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Mycotoxins contamination of food in Thailand (2000-2010): Food safety concerns for the world food exporter

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Abstract

Mycotoxins contaminate both raw agricultural commodities and processed food. As the world food exporter, Thailand has to be aware of food safety. Both international and local publications of major mycotoxins contamination of food in Thailand published from 2000-2010 were reviewed. A wide range of contamination levels were found. In Thailand, regulatory limit has been set only for aflatoxins. Global harmonization of mycotoxins regulation is rather impractical. It would be unfair to export the premium grade products but food-producing people have to consume contaminated food. Food surveillance system should be implemented. Analysis of mycotoxins in food should be performed with validated method. Health risk from mycotoxin exposure should not be overlooked.

Introduction

Mycotoxins contamination of food has been a worldwide problem. These secondary metabolites produced by fungi can occur in various foodstuffs, from raw agricultural commodities to processed food (Murphy *et al*., 2006). Food processing has varying impact on mycotoxin. Most mycotoxins are moderately stable in food processing systems (Bullerman and Bianchini, 2007). Mycotoxins exposure causes adverse effects in human and animal. Although human mycotoxicoses are difficult to be diagnosed, there have been some diseases which suggest or implicate mycotoxins involvement such as hepatocellular carcinoma, Balkan nephropathy and esophageal tumor (Bennett and Klich, 2003). Outbreaks of acute aflatoxicosis have been reported in Kenya, India, and Thailand (CAST, 2003). Human breast milk samples from Thailand and Australia were found to be contaminated with aflatoxin M1 (El-Nezami *et al*., 1995). Therefore possible human health risk from chronic dietary exposure to mycotoxins should be highly concerned.

The total number of mycotoxins has not been clarified. Maybe these toxic metabolites could number in the thousands (CAST, 2003). Due to the effect on human and animal health, the important mycotoxins are aflatoxins, trichothecenes, fumonisins, zearalenone, ochratoxin A and patulin (Bhat *et al*., 2010). Environmental factor such as humidity and temperature affect mycotoxin contamination both pre- and post-harvest stage (CAST, 2003). Therefore, mycotoxins occur differently in each part of the world. Aflatoxins are the major toxins which have been reported in Asia (Bhat *et al*., 2010). Mycotoxins research in Thailand focused on the occurrence of aflatoxin as well (FAO, 1989). However, the other mycotoxins should not be ignored.

Since mycotoxin contamination in food is hardly avoidable, occurrence data of mycotoxins in food as well as creating awareness among people is of great importance for food safety. Thai government has promoted the country to be the kitchen of the world (FAO, 2004a). Thailand has been one of the world's leading food exporters (FAO, 2004a). Thus importance of mycotoxins as one of the hazards and risks to food safety should not be overlooked. An overview of aflatoxin contamination of food and food products in Thailand was published in 2003 (Waenlor and Wiwanitkit, 2003). Since then there has been no review report on mycotoxins contamination of food in Thailand. This article aims to review the occurrence data of mycotoxins, not only aflatoxins, in food in Thailand which have been published from the year 2000 to 2010. Detection methods were summarized as well. Research needs and food safety concerns were discussed.

Retrieval of data

In this review, food means items intended

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for human consumption. The data on occurrence of mycotoxins in feed was excluded. PubMed, ScienceDirect and Scopus were used as search engines for international publications. Thai thesis database and Thai Universities Web Online Public Access Catalog (OPAC) were used for searching local publications and reports. Most of the full text articles could be accessed via internet otherwise hard copies could be retrieved from the university library. The literatures search was limited for publication from 2000-2010. Only the major mycotoxins mentioned above were included in the keywords used. Food, mycotoxin, aflatoxins, trichothecenes, deoxynivalenol (DON), fumonisins, zearalenone (ZEN), ochratoxin A (OTA), patulin (PAT), contamination, detection and Thailand were used as the main keywords.

