrey W. Cary, USDA, USA; Sofia N. Chulze, Universidad Nacional de Rio Cuarto, Argentina; Mari Eskola, EFSA; Piotr Goliński, Poznań University of Life Sciences, Poland; Tetsuhisa Goto, Shinshu University, Japan (retired); Clare Hazel, RHM Technology, United Kingdom; Rudolf Krska, University of Natural Resources and Life Sciences, Vienna, Austria; Antonio F. Logrieco, Institute of Sciences of Food Production, Italy; Rebeca López-García, Logre International, Mexico; Chris Maragos, USDA, USA; Monica Olsen, National Food Administration, Sweden; Roland Poms, MoniQA Association, Austria; James J. Pestka, Michigan State University, USA; Michael Rychlik, Technical University München, Germany; Helen Schurz Rogers, CDC/NCEH/DEEHS, USA; Hamide Z. Şenyuva, FoodLife International Ltd., Turkey; Joseph R. Shebuski, Cargill Corporate, USA; Trevor K. Smith, University of Guelph, Canada; Martien Spanjer, VWA, the Netherlands; Jörg Stroka, European Commission, IRMM; János Varga, University of Szeged, Hungary; Frans Verstraete, European Commission, DG Health and Consumer Protection; Cees Waalwijk, Plant Research International, the Netherlands; Thomas B. Whitaker, USDA, USA; Christopher P. Wild, IARC, WHO

Founding editor: Daniel Barug, Bastiaanse Communication, the Netherlands

Publication information
World Mycotoxin Journal: ISSN 1875-0710 (paper edition); ISSN 1875-0796 (online edition)

Subscription to ‘World Mycotoxin Journal’ (4 issues per year) is either on institutional (campus) basis or on personal basis. Subscriptions can be online only, printed copy, or both. Prices are available upon request from the publisher or from the journal’s website (www.WorldMycotoxinJournal.org). Subscriptions are accepted on a prepaid basis only and are entered on a calendar year basis. Subscriptions will be renewed automatically unless a notification of cancelation has been received before the 1 of December. Issues are sent by standard mail. Claims for missing issues should be made within six months of the date of dispatch.

Further information about the journal is available through the website www.WorldMycotoxinJournal.org.

Paper submission
http://mc.manuscriptcentral.com/wmj

Editorial office
Bastiaanse Communication
P.O. Box 179
3720 AD Bilthoven
The Netherlands
editorial@WorldMycotoxinJournal.org
Tel: +31 30 2294247
Fax: +31 30 2252910

Orders, claims and back volumes
Wageningen Publishers
P.O. Box 220
6700 AE Wageningen
The Netherlands
subscription@WorldMycotoxinJournal.org
Tel: +31 317 476516
Fax: +31 317 453417
Aflatoxins in cereals: worldwide occurrence and dietary risk assessment

P.D. Andrade and E.D. Caldas*

Laboratory of Toxicology, Faculty of Health Sciences, University of Brasília, Campus Darci Ribeiro, 70910-900, Brasília, DF, Brazil; eloisa@unb.br

Received: 20 October 2014 / Accepted: 4 February 2015
© 2015 Wageningen Academic Publishers

RESEARCH ARTICLE

Abstract

The worldwide occurrence of aflatoxins (AFB1, AFB2, AFG1, AFG2), genotoxic mycotoxins, in raw maize, rice, sorghum and wheat samples collected since the year 2000 was evaluated using published data and occurrence data from the GEMS/Food database (https://extranet.who.int/gemsfood). Dietary risk assessments were conducted using GEMS/Food total aflatoxin occurrence and food consumption data obtained from the 17 Cluster Diets. Risk characterisation arising from aflatoxin exposure was conducted using both cancer risk and margin of exposure (MOE) approaches. A total of 89 publications were retrieved from the literature, reporting data related to 18,097 samples, of which 37.6% were positive for at least one aflatoxin. The total upper bound (UB) mean for all samples analysed was 13.6 µg/kg, and was higher for rice (24.6 µg/kg) and sorghum (25.9 µg/kg). Of data related to the analysis of 4,536 samples reported to GEMS/Food database, 12.7% were positive for at least one aflatoxin. The total UB mean was 1.9 µg/kg, and was higher for rice (2.4 µg/kg) and maize (1.6 µg/kg). Total intakes ranged from 3.0 ng/kg bw/day (Cluster C11) to 17.1 ng/kg bw/day (Cluster C09). On average, the consumption of rice contributed to 41.6% of the total aflatoxin intake in all clusters, followed by wheat (35.4%), maize (21.2%) and sorghum (1.8%). The lowest cancer risk was found in cluster C11 (0.057 cancers/year/10^5 individuals), and the highest in cluster C09 (0.467 cancers/year/10^5 individuals). MOE ranged from 56 (C11) to 10 (C09), indicating a potential risk to consumers. These results highlight the need for continuous action by health authorities to decrease aflatoxin contamination in cereals, as they are staple foods in diets worldwide. These actions include the enforcement of code of practices at the national level and the establishment of maximum contamination levels by the Codex System.

Keywords: aflatoxins, cereal diets, dietary exposure, carcinogenicity, risks

1. Introduction

Cereals are staple foods in diets around the world. Wheat is the main cereal consumed in America and Asia accounting, respectively, for 14.1 and 24.3% of the total calorie intake in these regions. Rice is the main contributor to the total energy intake in Asia (28.5%) and wheat and maize contribute equally (30%) in Africa (FAO, 2014). The contamination of cereals with aflatoxins B1, B2, G1 and G2 (AFB1, AFB2, AFG1 and AFG2) has been reported worldwide. Mean concentrations in positive maize samples in Argentina and Uganda were, respectively, 35.8 µg/kg (total aflatoxins; 264/3,192 samples) (Garrido et al., 2012), and 19.5 µg/kg (total aflatoxins; 296/390 samples) (Kaaya and Kyamuhangire, 2006). The mean level of aflatoxins found in rice from Pakistan was 11.2 µg/kg (total aflatoxins; 185/413 samples) (Iqbal et al., 2012), while in South Korea it was only 1.7 µg/kg (total aflatoxins; 6/160 samples) (Ok et al., 2014). In Nigeria, 55% of the 168 sorghum samples were contaminated with AFB1, with levels up to 1,164 µg/kg (Hussaini et al., 2009), while in Turkey wheat samples reached levels up to 643.5 µg/kg (total aflatoxins; 24/41 samples) (Giray et al., 2007).

