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<th>Mycotoxin contamination in foodstuffs and feeds-health concerns in Thailand</th>
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<td>Tulayakul, Phitsanu; Sugita-Konishi, Yoshiko</td>
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**File Information**
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Mycotoxin contamination in foodstuffs and feeds—health concerns in Thailand

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Abstract

Many studies on mycotoxins have been carried out in various parts of the world. Thailand is one of many tropical countries to continuously encounter problems associated with mycotoxin contamination in foodstuffs and animal feed, and faces health concerns associated with humans and animals. This review has gathered background information from mycotoxin studies in Thailand in order to update the information on mycotoxin issues from 1967 until the present. The first report of mycotoxin contamination in animal feed was published in 1983. Among the various known mycotoxins, aflatoxins (AF) have been the main concern in human foodstuffs and animal feed, followed by deoxynivalenol (DON), fumonisin (FUM) and trichothecene (T) toxins respectively, while zearalenone (ZEA) has primarily been a concern regarding animal feed in Thailand. Hepatocellular carcinoma has been reported in association with patients consuming foods contaminated with AF. In addition, the standard limit of total aflatoxin (TAF) for foodstuffs has been set at 20 μg/kg in Thailand. It is therefore necessary to improve the control strategies and regulations for all mycotoxins in human foodstuffs and animal feed in Thailand.

Key Words: food, feed, health, mycotoxins, safety

Introduction

Mycotoxins are secondary metabolite toxins produced by fungi primarily belonging to the Aspergillus, Penicillium and Fusarium genera. These naturally occurring chemical compounds are to be found in a wide range of agricultural commodities in various regions of the world1,2,3. The most prevalent mycotoxins are aflatoxin (AF), ochratoxin (OT), deoxynivalenol (DON), zearalenone (ZEA), fumonisin (FUM), trichothecenes (T), of which the latter four toxins are all produced by the Fusarium species3. The contamination of human foodstuffs and animal feed by mycotoxins represents a major threat to the health of both humans and animals, as it can induce cancer, mutagenicity and estrogenic gastrointestinal, urogenital, vascular, kidney and nervous disorders, in addition to immune-toxicity1,3. AF are the most well-studied mycotoxins due to their established...
association with carcinogenesis\textsuperscript{2,4}. \textit{Aspergillus flavus} is known to produce aflatoxin B1 and B2\textsuperscript{5} and \textit{A. parasiticus} and \textit{A. nomius} are known to produce Aflatoxin B1, B2, G1 and G2, which are classified as total AF. These \textit{Aspergillus} species have been isolated from various types of soil in Thailand and endemic aflatoxin has been reported for maize and ground nuts\textsuperscript{6,7}.

**Research on mycotoxins and contamination in Thailand**

*The first research on mycotoxins in Thailand*

We herein summarise the data gathered thus far on the contamination of food products by mycotoxins in Thailand, from the first report published in 1967 through to the present day. The information focuses mainly on AF contamination in rice, peanuts, corn and various spices. There have been numerous studies on mycotoxin contamination to date, as shown in Table 1.

According to the data gathered here, the main focus of mycotoxin studies in human foodstuffs appears to be that of total aflatoxin (TAF), FUM and DON, in decreasing order of importance as shown in Fig. 1a. On the other hand, for animal feed, the study of mycotoxin contamination since 1983 appeared to have concentrated mainly on AF, followed by DON and ZEA as shown in Fig. 1b.