Mycotoxins contamination of food in Thailand

Due to high humidity and temperature, crops in tropical region are more susceptible to mold growth and mycotoxins contamination than those in cooler regions (Wagacha and Muthomi, 2008). Table 1 summarises mycotoxins contamination of food, number of samples, percentage of positive samples, detection level and method of analysis. Variety of food commodities such as cereal grains, spices, meat and ready-to-eat food such as cooked noodle were analysed and reported. Figure 1 shows percentage of each mycotoxin reported in literatures from 2000 to 2010. Most of the reports were published in peer-reviewed local journals. Six studies were published in the international journals Data from 2 theses were reviewed. Among 28 studies, 22 studies (79%) included aflatoxins into analysis. Ochratoxins, fumonisins and DON were reported in 5 studies (18%). T2-toxin (T-2) and ZEN were reported in 4 (14%) and 3 (11%) studies, respectively. There was no report of PAT.

Due to its toxicity, aflatoxins especially aflatoxin B_1 (AFB_1) have been extensively studied in term of occurrence and food contamination. In Thailand, Waenlor and Wiwanitkit (2003) reviewed aflatoxins contamination of food reported from 1967-2001 (13 international and local reports). The highest contamination rate was found in peanuts (36% of all contaminated foods), followed by milk (20.7%) and poultry (17.5%). However they did not report the detection level. In this paper, aflatoxins contamination of food has been reviewed from 2000-2010. Interestingly, corn and corn-based food has been reported in only one publication (Lipigorngoson *et al*., 2003). Corn is a good substrate for aflatoxins, fumonisins and fusarium toxins such as DON and ZEN (CAST, 2003). Further study on

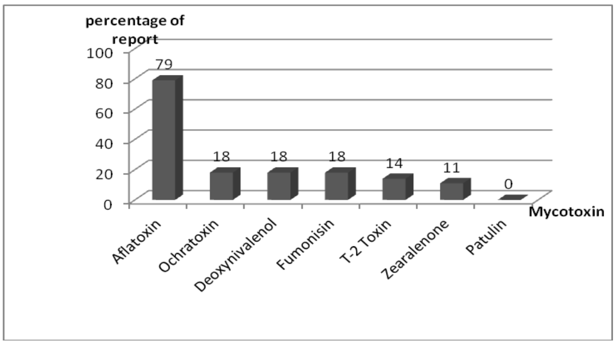

Figure 1. Percentage of each mycotoxin reported in literatures from 2000 to 2010

mycotoxin contamination in corn should be carried out. Aflatoxin contamination in peanuts has long been a major problem in Thailand. The study by Suprasert and Yurayart (2004) showed that 17% of 713 peanut samples contaminated with aflatoxins. Variety of peanut products was sampled from 1994-2002. A wide range of aflatoxins levels were found (0.7-3238 ppb). However, number of samples for each type of products was not mentioned. Aflatoxins contamination problem in peanut was emphasised in particular reports. For example, ready-to-eat noodle containing peanut showed higher rate and level of AFB_1 contamination than ordinary noodle which contained no peanut (Dhananiveskul *et al*., 2007). Aflatoxins contamination in peanut has not been a problem only in Thailand but also the other countries such as Brazil, Botsawana and Cyprus (Waenlor and Wiwanitkit, 2003). As a staple food in Thailand, mycotoxins contamination in rice has been studied. The results showed wide range of contamination from not detected level to 44 µg/kg (Suprasert, 2000; Kositcharoenkul *et al*., 2002; Suprasert and Suprasert *et al*., 2003; Jankhaikhot, 2005; Prasertsak *et al*., 2007; Suprasert, 2008; Chinaphuti and Aukkasarakul, 2009). Red cargo rice seemed to be more contaminated with aflatoxins than white rice. Spices were investigated for aflatoxins contamination as well. Chili, chili paste and curry paste were found to be contaminated in a significant level. These products should be monitored regularly. The study showed that inappropriate storage conditions especially in local shops may be the cause of fungi growth (Kladpan *et al*., 2006).