Aflatoxins are human liver carcinogens, with AFB1 shown to be genotoxic (IARC, 1993); as such, exposure should be as low as reasonably achievable (CAC, 1995). The complete elimination of aflatoxins from the food supply, however, is not possible, and worldwide strategies are needed to control and manage contamination (CAC, 2003). Aspergillus flavus and Aspergillus parasiticus infection and aflatoxin production in cereals are influenced by several
environmental factors such as temperature, humidity, insect damage and drought (Miraglia et al., 2009). Furthermore, aflatoxins can also be produced after harvesting the grain (Pitt et al., 2013), mainly during storage.

Several countries have established regulatory limits to control the presence of aflatoxins in cereals, including Brazil (Anvisa, 2011), European Union (EC, 2006), and the United States (USFDA, 2000). Internationally, maximum levels (ML) for aflatoxins in cereals are currently under discussion at the Codex Committee on Contaminants in Foods (FAO/WHO, 2014). Given the difficulty of eliminating aflatoxins from the food chain and considering the worldwide consumption of cereals, dietary risk assessments for aflatoxins are essential to help government authorities and the Codex Alimentarius to take actions aimed at reducing risk while still ensuring the food security.

In the context of food safety, risk assessment is a four-step conceptual framework that aims to estimate the risk of occurrence of adverse health effects after exposure to chemicals present in food. The hazard identification step is designed to identify the nature of the adverse health effects caused by human exposure to the contaminant, and the aim of the hazard characterisation step is to establish a quantitative relationship between exposure and the incidence of adverse effects. In the exposure assessment step the likely intake of contaminants through the diet is estimated, taking into account the concentration of the chemical in food, as well as consumption patterns. The risk characterisation step finalises the process, providing an estimation of the probability of occurrence of health outcomes in a population under defined exposure conditions (IPCS, 2009).

Dietary exposure assessments for aflatoxins have been conducted worldwide. In most studies, cereals accounted for over 90% of the total intake (Andrade et al., 2013; Ding et al., 2012; Li et al., 2014; Park et al., 2004; Yazdanpanah et al., 2013). Risk characterisation for aflatoxins has been conducted using two different approaches. The first, developed by the FAO/WHO Joint Expert Committee on Food Additives (JECFA), estimates the cancer risk for a given population considering the incidence of the hepatitis B virus (HBsAg+) individuals and the carcinogenic potency of aflatoxins, which was defined for HBV carriers and non-carriers (FAO/WHO, 1998). More recently, the margin of exposure (MOE) approach has been used by the European Food Safety Authority (EFSA) and was recommended by JECFA to evaluate compounds that are both carcinogenic and genotoxic (EFSA, 2005; FAO/WHO, 2006). The MOE is the ratio of a toxicological threshold obtained from animal studies and the estimated human exposure (IPCS, 2009).

This study aimed to evaluate the current scenario on aflatoxin contamination in raw maize, rice, sorghum and wheat commercialised worldwide, and to estimate the dietary exposure to aflatoxins and the potential health risks arising from this exposure. The first draft of this paper was the basis for the preparation of the Discussion Paper on Aflatoxins in Cereals presented at the 8th Session of the Codex Committee on Contaminants in Food (CX/CF 14/8/15; CAC, 2014a).

2. Materials and methods

**Aflatoxins occurrence: data obtained from the literature**

Occurrence data on aflatoxins in raw maize, rice, sorghum and wheat were obtained from published studies related to samples collected from 2000 to 2014. The search was conducted in the Web of Science database and Google Scholar in September 2012, July 2013, and May 2014, using the following keywords: ‘mycotoxin’ and ‘aflatoxin’ alone, or in combination with ‘maize’, ‘rice’, ‘sorghum’ and ‘wheat’, using the logical operator AND. Papers related to samples that were inoculated with mycotoxin producing fungi in the laboratory were excluded. Only peer review papers were considered in the search, written in English or in other languages.

For each crop, the mean values estimated for all studies were calculated by weighting the reported mean of each study by the number of samples analysed in that study. When only the median value was reported in the study, this value was used to estimate the weighted mean. When only the concentration range was reported, the midrange was used in the calculation. The lower bound of the total mean (LB) was estimated considering samples below the limit of detection (LOD) or below the limit of quantification (LOQ) as zero. The upper bound (UB) was obtained considering samples below LOD or below LOQ as %LOD or %LOQ. Whenever the LOD or LOQ of the method used in the study were not reported, limits found in other studies that used a similar analytical method were used in the calculation of the UB mean. When both LOD and LOQ were reported, the latter was used in the estimation.

**Aflatoxins occurrence: data from the GEMS/Food database**

The Global Environment Monitoring System/Food Contamination Monitoring and Assessment Programme (GEMS/Food) compile surveillance and monitoring data on food contamination submitted by national government authorities. In July 2013, the JECFA issued a specific public call for data on aflatoxin contamination in cereals, to be submitted to GEMS/Food (https://extranet.who.int/gemsfood). Data on total aflatoxin (AFB1 + AFB2 + AFG1 + AFG2) in raw maize, rice, sorghum and wheat were extracted from the GEMS/Food database using an ADS WHO partner login, and exported to MS Excel (Microsoft,
Redmond, WA, USA) spreadsheets. Data were obtained for all WHO regions and countries, with the sampling period starting in 2000. Data were extracted on October 21, 2013 and on July 02, 2014.