Thailand is located in a tropical zone with a hot and highly humid climate throughout the year. Thailand exports large quantities of agricultural products to many different countries. It has accordingly established an action plan to mitigate food safety issues under the supervision of the Department of Agriculture and the National Plant Protection Organisation, and the guidance of the Ministry of Agriculture and Cooperatives. The latter is in charge of food safety control for both local consumption and export. Since 1985, collaborative research on TAF in Thailand has been ongoing with support from several other countries and organisations, such as the United Kingdom, the United States Agency for International Development, and The United Nations Development Program (UNDP). In addition, the Tropical Agricultural Research Center (Japan) has approved the performance of a cooperative project on quality and preservation of maize from AF contamination. From 1986 to 1991, the Japanese International Cooperative Agency (JICA) provided financial support for the activities of the Maize Quality Improvement Center, within the Department of Agriculture in Thailand with a budget which financed advanced equipment\textsuperscript{8}. Nevertheless, many reports have demonstrated evidence of food contamination, such as the case with coconut cream flavoured peanuts exported to the Netherlands in 2004 and to the United Kingdom in 2006. These were found to be contaminated with a concentration of AF that exceeded the legal limits established by the Rapid Alert System for Food and Feed (RASFF), managed by the European commission\textsuperscript{9}. During the period from 2004–2006, basil seed (\textit{Ocimum basilicum}) and Job’s tear (\textit{Coix lacryma L.}) exported to Japan were rejected by the Ministry of Public Health, Labour and Welfare, via the Office of Agricultural Affairs because the cargo was found to be over the legal contamination limit for AF (10 \(\mu\)g/kg AFB1)\textsuperscript{9}.

**Mycotoxin contamination in foodstuffs in Thailand**

An overview study of AF contamination in various foods and products was first reviewed and carried out in Thailand between 1967–2001. The contamination data, obtained using thin layer chromatography (TLC)\textsuperscript{10}, showed that 38.9% of all samples (1,248/3,206 samples) were contaminated with TAF, and that more than half of the contaminated samples (728/1,248 samples) were composed of peanuts, milk and poultry. In addition, a surveillance study of mycotoxins in foodstuffs and feeds collected in Bangkok in 1999 reported that 30.5% (11/36 samples) of peanuts, corn, rice, coix seed and other common products showed an AFB1 contamination ranged from 0.01–626 \(\mu\)g/kg, as tested by HPLC. No ochratoxin A (OTA) contamination was detected in corn and
<table>
<thead>
<tr>
<th>Sampling year</th>
<th>Foodstuffs</th>
<th>Samples (N)</th>
<th>All toxins % positive</th>
<th>AFM1 % positive</th>
<th>DON % positive</th>
<th>FUM % positive</th>
<th>T2/HT2 % positive</th>
<th>OTA % positive</th>
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<tbody>
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<td>Rice (364)</td>
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<td>Peanut (216)</td>
<td>49</td>
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<td>1967</td>
<td>Corn (62)</td>
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<td>Spiced (248)</td>
<td>4.8</td>
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<td>1967</td>
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<td>Seed, Chilli pepper (2001)</td>
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<td>20.6**</td>
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<td>1977</td>
<td>Peanuts, ground &amp; roasted (33)</td>
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<td>Peanuts oil, crude (10)</td>
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<td>1990</td>
<td>Peanut product (33)</td>
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<td>1991</td>
<td>Rice grains, uncooked (20)</td>
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<td>1994</td>
<td>Corn seeds (24)</td>
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<td>Peanut oil, crude (4)</td>
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<td>Milk and dairy products (270)</td>
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<td>Poultry tissue (450)</td>
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<td>1999</td>
<td>Peanut, corn, rice, coix seed, dairy products (36)</td>
<td>30.55</td>
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<td>1999</td>
<td>Corn seed (28), Ground peanut (28)</td>
<td>5.55</td>
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<td>1999</td>
<td>Cereal grains (270)</td>
<td>78.57, 64.28</td>
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<tr>
<td>2000</td>
<td>Quail (20), Duck (6), Hen (6), Broiler (6); meats</td>
<td>100</td>
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<td>2000</td>
<td>Quail (20), Duck (6), Hen (6), Broiler (6); livers</td>
<td>100 (only Quail)</td>
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<td>Cereal grains (270)</td>
<td>10 to 47</td>
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<td>2005</td>
<td>Noodle soup without ground peanut (80)</td>
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<td>Noodle soup with ground peanut (40)</td>
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<td>2005</td>
<td>Cereal grains (270)</td>
<td>27 to 57 (T2)</td>
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<td>2006</td>
<td>Roasted coffee (44)</td>
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<td>Corn (24)</td>
<td>58</td>
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<td>2006</td>
<td>School Milk (150)</td>
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<td>2008</td>
<td>Coffee beans (64)</td>
<td>98*</td>
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<tr>
<td>2013</td>
<td>Unpolished rice (30)</td>
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<tr>
<td>2013</td>
<td>Unpolished glutinous rice (10)</td>
<td>10**</td>
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<tr>
<td>2013</td>
<td>Chilli powder (30)</td>
<td>96.66</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>2013</td>
<td>Chilli powder (30)</td>
<td>96.66</td>
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<td></td>
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<tr>
<td>2013</td>
<td>Dried chilli pods (30)</td>
<td>36.66</td>
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</table>

Data adapted from references (35, 36).