There were four reports of aflatoxin M_1 (AFM_1) contamination in milk. Recent reports in 2009 and 2010 show 85-100% of AFM_1 contamination in raw and pasteurized milk (Ruangwises and Ruangwises, 2009; Nakprasert *et al*., 2010; Ruangwises and Ruangwises, 2010). The detection levels were below US regulatory limit (0.5 µg/l) in pasteurized milk (Suprasert and Yurayart, 2002 a; Ruangwises and Ruangwises, 2009; Nakprasert *et al*., 2010;

Table 1. Mycotoxins contamination of food in Thailand reported in literatures from 2000 to 2010

Food	Number of samples	Mycotoxin analyzed	Percentage of positive samples	Detection level	Detection method (LOD or LOQ)	References
Oat meal	21	Aflatoxins Ochratoxins ZEN T-2 Fumonisins DON	52.4 33.3 61.9 61.9 38.1 28.6	0.83±1.63 ppb (7.1)[1] 0.74±1.98 ppb (8.2)[1] 25.02±31.14 ppb (102.9)[1] 31.57±41.15 ppb (115.2)[1] 2.87±12.7 ppm (58.3)[1] 0.04±0.08 ppm (0.3)[1]	ELISA (LOD, LOQ: not reported)	Im-erb and Suprasert, 2000
Job's tears (coix seed)	30	Aflatoxins Ochratoxins ZEN T-2 Fumonisins DON	73.3 40.0 53.3 26.7 53.3 30.0	2.15 ppb (8.4)[2] 0.71 ppb (8.9)[2] 41.26 ppb (204.7)[2] 9.49 ppb (74.1)[2] 0.61 ppm (12.2)[2] 0.09 ppm (0.5)[2]	ELISA (LOD, LOQ: not reported)	Puncha *et al.*, 2000
Brown rice Brown glutinous rice Red rice Wheat Lotus seed Job's tear Sorghum Barley Oat meal	30 30 30 30 30 30 30 30 30	Fumonisins	43 50 40 50 33 53 46 54 38	0.11 ppm (0.9)[2] 0.13 ppm (0.8)[2] 0.13 ppm (0.8)[2] 0.24 ppm (1.5)[2] 0.08 ppm (0.4)[2] 0.61 ppm (12.2)[2] 0.55 ppm (10.2)[2] 0.51 ppm (10.7)[2] 2.87 ppm (58.3)[2]	ELISA (LOD, LOQ: not reported)	Suprasert and Suprasert, 2000
Lotus seed	30	Aflatoxins Ochratoxins ZEN T-2 Fumonisins DON	57 30 60 33 33 10	0.76 ppb (6.8)[2] 0.82 ppb (13.6)[2] 27.27 ppb (131.2)[2] 13.9 ppb (127.4)[2] 0.08 ppm (0.4)[2] 0.04 ppm (0.9)[2]	ELISA (LOD, LOQ: not reported)	Suprasert and Chulamorakot, 2001

Food	Number of samples	Mycotoxin analyzed	Percentage of positive samples	Detection level	Detection method (LOD or LOQ)	References
Chicken liver Chicken muscle	450 450	Aflatoxins	55.11 21.33	0.16±0.02 ppb 0.012±0.003 ppb	HPLC- FLD (LOD, LOQ: not reported)	Bintvihok and Davitiyananda, 2002
Paddy Brown rice (milling) Brown rice (Trade)	32 58 63	Aflatoxins	56.3 60.3 72.0	1-44 µg/kg 2-34 µg/kg 2-18 µg/kg	ELISA (LOD, LOQ: not reported)	Kositcharoenkul *et al.*, 2002
Raw cow milk UHT milk Pasteurized milk Powder milk Sweetened condensed milk Soya milk	88 51 59 60 4 81	AFM_1	46.6 - 8.5 - - -	0.01-1.4 ppb - 0.09-0.33 ppb - - -	Immunoaffinity column/HPLC-FLD (LOD, LOQ: not reported)	Suprasert and Yurayart, 2002a
Dried cayenne pepper and dried Thai pepper Ground dried cayenne pepper and ground dried Thai pepper Pepper Garlic Shallot Satay sauce Soy sauce Other spices	35 29 37 27 17 2 5 11	Aflatoxins	11 10 - 4 - - - -	12.26-61.28 ppb 7.84-14.40 ppb - 6.59 ppb (1 sample) - - - -	TLC (LOD, LOQ: not reported)	Suprasert and Yurayart, 2002b