The informed food codes (WHO food identifier, WHO food code and local food identifier) were used to identify processed commodities, which were not included in this study. Rice samples that included inedible portions (husk) or that were submitted to heat treatment (cooked) prior to analysis were also excluded. When the portion analysed was not mentioned, it was assumed that the analysis was performed in the cereal edible portion. Information regarding analytical quality assurance was also obtained from the GEMS/Food database.

For some samples, there were up to six entries in the database (individual aflatoxins, sum of AFB\textsubscript{1} and AFB\textsubscript{2}, and total aflatoxins), but only the total aflatoxins value was considered. When the total aflatoxins value was not included, it was estimated from the individual aflatoxin values. When values reported were below LOQ or LOD, they were considered as 0 or ½LOQ/LOD in the LB or UB estimations of the means, respectively. When both LOD and LOQ were reported, ½LOQ was used. Where LOD or LOQ was not reported, the value informed for other samples from the same laboratory or country was used.

Consumption of cereals: data from the 17 GEMS/Food Consumption Cluster Diets

The Food and Agriculture Organization of the United Nations (FAO) compiles country-level data on the production and trade of food commodities, producing food balance sheets that provide data on the overall per capita supply of commodities within countries (FAO, 2014). GEMS/Food uses the FAO Food Supply Utilisation Account data to determine the food consumption patterns that are used in chronic dietary risk assessments conducted at the international level by FAO/WHO scientific panels, including the JECFA. The 17 GEMS/Food cluster diets were elaborated based on FAO Food Supply Utilisation Account data from 2002 to 2007 for 179 countries. Clusters were formed according to their consumption system profiles (combination of different food products and local factors such as availability, seasonality and socio-cultural habits) using statistical methods (Sy et al., 2013). The average data were weighted by the population size to determine the average kg/person/cluster over a 5 year period. The countries included in each Cluster are shown in Figure 1. Body weight (bw) is 60 kg for all clusters, except cluster 09 (55 kg).

Dietary risk assessment

Total chronic intake of aflatoxins through the consumption of rice, maize, wheat and sorghum for each of the GEMS/Food Cluster Diets was estimated using the International Estimated Daily Intake (IEDI) 17 Cluster diets template, developed by the Dutch National Institute for Public Health and the Environment, in cooperation with the WHO, to conduct dietary intake by the FAO/WHO Joint Meeting on Pesticide Residues (FAO/WHO, 2013). The IEDI 17 Cluster diets template estimates the dietary intake of aflatoxins, according to FAO/WHO recommendation (FAO/WHO, 2005), as shown in Equation 1:
Table 1. Summary of published data on aflatoxins in cereal samples collected from 2000 onwards.

<table>
<thead>
<tr>
<th>Country</th>
<th>Cereal</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>African continent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Algeria</td>
<td>W</td>
<td>Riba et al., 2010</td>
</tr>
<tr>
<td>Benin and Togo</td>
<td>M</td>
<td>Egal et al., 2005</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>M</td>
<td>Probst et al., 2014; Warth et al., 2012</td>
</tr>
<tr>
<td>Cameroon</td>
<td>M</td>
<td>Abia et al., 2013; Probst et al., 2014</td>
</tr>
<tr>
<td>Egypt</td>
<td>M</td>
<td>Nogaim et al., 2011</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>S</td>
<td>Chala et al., 2014; Probst et al., 2014</td>
</tr>
<tr>
<td>Kenya</td>
<td>M, W</td>
<td>Daniel et al., 2011; Muthomi et al., 2008; Mwihia et al., 2008; Probst et al., 2014</td>
</tr>
<tr>
<td>Ivory Coast</td>
<td>M, R</td>
<td>Probst et al., 2014; Sangare-Tigori et al., 2006</td>
</tr>
<tr>
<td>Lesotho</td>
<td>M</td>
<td>Mohale et al., 2013; Probst et al., 2007</td>
</tr>
<tr>
<td>Malawi</td>
<td>S</td>
<td>Matumba et al., 2011; Probst et al., 2014</td>
</tr>
<tr>
<td>Morocco</td>
<td>W</td>
<td>Zinedine et al., 2006</td>
</tr>
<tr>
<td>Mozambique</td>
<td>M</td>
<td>Probst et al., 2014; Warth et al., 2012</td>
</tr>
<tr>
<td>Nigeria</td>
<td>M, R, S, W</td>
<td>Adejumo et al., 2013; Ayejuyo et al., 2011; Bandyopadhay et al., 2007; Bankole and Mabekoje, 2004; Hussain et al., 2009; Makun et al., 2011</td>
</tr>
<tr>
<td>South Africa</td>
<td>M</td>
<td>Chilaka et al., 2012; Shephard et al., 2013</td>
</tr>
<tr>
<td>Tanzania</td>
<td>M</td>
<td>Kimanya et al., 2008; Probst et al., 2014</td>
</tr>
<tr>
<td>Uganda</td>
<td>M</td>
<td>Kaaya and Kyamuhangire, 2006; Probst et al., 2014</td>
</tr>
<tr>
<td>Zambia</td>
<td>M</td>
<td>Mukanga et al., 2010; Probst et al., 2014</td>
</tr>
<tr>
<td>D. Republic of Congo, Ghana,</td>
<td>M</td>
<td>Probst et al., 2014</td>
</tr>
<tr>
<td>Mali, Rwanda, Senegal, Sierra-Leone, Somalia, Zimbabwe</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cancer risk = \( P_{cancer} \times \text{total intake} \) (2)

\[ P_{cancer} = (PHBsAg^+ \times \%\text{pop.HBsAg}^+) + (PHBsAg^- \times \%\text{pop.HBsAg}^-) \] (3)