Depending on the analytical method used, the sample levels that exceeded the LOQ (limit of quantification) were considered to be positive samples.

**AFB1 concentration was determined to be higher than 20 ppb.
*AFM1 concentration was determined to be higher than 0.5 ppb.
*OTA concentration was determined to be higher than 5 ppb.
(−) indicates an analysis was done, however, the concentration was lower than the LOD (limit of detection).
cereal products, while citrinin contamination was found in 50% (4/8 samples) in the range of 0.4–4.0 μg/kg, FUM(B1) and FUM(B2) contamination were detected in 25% (2/8 samples) at level of 130 and 630 μg/kg, and 20 and 160 μg/kg, respectively; however, no patulin contamination was found in juice products \(^{11}\). There were also reports of mycotoxin contamination in coffee products. A surveillance study on OTA contamination in roasted coffee and corn, in the Bangkok area, was performed for a period from 2004–2005. In this study, immune-affinity chromatography (IAC) combined with high performance and thin layer chromatography (HPTLC) was used. As a result, 58% (14/24) of the corn samples were found to be OTA-positive; however, none of these samples had OTA levels above 5 μg/kg (the standard amount allowed by the EU). In contrast, 6.81% (3/44) of the roasted coffee samples were found to have OTA contaminations within the range of <1–4.6 μg/kg \(^{12}\).

Concerning the analysis of 3,269 samples of export rice collected during 2006–2009, the AF levels were less than 20 μg/kg. While for AF contamination in commercial red paste curry from fresh markets in Thailand, ELISA assays detected AF-Positives for 58.3%, 58.3%, 50.0%, 45.4% and 41.7% in Bangkok, Suphanburi, Nakhon-Pathom, Samut Songkhram and Saraburi provinces, respectively\(^{13}\). T-2 toxin contamination in cereal grains was investigated in oatmeal, rice, brown rice, red rice, sticky brown rice, wheat, barley, Job’s tear, and lotus seeds using an ELISA. The result showed that oatmeal was contaminated with T-2 toxin at the highest level of 31.6 μg/kg, while Job’s tear was contaminated at the lowest level at 9.5 μg/kg, and a moderate level was found in the other samples ranging from 9.5–31.6 μg/kg \(^{14}\). However, DON contamination was assayed in nine similar cereals using an ELISA, revealing DON levels ranged from the limit of detection (LOD)–1.0 mg/kg. Among the nine cereals investigated, red rice had the highest level of DON, 1.0 mg/kg, while brown rice demonstrated the highest frequency of contamination at 47% and an average level of 0.09 mg/kg \(^{15}\). FUM contamination in nine cereal grains was also surveyed and was found in the range of 0.08–2.87 mg/kg. Oatmeal showed the highest FUM contamination level (2.87 mg/kg), while lotus seed was the lowest contaminated at 0.08 mg/kg \(^{16}\).

Additionally, a study was carried out on mycotoxin contamination in rice noodles coated with peanut oil, as rice noodles are a very popular in Thailand and in other Asian countries. To determine the reduction ratio during cooking, rice noodles from Chiang Mai province were analysed using TLC and fluorometry. The AFB1 contents of samples before and after cooking in

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**Fig. 1a. Distribution of mycotoxin contamination in human foodstuffs during the period from 1967–2013 in Thailand.**