Food	Number of samples	Mycotoxin analyzed	Percentage of positive samples	Detection level	Detection method (LOD or LOQ)	References
Dried chili spur pepper Fresh cayenne pepper Green chili spur pepper Shallot Garlic Galangal Lemongrass Kaffir lime (skin) Coriander (root) Lesser ginger Sour curry paste Red curry paste Thai-Indian curry paste Green curry paste	18 18 18 18 18 18 18 18 18 18 30 30 30 30	Aflatoxins	Not reported	0.39±0.94 ppb (4.03)[1] 0.30±0.36 ppb (2.02)[1] 0.22±0.25 ppb (1.17)[1] 0 0 3.99±1.77 ppb (12.05)[1] 0.48±0.72 ppb (2.99)[1] 8.52±1.20 ppb (13.07)[1] 0 0.12±0.32 ppb (1.27)[1] 3.50±0.92 ppb (8.21)[1] 2.11±1.91 ppb (13.20)[1] 2.72±1.18 ppb (9.61)[1] 5.83±2.28 ppb (16.36)[1]	ELISA (LOD: 0.4 ppb)	Dilokpimol, 2003
Swine liver Swine muscle	315 315	Aflatoxins	20.3 10.2	0.162±0.013 ppb 0.012±0.003 ppb	HPLC-FLD (LOD, LOQ: not reported)	Bintvihok and Davitiyananda, 2003
Corn Peanuts	28 28	AFB_1	85.7 67.9	5-450 µg/kg 4-576 µg/kg	ELISA (LOD: 4 µg/kg)	Lipigorngoson *et al*., 2003
Brown rice Brown glutinous rice Red rice Wheat Lotus seed Job's tear Sorghum Barley Oat meal	30 30 30 30 30 30 30 30 30	DON	47 37 33 30 10 30 29 11 29	0.09 ppm (0.4)[2] 0.09 ppm (0.5)[2] 0.12 ppm (1.0)[2] 0.07 ppm (0.4)[2] 0.04 ppm (0.9)[2] 0.09 ppm (0.5)[2] 0.06 ppm (0.4)[2] 0.03 ppm (0.3)[2] 0.04 ppm (0.3)[2]	ELISA (LOD, LOQ: not reported)	Suprasert *et al*., 2003

Food	Number of samples	Mycotoxin analyzed	Percentage of positive samples	Detection level	Detection method (LOD or LOQ)	References
Peanut products (coated, fried, roasted, satay sauce, peanut wafer, peanut bar, mix peanut, peanut cake, peanut butter, peanut candy, peanut chocolate, peanut icecream, peanut nougat, peanut puff, peanut oil)	713	Aflatoxins	17	0.7-3238 ppb	TLC/Densitometer (LOD, LOQ: not reported)	Suprasert and Yurayart, 2004
Unpolished rice Polished rice Semi-polished rice Unpolished rice	60 10 10 10	Aflatoxins AFG_1[3] AFG_1[3] AFG_1[3]	82 30 80 100	0.3-9.62 µg/kg 0.43-0.45 µg/kg 0.45-1.54 µg/kg 0.34-2.15 µg/kg	HPLC- Fluorescence detector (LOD: Aflatoxin B_1=0.32 ng/g, Aflatoxin B_2=0.37 ng/g, Aflatoxin G_1=0.23 ng/g and Aflatoxin G_2=0.30 ng/ml)	Jankhaikhot, 2005
Chili paste	76	AFB_1 AFB_2 AFG_1 AFG_2	9.2 0 71.0 2.6	0-12.6 µg/kg - 0-226.9 µg/kg 0-38.4 µg/kg	HPLC- Fluorescence detector (LOD: Aflatoxin B_1=0.5 ng/ml, Aflatoxin B_2=0.25 ng/ml, Aflatoxin G_1=1.0 ng/ml and Aflatoxin G_2=1.0 ng/ml)	Reungsitagoon *et al*., 2005