The MOE was given by the ratio between the benchmark dose level that caused a 10% increase in cancer incidence in rodents (BMDL10 = 170 ng/kg bw/day; 95% lower confidence limit) (EFSA, 2007) and the total intake (Equation 4). MOE values lower than 10,000 may indicate a public health concern (EFSA, 2005).

\[ \text{MOE} = \frac{\text{BMDL10}}{\text{total intake}} \] (4)

3. Results

Aflatoxins occurrence: data from the literature

A total of 89 publications reporting data on aflatoxins contamination in raw cereal samples collected since 2000 were retrieved from the literature. The first such study was published in 2003, and the highest numbers of papers were found in 2011 and 2012 (15 and 14 papers, respectively). A summary of the published studies, grouped by continent, is shown in Table 1. Data covers samples collected in a wide range of countries. Most papers concerned maize (n=47) and rice (n=39), and 18 studies analysed two or more cereals of interest to this study. The majority of papers...
One study reported that the laboratory participated in proficiency testing, two in interlaboratory studies, and one reported the use of certified reference material for method validation. Thirty papers did not provide any analytical quality assurance information. Even though quality assurance information was not available in some studies, all data were included in the dataset in order to describe the occurrence scenario.

Table 2 summarises the published data on aflatoxin levels in cereals. A total of 18,097 samples were analysed in the studies, with maize accounting for 54.3% of the samples (9,819 samples), followed by rice (21.1%). About 41% of the samples were collected in Asia, of which 39.2% were rice samples. Maize was the main cereal analysed in American countries, accounting for 85.6% of the samples for the region. Most of the analysed wheat samples were from Asian countries (72.1%). Sorghum was only analysed in samples from African and Asian countries.

Considering all samples analysed in the studies, 37.6% were positive for at least one aflatoxin (Table 2). Sorghum had the highest incidence of positive samples (68.9%), followed by rice (52.3%). Contaminated rice, sorghum and wheat samples were mostly from Asia (about 80%), while 40% of contaminated maize came from Africa. There was no positive wheat sample reported in the American continent and the lowest incidence of aflatoxins for the other commodities was also found in this continent.
The mean aflatoxin level found in positive samples, considering all cereals, was 34.2±3.4 µg/kg, with rice samples having the highest mean among the grains analysed (46.6±3.6 µg/kg). The highest aflatoxin level (48,000 µg/kg) was found in a sample collected in Kenya (Daniel et al., 2011). Samples of maize and rice analysed from Asia had the highest mean of positive samples (35.6 µg/kg and 54.0 µg/kg, respectively), while Africa showed the highest mean level of contamination in sorghum (79.7 µg/kg), and Europe in wheat (46.9 µg/kg). The total UB mean of all samples analysed was 13.6 µg/kg. Sorghum samples had the highest total mean, with similar lower and UB levels (25.7 and 25.9 µg/kg).

**Table 2. Worldwide occurrence of total aflatoxin in cereals obtained from published literature (samples collected from 2000 onwards).**

<table>
<thead>
<tr>
<th>Cereal</th>
<th>Positive/analysed samples (%)</th>
<th>Positive samples (µg/kg)</th>
<th>Total mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SE</td>
<td>Range</td>
<td>LB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(µg/kg)</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>47</td>
<td>2,496/9,819 (25.4)</td>
<td>28.2±5.5</td>
</tr>
<tr>
<td>Africa</td>
<td>20</td>
<td>997/7,771 (36.0)</td>
<td>25.9±6.2</td>
</tr>
<tr>
<td>America</td>
<td>9</td>
<td>409/4,056 (10.1)</td>
<td>30.8±4.5</td>
</tr>
<tr>
<td>Asia</td>
<td>12</td>
<td>655/1,134 (57.8)</td>
<td>35.6±19.9</td>
</tr>
<tr>
<td>Europe5</td>
<td>6</td>
<td>435/1,858 (23.4)</td>
<td>20.1±5.5</td>
</tr>
<tr>
<td>Rice</td>
<td>39</td>
<td>1,995/3,811 (52.3)</td>
<td>46.6±3.6</td>
</tr>
<tr>
<td>Africa</td>
<td>6</td>
<td>64/99 (64.6)</td>
<td>28.9±13.3</td>
</tr>
<tr>
<td>America</td>
<td>7</td>
<td>205/625 (32.8)</td>
<td>5.2±7.6</td>
</tr>
<tr>
<td>Asia</td>
<td>23</td>
<td>1,654/2,889 (57.3)</td>
<td>54.0±4.6</td>
</tr>
<tr>
<td>Europe</td>
<td>3</td>
<td>72/198 (36.4)</td>
<td>8.8±3.1</td>
</tr>
<tr>
<td>Sorghum</td>
<td>11</td>
<td>1,433/2,079 (68.9)</td>
<td>37.3±17.4</td>
</tr>
<tr>
<td>Africa</td>
<td>9</td>
<td>257/463 (55.5)</td>
<td>79.7±21.1</td>
</tr>
<tr>
<td>Asia</td>
<td>2</td>
<td>1,176/1,616 (72.8)</td>
<td>27.8±11.4</td>
</tr>
<tr>
<td>Wheat</td>
<td>18</td>
<td>874/2,388 (36.6)</td>
<td>18.0±9.1</td>
</tr>
<tr>
<td>Africa</td>
<td>6</td>
<td>66/206 (32.0)</td>
<td>4.9±1.4</td>
</tr>
<tr>
<td>America</td>
<td>2</td>
<td>0/56 (0.0)</td>
<td>–</td>
</tr>
<tr>
<td>Asia</td>
<td>7</td>
<td>691/1,721 (40.2)</td>
<td>14.4±1.9</td>
</tr>
<tr>
<td>Europe</td>
<td>3</td>
<td>117/405 (28.9)</td>
<td>46.9±51.4</td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>6,798/18,097 (37.6)</td>
<td>34.2±3.4</td>
</tr>
</tbody>
</table>

1 n = number of studies; SE = standard error.  
2 Mean of all samples.  
3 Lower bound: samples < LOD/LOQ = zero.  
4 Upper bound: samples < LOD/LOQ = ½LOD/½LOQ.  
5 Includes monitoring data collected by EFSA (2007).  
6 Mean of positive samples not available in EFSA (2007).  
7 Mostly rice collected on the market, but some studies may include rice samples with the husk.