**Fig. 1b. Distribution of mycotoxin contamination in animal feed during the period from 1983–2014 in Thailand.**
boiling water were 20.24 ± 41.16 and 15.75 ± 37.88 μg/kg, respectively. While, AFB1 levels in peanut oil were shown to be higher with 343.35 ± 298.17 μg/kg. The results indicated that peanut oil was a main source of AFB1 contamination in this product\textsuperscript{17}. In 2006 and 2007, 32 Thai dried coffee bean samples collected from Chiang Mai and 32 Thai dried coffee bean samples from Chumphon provinces were tested for the presence of OTA. Sixty-four coffee bean samples were analysed using ELISA and 94% were found to be contaminated with OTA at levels of <0.6-5.5 μg/kg (Arabica) and 1-27 μg/kg (Robusta). A. melleus was the predominant fungal species found in Arabica coffee beans, while A. carbonarius and A. niger were the dominant fungi isolated from Robusta coffee beans. However, it was interesting to note that A. ochraceus was not detected in any of the coffee samples\textsuperscript{18}. In 2008 and 2009, AFB1 contamination was reported in rice sold to Canada, of which the five most highly contaminated samples contained 1.44-7.14 μg/kg in 2008 and 1.45-3.48 μg/kg in 2009. These contaminated samples consisted mostly of basmati rice from India and Pakistan and black and red rice from Thailand. In the same study, 15.15% (15/99 samples) of samples were contaminated with FUM(B1) at level of ≥ 0.7 μg/kg and FUM (B2) and (B3) were also presented at level of ≥ 1 μg/kg in year 2008. Of the 100 rice samples analyzed in 2009, only one case of FUM contamination was found at a level of 14 μg/kg in black sweet rice from Thailand \textsuperscript{19}. These surveys revealed that AF contamination is still a main concern for dairy cattle feed in Thailand.

Mycotoxin contamination in animal feed in Thailand

One decade after the first reports on AF contamination in food were published in 1967, a report on the contamination of animal feed was published in 1983, which mainly focused on TAF, rather than other mycotoxins, as shown in Table 2. There was a report of mycotoxins contamination in roughage feed for dairy cattle in Nakhon Pathom, Ratchaburi and Phetchaburi provinces in Thailand. AFB1, AFB2, AFG1, AFG2, OT, FUM(B1), FUM(B2), DON and ZEA contamination was found at mean levels of 15.35 ± 14.55, 1.39 ± 1.23, 1.90 ± 3.49, 0.16 ± 0.37, 3.99 ± 5.26, 62.92 ± 105.92, 8.97 ± 49.93, 66.90 ± 88.27 and 40.13 ± 36.67 μg/kg, respectively. Among the feed samples, 35% (11/31) were compliant with the EU regulation of < 5 μg/kg for AFB1 and 61% (19/31) were compliant with the FDA regulation at < 20 μg/kg for AFB1\textsuperscript{20}. These surveys revealed that AF contamination is still a main concern for dairy cattle feed in Thailand.
Table 2. Incidence of mycotoxin contamination in animal feed in Thailand during the period from 1983–2014