Food	Number of samples	Mycotoxin analyzed	Percentage of positive samples	Detection level	Detection method (LOD or LOQ)	References
Brown rice	30	T-2	53	14 ppb (109.1) [2]	ELISA (LOD: 7.5 ppb)	Suprasert and Suprasert 2005
Brown glutinous rice	30		33	17 ppb (138.9) [2]		
Red rice	30		33	7.4 ppb (102.3) [2]		
Wheat	30		40	17.6 ppb (98.6) [2]		
Lotus seed	30		33	13.9 ppb (127.4) [2]		
Job's tear	30		27	9.5 ppb (74.1) [2]		
Sorghum	30		42	22.5 ppb (95) [2]		
Barley	30		39	15 ppb (101.5) [2]		
Oat meal	30		57	31.6 ppb (115.2) [2]		
Raw peanut (local)	59	Aflatoxins	27.1[4]	Not detected-863.1 ppb	TLC, HPLC, ELISA (LOD, LOQ: not reported)	Kladpan *et al.*, 2006
Raw peanut (imported)	27		0 [4]	Not detected-3.4 ppb		
Roasted ground peanut	35		77.1 [4]	2.4-56.1 ppb		
Processed peanut	62		19.4 [4]	Not detected-571.9 ppb		
Dried chili	33		43.5	>4 ppb but < 20 ppb	HPLC (LOD, LOQ: not reported)	
Dried and ground chili	40		77.5			
Dried pepper	6		66.7			
Chili paste	3		33.3			
Dried pepper or chili (imported)	3		33.3			
Ready-to-eat noodle		Aflatoxins			HPLC- Fluorescence detector (LOD, LOQ: not reported)	Dhananiveskul *et al.*, 2007
Ordinary	40		40	0.01-1.41 ng/g		
Tom-yam style	40		90	0.01-6.95 ng/g		
Pad-thai (Thai style - fried noodle)	24		100	0.05-8.89 ng/g		
Brown rice	57	AFB_1	Not report	0-11 ppb	Detection method, LOD and LOQ were not reported.	Prasertsak *et al.*, 2007

Food	Number of samples	Mycotoxin analyzed	Percentage of positive samples	Detection level	Detection method (LOD or LOQ)	References
Dried coffee beean (Arabica)	32	Ochratoxins	89	<0.6-5.5 μg/kg	ELISA (lower detection limit = 25 ng/kg	Noonim *et al.*, 2008
Dried coffee bean (Robusta)	32		100	1.3-27 μg/kg		
Wheat products		DON			HPLC-UV detector (LOQ = 0.10 μg/g)	Poapolathep *et al.*, 2008
Noodle	30		6.67	0.17-0.35 μg/g		
Bread	30		16.67	0.14-1.13 μg/g		
Cereal	30		33.33	0.13-0.39 μg/g		
Brown rice	30	Aflatoxins	90	2.15±1.84 ppb (6.3) [1]	ELISA (LOD: 2.0 ppb)	Suprasert, 2008
Brown glutinous rice	30		83	2.93±3.11 ppb (11.0) [1]		
Red rice	30		93	3.82±2.92 ppb (11.7) [1]		
Wheat	30		87	2.43±1.47 ppb (5.0) [1]		
Job's tear	30		73	2.15±2.57 ppb (8.4) [1]		
Sorghum	30		96	3.16±5.09 ppb (22.9) [1]		
Barley	30		57	3.96±16.60 ppb (88.4) [1]		
Oat meal	30		52	0.83±1.63 ppb (7.1) [1]		
White rice	25	AFB_1	56	0.702 μg/kg (2.53) [2]	ELISA (LOD, LOQ: not reported)	Chinaphuti and Aukkasarak-ul, 2009
		OTA	0	-		
Brown rice	25	AFB_1	92	2.912 μg/kg (4.56) [2]		
		OTA	40	0.292 μg/kg (1.6) [2]		
Commercial red curry paste	83	Aflatoxins	60	Not detected-17.98 ppb	HPLC-Fluorescence detector (LOD, LOQ: not reported)	Muangsrich-an *et al.*, 2009
Dried coffee bean	12	Fumonisin B_2	58.33	1-9.7 ng/g	LC-MS/MS (LOD = 0.5 ng/g)	Noonim *et al.*, 2009

Food	Number of samples	Mycotoxin analyzed	Percentage of positive samples	Detection level	Detection method (LOD or LOQ)	References
Pasteurized milk	150	AFM_1	100	0.012-0.114 μg/l	HPLC-Fluorescence detector (LOQ = 0.01 μg/l)	Ruangwises and Ruangwises, 2009
Raw milk	240	AFM_1	100	0.014-0.197 μg/l	HPLC-Fluorescence detector (LOQ = 0.01 μg/l)	Ruangwises and Ruangwises, 2010
Pasteurized milk	110	AFM_1	85.45	0.004-0.211 μg/l	HPLC-Fluorescence detector (LOD = 0.004 μg/l, LOQ = 0.01 μg/l)	Nakprasert *et al.*, 2010

[1] mean±standard deviation (SD), maximum value is in parenthesis. [2] mean, maximum value is in parenthesis. [3] The author measured AFB_1, B_2 and G_2 as well but they were not detected. [4] positive samples were contaminated with aflatoxins more than 20 μg/kg.