The mean aflatoxin level found in positive samples, considering all cereals, was 34.2±3.4 µg/kg, with rice samples having the highest mean among the grains analysed (46.6±3.6 µg/kg). The highest aflatoxin level (48,000 µg/kg) was found in a sample collected in Kenya (Daniel et al., 2011). Samples of maize and rice analysed from Asia had the highest mean of positive samples (35.6 µg/kg and 54.0 µg/kg, respectively), while Africa showed the highest mean level of contamination in sorghum (79.7 µg/kg), and Europe in wheat (46.9 µg/kg). The total UB mean of all samples analysed was 13.6 µg/kg. Sorghum samples had the highest total mean, with similar lower and UB levels (25.7 and 25.9 µg/kg).

**Aflatoxins occurrence: data from the GEMS/Food database**

Figure 2 shows the countries that submitted data on aflatoxins in raw maize, rice, sorghum and wheat to the GEMS/Food database, related to 4,536 samples collected since the year 2000. Singapore submitted the largest dataset (1,028 samples), followed by Canada (967), the Republic of Korea (392), Germany (387), and Brazil (377). Most maize samples came from the USA (27.9%), rice from Singapore (27.8%), sorghum from Republic of Korea (85.5%) and wheat from Canada (81.5%). On average, 324 samples were collected for analysis each year, most of which in 2005 and 2011 (32% of all samples). The smallest number of samples was obtained in 2000 (0.9%), and 2004 (0.6%).

The GEMS/Food dataset was comprised mainly of samples collected by random sampling (78.5% of the samples), and 20.0% by target sampling. For 1.5% of the samples, the sampling method was not informed. Information on portions analysed was not available for 21 samples, none of which were contaminated with aflatoxins. Regarding analytical quality assurance of the laboratory, the GEMS/Food system allows one of four options to be checked: officially accredited methodology, internal quality assurance, proficiency testing, and unknown. For most of the samples (53.3%) officially accredited methodologies were used; for 19.3% the laboratory had internal quality assurance, proficiency testing, and unknown.
assurance, and for 17.9% the laboratory participated in proficiency testing. This information was unknown or was not provided for the remaining samples (9.5%). All samples were kept in the dataset, even those analysed by laboratories that have not provided quality assurance information.

Table 3 summarises the data submitted to GEMS/Food, grouped by continent. Considering all samples analysed, 12.7% were positive for aflatoxins, with a mean of 10.7±35.3 µg/kg. Total LB and UB means were, respectively, 1.4 µg/kg and 1.9 µg/kg. Rice was the commodity with the largest number of records in the database (66.6%), and with the highest incidence of positive samples (17.7%), including the highest aflatoxin level (347 µg/kg in a Mali sample). Rice also had the highest LB and UB values (1.9 and 2.4 µg/kg, respectively). Wheat was the cereal with the lowest incidence and levels of aflatoxins (Table 3).

Consumption of cereals: data from the 17 GEMS/Food Cluster Diets

Consumption data for maize, rice, sorghum and wheat (including processed products) for the 17 clusters are summarised in Figure 3. Wheat is the cereal most consumed worldwide (daily mean of 205.8 g/person), and the most consumed in 11 of the 17 clusters, including C01, C02, and C06 (mainly countries in Northern Africa and Asia; Figure 1). Rice is the second cereal most consumed (91.3 g/person/day), and the main cereal consumed in clusters C05, C09, and C14 (mostly South American and Asian countries; Figure 1). Maize (mean of 48.9 g/person/day) is the main cereal consumed in clusters C03, C13, and C16 (mostly African countries; Figure 1). The mean worldwide consumption of sorghum is 11 g/person/day, with the highest consumption in clusters C13 (89.2 g/person/day), and C16 (35.4 g/person/day).

Dietary risk assessment of aflatoxins using GEMS/Food data

The UB total intakes of aflatoxins through the consumption of maize, rice, sorghum and wheat ranged from 3.0 ng/kg bw/day (Cluster C11) to 17.1 ng/kg bw/day (Cluster C09) (Table 4). LB intakes varied from 0.7 to 12.1 ng/kg bw/day (data not shown). As the concentration for each cereal in the intake calculation was constant (UB mean concentration for each crop; Table 3), only the consumption pattern had an impact on the total aflatoxin intake among the clusters.

On average, the consumption of rice contributed to 41.6% of the total intake in all clusters, followed by wheat (35.4%), maize (21.2%) and sorghum (1.8%). Figure 4 shows the impact of each cereal in total intake for each cluster. The highest impact of rice was mainly due to the highest contamination level (2.4 µg/kg), while for wheat, high consumption was the parameter that most affected intake, as the concentration was low (0.6 µg/kg). The consumption of rice contributed from 46.8 to 89.1% to total intake for eight clusters, including C05, C09, C14 and C17 (mostly Asian countries; Figure 1). Wheat was the main contributor to total intake for clusters C13 and C16 (42.4-59.4%; mostly African countries; Figure 1). The contribution of sorghum to total intake reached a maximum of 13.4% in C13 (Figure 4).

Risk characterisation from the exposure to aflatoxins was estimated using the cancer risk and MOE approaches, and the results are shown in Table 4. The lowest cancer risk was found in cluster C11 (0.057 cancers/ year/10^5 individuals) and the highest in cluster C09 (0.467 cancers/year/10^5 individuals). MOE ranged from 56 (C11) to 10 (C09).
Table 3. GEMS/Food data on aflatoxins in cereals grouped by continent.