<table>
<thead>
<tr>
<th>Sampling year</th>
<th>Foodstuffs</th>
<th>Samples (N)</th>
<th>Aflatoxin % positive</th>
<th>AFM1 % positive</th>
<th>Zearalenone % positive</th>
<th>DON % positive</th>
<th>FUM % positive</th>
<th>T2/HT2 % positive</th>
<th>OTA % positive</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>Mixed feeds (185)</td>
<td></td>
<td>72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>karunyavanich et al., 1983</td>
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<tr>
<td>1987</td>
<td>Animal feeds (24)</td>
<td></td>
<td>88***</td>
<td></td>
<td></td>
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<td></td>
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<td>suttajit et al., 1987</td>
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<td>1995</td>
<td>Mixed feeds (98)</td>
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<td>72</td>
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<td></td>
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<td>karunyavanich et al., 1995</td>
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<td>1997</td>
<td>Corn used as animal feeds (224)</td>
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<td>82.6***</td>
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<td>Kachareon et al., 1997</td>
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<td>1997</td>
<td>Peanut meal used as animal feeds (26)</td>
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<td></td>
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</tr>
<tr>
<td>2000</td>
<td>Corn, Soybean mill, peanut product, cassava, rice bran</td>
<td></td>
<td>24.02**</td>
<td>8.11*</td>
<td>7.5*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tangmunkhong et al., 2003 (39)</td>
</tr>
</tbody>
</table>
| 2001          | Corn, Soybean mill, peanut product, cassava, rice bran | | 10.98** | 1.33* | 1.33* | | | | | Total sample of 1373 samples &
| 2002          | Corn, Soybean mill, peanut product, cassava, rice bran | | 5.68** | 6.18* | 0.83* | | | | | Total complete feeds of 915 samples from year 2000-2003 |
| 2003          | Corn, Soybean mill, peanut product, cassava, rice bran | | 4.29** | 0.71* | - | | | | | |
| 2000          | Complete feeds                      |             | 14.29**              | 11.7*            | 12.33*                 |               |               |                  |                |                       |
| 2001          | Complete feeds                      |             | 13.39**              | 1.79*            | 1.79*                  |               |               |                  |                |                       |
| 2002          | Complete feeds                      |             | 7.53**               | 6.63*            | 2.11*                  |               |               |                  |                |                       |
| 2003          | Complete feeds                      |             | 1.39**               | 1.39*            | -                      |               |               |                  |                |                       |
| 2006          | Commercial Animal feed (25)         |             | 92                   | 86               | 100 (T2)               | 30            |               |                  |                | Charoenpornsook & kavisarasai 2006 (25) |
| 2008          | Corn, Soybean mill, peanut products, cassava, rice bran, DDGS | | 6.11** | 4.38* | 11.47* | - | | | | Tangmunkhong et al., 2011 (24) |
| 2009          | Corn, Soybean mill, peanut products, cassava, rice bran, DDGS | | 7.10** | 7.94* | 10.55* | - | | | | Total sample of 5527 samples &
| 2010          | Corn, Soybean mill, peanut products, cassava, rice bran, DDGS | | 7.87** | 4.84* | 11.11* | - | | | | Total complete feeds of 2358 samples &
| 2011          | Corn, Soybean mill, peanut products, cassava, rice bran, DDGS | | 5.36** | 3.46* | 7.80* | - | | | | from 2008-2011 |
| 2008          | Complete feeds                      |             | 3.49**               | 1.51*            | 2.89*                  | -             |               |                  |                |                       |
| 2009          | Complete feeds                      |             | 3.57**               | 11.50*           | 4.39*                  | -             |               |                  |                |                       |
| 2010          | Complete feeds                      |             | 6.50**               | 6.70*            | 4.23*                  | -             |               |                  |                |                       |
| 2011          | Complete feeds                      |             | 28.68**              | 1.69*            | 15.38*                 | -             |               |                  |                |                       |
| 2012          | Dairy feeds (31)                    |             | 39**                 |                  |                        |               |               |                  |                | Yawongsa et al., 2013 (23) |
| 2013          | Corn-DDGS (59)                      |             | 81.35                | 49.15            | 98.3                   |               |               |                  |                | Tansakul et al., 2013 (28) |
| 2014          | Commercial dog food (30)            |             | 100                  |                  | 23.33                  |               |               |                  |                | Tansakul et al., 2014 (27) |
| 2014          | Commercial cat food (30)            |             | 30                   |                  |                       |               |               |                  |                |                       |

Data adapted from references 35, 36

Depending on the analytical method used, the sample levels that exceeded the LOQ (limit of quantification) were considered to be positive samples.

**AFB1 concentration was determined to be higher than 20 ppb.

***AFB1 concentration was determined to be higher than 100 ppb.

ZEA concentration was determined to be higher than 200 ppb.

DON concentration was determined to be higher than 1000 ppb.

FUM concentration was determined to be higher than 1000 ppb.