Ruangwises and Ruangwises, 2010). In raw milk, a few samples showed the level higher than 0.5 µg/l (Suprasert and Yurayart, 2002 a). There were two reports of aflatoxins contamination in liver and muscle of swine and chicken (Bintvihok and Davitiyananda, 2002; Bintvihok and Davitiyananda, 2003). The results of AFM_1 contamination in milk and aflatoxoins contamination in animal tissue not only showed the possibility of human exposure to aflatoxins from animal products but also imply the carry-over of the toxin from feed to milk and animal tissue. AFB_1 were found in higher level than the other metabolites in both chicken and swine. AFB_1 levels were 0.6092±0.0994 ppb and 0.045 ±0.0116 ppb in liver and muscle of chicken, respectively (Bintvihok and Davitiyananda, 2002). In swine the level in liver was 0.518±0.084 ppb and 0.036 ±0.011 ppb in muscle (Bintvihok and Davitiyananda, 2003).

Two trichothecenes, T-2 and DON, were examined in cereal grains and wheat product. The highest level found for T-2 and DON were 31.6 ppb in oat meal and 0.17 ppm in noodle, respectively (Suprasert and Suprasert, 2005; Poapolathep *et al*., 2008). Even though wheat and wheat products are not the major food staple in Thailand, these contamination level imply the need for food standard in the country.

Ochratoxins contaminations were investigated in cereal grains and coffee. The levels in cereal grain were within EU standard (not exceed 5 ppb in raw cereal grain and 3 ppb in cereals products) (Im-erb and Suprasert, 2000; Puncha *et al*., 2000; Suprasert and Chulamorakot, 2001; Chinaphuti and Aukkasarakul, 2009). However, some of the level in dried coffee sample exceeded the EU standard. Coffee is one of the major human source of exposure to ochratoxin besides cereals, wine, grape juice and pork (Murphy *et al.*, 2006). Eighty nine percent of dried Arabica coffee bean and 100% of dried Robusta coffee bean planted in Thailand were contaminated with ochratoxin (the highest level was 27 µg/kg) (Noonim *et al.*, 2008). Although ochratoxins are of concerned in Europe and for some food in Africa (Murphy *et al*., 2006), one should be aware of this mycotoxin in coffee planting in Southeast Asia as well.

ZEN, estrogenic mycotoxin, was determined in 3 cereal grains e.g. oat meal, job's tears and lotus seed. However, there was no report in the susceptible grain like maize. The maximum level in oat meal and lotus seed exceeded 100 ppb and even more than 200 ppb in job's tear. The maximum limit for ZEN in cereal and cereal products in France is 50 ppb (µg/kg) (Zinedine *et al*., 2007).

Fumonisins were studied in cereal grains and dried coffee bean (Im-erb and Suprasert, 2000; Puncha *et al*., 2000; Suprasert and Suprasert, 2000; Suprasert and Chulamorakot, 2001; Noonim *et al*., 2009). The levels were found between 0.08-2.87 ppm in cereal grains and 1-9.7 ng/g in dried coffee bean. Similar to the case of ZEN, highly susceptible product like maize was not studied. There was no report of PAT. This mycotoxin is of high concern in fruit juice especially apple juice (Murphy *et al.*, 2006). Occurrence of PAT in food especially fruit and apple juice is needed in Thailand.

Sampling and detection method

The distribution of mycotoxins in food is vary widely even within a seed (CAST, 2003). Therefore sampling is one of the most important steps for determination of mycotoxins in food. In fact, sampling error is considerably higher than analytical error (CAST, 2003). It is not possible to examine mycotoxin level in food with 100% certainty. Therefore the results should be express with uncertainty level such as standard deviation or standard error of mean. However some reports did not show those values. The recent method of analysis for mycotoxins and sampling has been reviewed (Shephard *et al*., 2011; Shephard *et al*., 2012). Immunochemical methods, highly sensitive LC-MS methods and conventional techniques have been used for mycotoxins detection. Most of reports from Thailand obtained samples by purchasing products from local markets. However sampling plan were not focused, those results are valuable for surveillance information.