<table>
<thead>
<tr>
<th>Positive/analysed samples (%)</th>
<th>Positive samples (µg/kg)</th>
<th>Total mean²</th>
<th>Lower bound: samples &lt; LOQ = zero.</th>
<th>Upper bound: samples &lt; LOD/LOQ = ½LOD/½LOQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>America</td>
<td>33/588 (5.6)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Asia</td>
<td>5/224 (2.3)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Europe</td>
<td>4/85 (4.7)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Rice</td>
<td>536/3,021 (17.7)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Africa</td>
<td>84/98 (9.5)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>America</td>
<td>223/615 (36.3)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Asia</td>
<td>66/1,553 (4.2)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Europe</td>
<td>163/755 (21.6)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Sorghum</td>
<td>4/83 (4.8)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>America</td>
<td>2/210 (100.0)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Asia</td>
<td>2/80 (2.5)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Europe</td>
<td>0/1 (0.0)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Wheat</td>
<td>3/844 (0.4)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>America</td>
<td>0/888 (0.0)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Asia</td>
<td>0/54 (0.0)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Europe</td>
<td>3/152 (2.9)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Total</td>
<td>576/4,536 (12.7)</td>
<td>13.0±18.7</td>
<td>0.2-93.1</td>
<td>0.7-1.6</td>
</tr>
</tbody>
</table>

1 ND = not detected; SD = standard deviation.  
2 Total mean = mean of all samples.  
3 Lower bound: samples < LOD/LOQ = zero.  
4 Upper bound: samples < LOD/LOQ = ½LOD/½LOQ  
5 Africa: samples from Mali; America: samples from Brazil, Canada and USA; Asia: samples from Japan, Philippines, Republic of Korea, Singapore, Thailand; Europe: samples from Austria, Belgium, Cyprus, Czech Republic, France, Germany, Greece, Ireland, Italy, Latvia, Portugal, Slovakia, Slovenia, Spain and Sweden.

Figure 3. Consumption of maize, rice, sorghum and wheat for the 17 Cluster diets, including consumption of processed cereals (WHO, 2014). For Clusters, see Figure 1.
In this study, we reported data on aflatoxin contamination in maize, rice, wheat and sorghum grains obtained from the published literature and the GEMS/Food database. Literature data concerned samples collected in 64 countries; data from the GEMS/Food were submitted by 24 countries. No data on samples collected in Oceania countries were available in either dataset. Aflatoxin contamination data were mostly available for maize (54.2% of all samples analysed in the studies), while most of the data submitted to GEMS/Food were related to rice (66.6%). The interest in sorghum was lower in the literature in comparison with the other cereals, and the data provided to GEMS/Food were also very limited (83 samples), and did not include samples collected in African countries, the highest consumers of sorghum worldwide. This dataset will probably increase in the next few years as a FAO/WHO project on mycotoxins in sorghum is being conducted, with samples collected in the four largest producing/exporting countries of this commodity (Burkina Faso, Ethiopia, Mali, and the Sudan) (CAC, 2012). Under this project, up to February 2014, a total of 20,908 of sorghum samples have been analysed, with 3.1% of samples positive for mycotoxins, mainly aflatoxins, fumonisins, and sterigmatocystin (CAC, 2014b). Data reported in the literature may include some monitoring data submitted to the GEMS/Food database, however it was not possible to trace it back. Nevertheless, the dietary risk assessment was conducted using only the GEMS/Food dataset.

### Table 4. Upper bound of the aflatoxin intake, cancer risk and margin of exposure through the consumption of maize, rice, wheat and sorghum for GEMS/Food Clusters C01 to C17 (ng/kg bw/day).

<table>
<thead>
<tr>
<th>Aflatoxins (µg/kg)</th>
<th>C01</th>
<th>C02</th>
<th>C03</th>
<th>C04</th>
<th>C05</th>
<th>C06</th>
<th>C07</th>
<th>C08</th>
<th>C09</th>
<th>C10</th>
<th>C11</th>
<th>C12</th>
<th>C13</th>
<th>C14</th>
<th>C15</th>
<th>C16</th>
<th>C17</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBsAg+</td>
<td>3%</td>
<td>6%</td>
<td>8%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>6%</td>
<td>6%</td>
<td>6%</td>
<td>8%</td>
<td>6%</td>
<td>6%</td>
<td>8%</td>
<td>6%</td>
<td>8%</td>
</tr>
<tr>
<td>Rice</td>
<td>2.4</td>
<td>1.8</td>
<td>0.6</td>
<td>3.4</td>
<td>4.5</td>
<td>7.8</td>
<td>3.7</td>
<td>0.8</td>
<td>0.6</td>
<td>14.8</td>
<td>3.0</td>
<td>0.7</td>
<td>3.4</td>
<td>2.1</td>
<td>11.4</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Maize</td>
<td>1.6</td>
<td>0.8</td>
<td>1.2</td>
<td>2.9</td>
<td>1.4</td>
<td>1.6</td>
<td>2.0</td>
<td>0.5</td>
<td>0.7</td>
<td>0.8</td>
<td>1.1</td>
<td>0.2</td>
<td>1.7</td>
<td>3.1</td>
<td>0.3</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.6</td>
<td>3.8</td>
<td>3.4</td>
<td>0.4</td>
<td>2.8</td>
<td>1.7</td>
<td>4.3</td>
<td>2.5</td>
<td>2.4</td>
<td>1.5</td>
<td>2.4</td>
<td>2.2</td>
<td>1.7</td>
<td>0.6</td>
<td>1.1</td>
<td>2.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.6</td>
<td>0.04</td>
<td>0.001</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.03</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.07</td>
<td>0.9</td>
<td>0.02</td>
<td>0.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>1.9</td>
<td>6.5</td>
<td>5.2</td>
<td>6.8</td>
<td>8.8</td>
<td>11.2</td>
<td>10.1</td>
<td>3.9</td>
<td>3.8</td>
<td>17.1</td>
<td>6.4</td>
<td>3.0</td>
<td>6.9</td>
<td>6.7</td>
<td>12.8</td>
<td>4.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Cancer risk1</td>
<td>0.121</td>
<td>0.143</td>
<td>0.227</td>
<td>0.165</td>
<td>0.21</td>
<td>0.189</td>
<td>0.072</td>
<td>0.071</td>
<td>0.0467</td>
<td>0.121</td>
<td>0.057</td>
<td>0.189</td>
<td>0.222</td>
<td>0.352</td>
<td>0.084</td>
<td>0.114</td>
<td>0.144</td>
</tr>
<tr>
<td>MOE2</td>
<td>26.3</td>
<td>32.6</td>
<td>24.8</td>
<td>19.2</td>
<td>15.1</td>
<td>16.8</td>
<td>44.0</td>
<td>44.9</td>
<td>10.0</td>
<td>26.4</td>
<td>56.0</td>
<td>24.6</td>
<td>25.5</td>
<td>13.2</td>
<td>37.8</td>
<td>49.4</td>
<td>32.4</td>
</tr>
</tbody>
</table>