(−) indicates an analysis was done, however, the concentration was lower than the LOD (limit of detection).
and monitoring of other mycotoxins in feed must be carried on in long term. Moreover, a study of mycotoxin contamination in animal feed samples and commercial animal feed collected between 2008–2011, using the ELISA method to analyse AF, ZEA, FUM and T-2/HT-2 contamination, was carried out\textsuperscript{24}. A total number of 5,527 raw samples from imported and domestic corn, soybean mill, peanut products, cassava rice bran, and Dried Distillers Grains with Solubles (DDGS) were examined. In raw materials, the ratios of Total AF levels above 20 $\mu$g/kg were 6.11%, 7.10%, 7.87% and 5.36% in samples taken in 2008, 2009, 2010, and 2011, respectively. The ratios of ZEA levels above 100 $\mu$g/kg were 4.38%, 7.94%, 4.84% and 3.46% and of FUM levels above 1,000 $\mu$g/kg were 11.47%, 10.55%, 11.11% and 7.80%, respectively, while none of the samples showed T-2/HT-2 levels of more than 100 $\mu$g/kg according to the ELISA test’s limit of detection (LOD). The above results could not make the conclusion of the increasing trend of mycotoxin contamination since the ratio of contamination were varies with yearly basis. In commercial feeds, the ratios of AF levels above 20 $\mu$g/kg were 3.40%, 3.57%, 6.50% and 28.68%; ZEA levels above 100 $\mu$g/kg were 1.51%, 11.50%, 6.70% and 1.69%; and FUM levels above 1,000 $\mu$g/kg were 2.89%, 4.39%, 4.23% and 15.38% in 2008, 2009, 2010 and 2011, respectively. None of the commercial feeds showed T-2/HT-2 levels of more than 100 $\mu$g/kg in any of the above mentioned years.

AFB1 was detected in 92% of the samples (23/25 samples) with an average level of 7.56 $\mu$g/kg. OTA was detected in 30% (3/10 samples) of these feed at levels of 10.48, 11.14 and 12.35 $\mu$g/kg. DON was detected in 86% of the samples (13/15) at an average level of 33.77 $\mu$g/kg. T-2 toxin was detected in all samples (10/10) with an average level of 6.91 $\mu$g/kg. Three out of ten samples were contaminated with four mycotoxins, suggesting a high risk of multi-contamination (exposure to several toxins at the same time) due to indirect exposure to meat and other products from animals consuming contaminated animal feed\textsuperscript{25}. Remarkably, heavy contamination of AF, ZEA and FUM were found in corn-DDGS and rice bran\textsuperscript{24}. Nevertheless, in 59 DDGS samples, five contaminants were identified, including FB1, FB2, DON, ZEA and beauvericin A (BEA) using LC-MS/MS. In addition, 50.8% of all samples were found to be co-contaminated with all five mycotoxins and none of the samples were free of mycotoxins. The mean toxin levels detected were 9 mg/kg FB1, 6 mg/kg FB2, 1.2 mg/kg DON, 0.9 mg/kg ZEA and 0.35 mg/kg BEA, while the maximum level of FB1 and FB2 was 143 mg/kg and 125 mg/kg, respectively, which is of acute toxicological relevance\textsuperscript{26}. Moreover, a survey of AF and OTA in pet food was carried out from April 2011 to February 2012 using HPLC. All dog food samples showed AF contamination at trace levels of approximately 3.17 $\pm$ 2.43 $\mu$g/kg while none were reported for cat food. However, seven out of 30 dog food samples and nine out of 30 cat foods samples were found to be contaminated with OTA at mean values of 14.04 $\pm$ 9.44 $\mu$g/kg and 2.46 $\pm$ 2.10 $\mu$g/kg, respectively\textsuperscript{27}.

An examination of mould in commercial animal feed samples in 2006 revealed the presence of \textit{Aspergillus} spp., \textit{Penicillium} spp., \textit{Fusarium} spp., and non-septate fungi, cultivated from the samples, thus suggesting that the risk of mycotoxin contamination from these fungi could increase during storage.

**Public health concerns regarding mycotoxins in Thailand**

It has long been known that dietary AF reduces the growth rate and compromises productivity in animals and human. The risk of liver cancer due to AF in carriers of the chronic hepatitis B virus and AF is 30 times greater than in non-carriers exposed to AF\textsuperscript{4,28}. Mycotoxin contamination is considered to be a major problem which affects both human and animal health and also has damaging economic consequences.