1 Cancers/year/10¹⁰ individuals, estimated according to FAO/WHO (1998).
2 Based on a BMDL₁₀ in rodents of 170 ng/kg bw/day (EFSA, 2007).

### Figure 4. Impact of maize, rice, sorghum and wheat on the total aflatoxin intake for each cluster. For Clusters, see Figure 1.
With the exception of rice samples from Africa and American continents, the incidence of aflatoxins and the concentration were higher in the published data than in the GEMS/Food database, probably due to sampling differences in the two data sources. Research studies normally do not follow strict sampling plans, and may include samples involved in outbreaks of mycotoxin contamination, not reflecting the general scenario of a specific region or country. This was the case of a survey conducted in Kenya, where some samples were collected in households of patients involved in the aflatoxicosis outbreak (Daniel et al., 2011). On the other hand, the data provided to the GEMS/Food by national authorities were mostly collected under monitoring programs (non-target sampling) and are more representative of mycotoxin contamination in a given country.

In general, higher incidence and concentration calculated from the literature lead to higher aflatoxin mean levels (for positive samples and for all samples) compared to GEMS/Food data. On the other hand, mean levels calculated from published data may be underestimated, as in some studies only the concentration range was reported, and the midrange was used in the estimation (Matumba et al., 2011; Ratnavath et al., 2012; Reddy et al., 2009; Reiter et al., 2012; Riba et al., 2010). The exclusion of the study that reported the highest value of aflatoxin contamination (maize sample – 48,000 µg/kg) did not have a significant impact on the mean values for this cereal.

UB and LB of total means did not differ greatly in both datasets, which show that LOQs and or LODs of the methods used for analysis were low. The method LOQs for aflatoxins in the published studies ranged from 0.03 µg/kg (high-performance liquid chromatography with fluorescence detection) (Reinhold and Reinhardt, 2011; Yazdapanah et al., 2013) to 4 µg/kg (thin layer chromatography) (Garrido et al., 2012). Method LOQs provided to GEMS/Food were in the range of 0.05-8.7 µg/kg, although method description was not available in the database. It is important to emphasise that the uncertainties of the UB and LB estimations made using literature or GEMS/Food data could not be assessed due to the limitation of the information provided in both cases.

In this study, we used the UB mean concentration for each crop derived from all the data provided to GEMS/Food to estimate the total exposure. This is justifiable as the crops produced in one region may be in the international trade and consumed elsewhere. With the concentration level for each cereal remaining constant, only the consumption pattern had an effect on the total aflatoxin intake in each cluster. In four of the five clusters that showed the highest intake (8.8 to 17.1 ng/kg bw/day), rice was the cereal that most contributed to the total intake, indicating the importance of controlling fungi infection and aflatoxin levels in this commodity.

Various studies published in the literature have estimated the dietary intake of aflatoxins (Table 5). In Malaysia (C05), the total UB intake of 58.0 ng/kg bw/day (from the consumption 38 foods, both raw and processed) (Chin et al., 2012) was much higher than the intake for cluster C05 estimated in this study (11.2 ng/kg bw/day). On the other hand, the UB intake estimated for the total Brazilian population, also included in cluster C05, was considerably lower (6.8 ng/kg bw/day) (Andrade et al., 2013), with rice contributing to 97.1% of the total intake.

The intakes obtained for C06, C07, C09 and C10 in this study were higher than the intakes found in countries belonging to these clusters. For example, the intake in France (C07), estimated through consumption of 212 foods (including rice and wheat products), was 0.9 ng/kg bw/day (Sirot et al., 2013) while in China (C09) the intake of individual commodities reached 5.8 ng/kg bw/day (rice) (Ding et al., 2012), as shown in Table 5. Most studies considered cereals in the intake estimations, but focused mainly on processed products, unlike the present study in which only contamination data on the raw commodity were considered. A case in point is the assessment performed in Japan, which only considered cooked rice (Sakuma et al., 2013). Intakes found in the present study were also higher than the most recent risk assessment conducted by JECFA (Bendford et al., 2010; FAO/WHO, 2008) (0.4-3.7 ng/kg bw/day), using the previous GEMS/Food Consumption Cluster Diets (13 Clusters). The only cereal considered in the JECFA assessment was maize (including processed products), in addition to peanuts, oilseeds, cocoa products, dried fruits, peanut oil, spices, tree nuts, dried figs, butter of Karité, and other nuts.