The regulation value of mycotoxins has been established in Thailand (Table 3). The frequency of mycotoxin contamination in foodstuffs and
animal feed in Thailand shows that many products are contaminated or co-contaminated with AFM1, DON, FUM, T-2, and OTA, in addition to AF. However, the mycotoxin regulations for imported/exported food primarily depends upon the partner with Thailand, as shown in Table 3. Considering the impact of adverse health effects, mycotoxin regulations should be aligned on the CODEX Alimentarius international food standard.

The monitoring of AF exposure using biomarkers has been mentioned with respect to the incidence of hepatocellular carcinoma (HCC) in Thailand, as previously reported by Makarananda et al., in 1998 who used an ELISA to conduct epidemiological studies and to monitor short-term exposure to AF. The presence of albumin-AFB1 adducts in peripheral blood counts has also been previously reported in a long-term exposure assessment of the prevalence of the p53 mutation at codon 249. AF contamination has long been reported to be a major problem related to hepatic diseases in Egypt and in many African countries. AF contamination has an incidence of 43.75% among African countries, followed by FUM and OTA at 21.87% and 12.5%, respectively. AF residues can be found in the liver, muscle and eggs of domestic fowl according to the results of feeding experiments with a diet containing AFB1 in Thailand. There has been only one report regarding AFM1 found in human breast milk samples. In that study, 73 breast milk samples from women from Victoria, Australia and 11 samples from women from Thailand were analysed for AFM1 contamination using an ELISA. AFM1 was detected in 11 of the 73 samples from Victoria and in five of the 11 samples from Thailand at a median concentration of 0.071 ng/ml (range: 0.028 to 1.031 ng/ml) and 0.664 ng/ml (range: 0.039 to 1.736 ng/ml), respectively.

In conclusion, there are a number of reasons for Thailand to be concerned about mycotoxin contamination in human foodstuffs and animal feed and associated health issues. One of the main reasons behind this contamination resides in the geographical location of Thailand, which is located in a tropical zone with a hot and humid atmosphere. Mycotoxin contamination in human foodstuffs is largely due to AF contamination, which potentially induces hepatocellular carcinoma and is genotoxic to humans and/or animals. Moreover, further detailed studies on mycotoxins contamination such as ZEA, OTA, T2/HT2, DON and BEA and its metabolic effects are needed to better elucidate the consequences of their toxicity.

Table 3. Food mycotoxin regulations for main countries trading with Thailand

<table>
<thead>
<tr>
<th>Country/Organization</th>
<th>AFB1</th>
<th>TAF</th>
<th>AFM1</th>
<th>Patulin</th>
<th>DON</th>
<th>OTA</th>
<th>FUM</th>
<th>ZEA</th>
<th>Citrinin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thailand</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>10</td>
<td>50</td>
<td>1100</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Vietnam</td>
<td>10</td>
<td>0.5</td>
<td>1100</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>20</td>
<td>0.5</td>
<td>50</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaysia</td>
<td>35</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>5</td>
<td>0.5</td>
<td>50</td>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU</td>
<td>2, 12</td>
<td>0.05</td>
<td>25, 50</td>
<td>500, 750</td>
<td>2</td>
<td>800, 1000</td>
<td>50, 75</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>Australia/Newzealand</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>USA</td>
<td>20</td>
<td>0.5</td>
<td>50</td>
<td>1000</td>
<td></td>
<td></td>
<td>2000-4000</td>
<td></td>
<td></td>
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<tr>
<td>India</td>
<td>30</td>
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<td></td>
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<tr>
<td>Codex</td>
<td>15</td>
<td>0.5</td>
<td>50</td>
<td>5</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>5, 10, 20</td>
<td>0.5</td>
<td>50</td>
<td>1000</td>
<td></td>
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</tr>
</tbody>
</table>

Adapted from references 37,38,47

Abbreviations: AFB1, aflatoxinB1; TAF, total aflatoxin; AFM1, aflatoxin M1; DON, deoxynivalenol; OTA, ochratoxin A; FUM, fumonisin (including FB1, FB2and FB3); ZEA, zearealenone.
In addition, the food safety control strategies for mycotoxin must be re-evaluated in order to ensure the safety of foodstuffs and feed in Thailand.

Acknowledgements

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