Chronic dietary risk characterisation for aflatoxins from the consumption of cereals was conducted in this study using two available approaches. One limitation to the cancer risk approach estimate is related to the prevalence rates of the hepatitis B virus, which were derived from the prevalence map made by the CDC (2014), and agreement with the GEMS/Cluster was not always possible. For example, Brazil (C05), Canada and the United States of America (C10) are considered by CDC as countries with low prevalence of hepatitis B virus (<2% HBsAg *). In this paper, a prevalence rate of 3% HBsAg * was used for C05 and C10, as they include countries with low-intermediate prevalence of hepatitis B virus (2-4% HBsAg *). Estimation made by the Brazilian Ministry of Health indicates that actual prevalence in the country is 0.37% (Brasil, 2010).

The total exposure to aflatoxins and the risk estimates shown in this paper may be overestimated, as they do not consider the impact of cereal processing on aflatoxin levels,
such as sorting, milling and cooking (Castells et al., 2007; Hussain and Luttfullah, 2009; Hwang and Lee, 2006; Park and Kim, 2006; Pearson et al., 2004; Siwela et al., 2005). On the other hand, no other sources of aflatoxin exposure were considered, such as peanuts and oil seeds, which were shown to contribute significantly to the total exposure estimated by the JECFA for the 13 Cluster Diets (FAO/WHO, 2008; Benford et al., 2010).
This work clearly showed that aflatoxin in rice is a major concern due to its high concentration and consumption patterns in certain regions of the world. Currently, the Codex ML for aflatoxins are only established for almonds, Brazil nuts, hazelnuts, peanuts, pistachios, and dried figs (CAC, 1995), food commodities whose average consumption is much lower than for cereals (maximum of 18.8 g/person/day for peanuts in C13; WHO, 2014). The establishment of a ML for rice would remove the most contaminated samples from the market and would have a significant impact on exposure in various regions of the world. For example, if a hypothetical ML of aflatoxins in rice were set at 40 μg/kg, the cancer risk would be reduced by up to 48% in comparison with a no limit situation. At MLs of 20 and 10 μg/kg, the risk would be reduced by up to 63%. Lower limits would not have a significant impact on cancer risk for all clusters, except C09 and C14 (Asian countries), for which a ML of 1 μg/kg would decrease the risk by 76 and 77.8%, respectively. This lower level, however, would have a significant impact on the food supply (about 20% of the samples rejected), when compared with the higher MLs (up to 4% of the samples rejected).

The dietary risk assessment of aflatoxins in cereals conducted in this study used incidence data provided to the GEMS/Food up to July 2014, in response to a public call made by the JECFA and requested by the 7th Session of the CCCF (REP13/CF) to support the discussion on aflatoxins in cereals at the international level. However, only 24 countries responded to this call, yielding a database that is not representative of every region of the world. For example, no rice data were available for China, a country with a high rice consumption rate and that is part of Cluster C09, which had the highest total intake of aflatoxins. In spite of these limitations, the information provided in this paper is of most relevance as it shows rice as a major driver of mycotoxin exposure in most clusters. Furthermore, the study clearly indicates the need for additional data on aflatoxin contamination in cereals, mainly from countries for which these data are lacking, in support of a more sound risk assessment, and the establishment of ML by the Codex Alimentarius.

5. Conclusions

Occurrence data summarised in the present study showed that raw cereals are frequently contaminated with aflatoxins, a genotoxic mycotoxin. Rice was one of the most contaminated cereals, and presented the highest concentration in both literature and GEMS/Food datasets. The dietary risk assessment conducted in this paper indicated a health concern for all 17 GEMS/Food Clusters (MOE<50), with the consumption of rice, wheat and/or maize as the main contributors to aflatoxin intake. Even if the impact of cereal processing on contamination levels had been considered, the MOE would still be much lower than that considered of low health concern for genotoxic compounds such as aflatoxins (>10,000).

Since cereals are staple foods worldwide, and the elimination of aflatoxins from the food supply is not possible, they should be constantly monitored and actions taken to maintain concentration as low as possible. Actions aimed at lowering the risk of aflatoxin exposure, while still ensuring the food supply, include the enforcement of codes of practices and the establishment of ML. Therefore, considering the results of this study, priority should be given to actions focusing on rice, wheat and maize.

Acknowledgments

The authors would like to acknowledge Dr. Philippe Verger from the WHO for all the support given with the GEMS/Food database, and the Brazilian Codex Group for Contaminants in Food for the suggestions given during the preparation of the draft document. We also would like to thank the financial support provided by the National Council of Scientific and Technological Development (CNPq) and the Coordination for the Improvement of Higher Education Personnel (CAPES) for supporting P.D. Andrade with a PhD scholarship.

References

Adejumo, O., Atanda, O., Raiola, A., Somorin, Y., Bandyopadhyay, R., and Ritieni, A., 2013. Correlation between aflatoxin M-1 content of breast milk, dietary exposure to aflatoxin B-1 and socioeconomic status of lactating mothers in Ogun State, Nigeria. Food and Chemical Toxicology 56: 171-177.
Aflatoxins in cereals: occurrence and dietary risk assessment


Benford, D., Leblanc, J.C. and Setzer, R.W., 2010. Application of the margin of exposure (MoE) approach to substances in food that are genotoxic and carcinogenic: example: aflatoxin B1 (AFB1). Food and Chemical Toxicology 48: 534-541.


Covarelli, L., Beccari, G. and Salvi, S., 2011. Infection by mycotoxigenic fungal species and mycotoxin contamination of maize grain in Umbria, Central Italy. Food and Chemical Toxicology 49: 2365-2369.


European Food Safety Authority (EFSA), 2005. Opinion of the scientific committee on a request from EFSA related to a harmonized approach for risk assessment of substances which are both genotoxic and carcinogenic. EFSA Journal 282: 1–31.

European Food Safety Authority (EFSA), 2007. Opinion of the scientific panel on contaminants in the food chain on a request from the commission related to the potential increase of consumer health risk by a possible increase of the existing maximum levels for aflatoxins in almonds, hazelnuts and pistachios and derived products. EFSA Journal 446: 1–127.


P.D. Andrade and E.D. Calsdas