As can be seen in figure 2, approximately half of the methods used in the reports were enzyme-linked immunosorbent assay (ELISA) and high performance liquid chromatography (HPLC). The limited budget, high throughput and user friendly of ELISA make this method popular among laboratories in Thailand. In general, ELISA should be used as a screening method and the results should be confirmed by the other standard method like HPLC. In one case, the report of mycotoxin contamination in food was a test of developed ELISA method (Lipigorngoson *et al*., 2003).

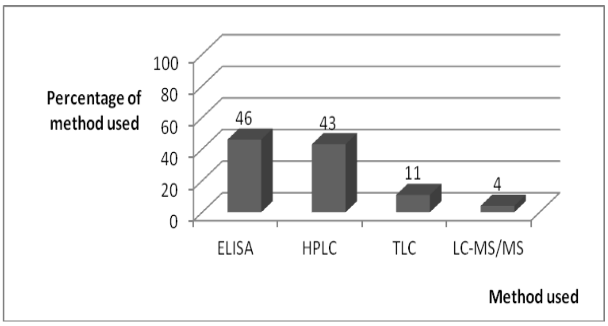

Figure 2. Percentage of method used for mycotoxins analysis

There were 12 reports (43%) using HPLC with either UV or fluorescence detector (FLD) as a method of detection. Sample preparation before HPLC analysis is of importance as well since food contains enormously analytical interference. The useful technique for sample clean-up is solid phase extraction (SPE) which is more efficient than a conventional liquid-liquid extraction method. However the commercially available columns especially immunoaffinity column are relatively expensive.

There were 3 reports using TLC as detection method. TLC remains important to mycotoxins analysis in developing countries as it is simple and inexpensive.

Due to the limited Liquid Chromatography-Mass Spectrometry (LC-MS) available in Thailand, there are only 1 report mentioned this instrument. LC-MS has been a powerful tool for simultaneously determination of mycotoxins (Songsermsakul and Razzazi, 2008). The advantage of determining several mycotoxins in one run is that one sample could be contaminated by more than 1 mycotoxin. The instrument provides high selectivity and sensitivity for both qualitative and quantitative analysis.

The method used should be validated for each matrix to ensure the reliability. The validated method for mycotoxin analysis is available and published online by the Association of Official Analytical Chemists (AOAC International, 2005). Sixteen reports did not show either limit of detection (LOD) or limit of quantitation (LOQ). A key question about those reports is the reliability of results.

Food safety and international trade associated with mycotoxins

As the world food exporter, food safety is an important issue for Thailand. Mycotoxins, particularly aflatoxins have long been an important problem and make the country lost export value about 50 million USD per year in case of corn (Dohlman, 2003). Rice is the most valuable agricultural product of Thailand. Aflatoxins, fumonisins, DON, T-2 and OTA were analysed. The results on table 1 show that the contamination levels were low for all mycotoxins. There was no sample which contained aflatoxins exceeded the action level of Thailand (20 ppb). However the survey in Canada in 2007-2009 (Bansal *et al*., 2011) showed that black and red rice from Thailand contaminated with AFB_1 although with low level (1.4-7.1 ng/g). In addition black glutinous rice was positive for OTA (0.49 ng/g). Black sweet rice from Thailand was also positive for Fumonisin B_1 at level of 14 ng/g. Even though the levels found were not high, one should be concerned about the mycotoxin contamination in export product. In 2008, Thai rice exported to Japan was found to be contaminated with mold and aflatoxins (Chinaphuti and Aukkasarakul, 2009). Recently, AFB_1 were found in imported wheat and barley in Malaysia (Reddy and Salleh, 2010). The products were from India and Thailand. Moreover Russia required the information on mycotoxin contamination in exported Thai rice such as citrinin and OTA (Chinaphuti and Aukkasarakul, 2009). These reports would alert Thailand to prepare surveillance program for export product. The National Bureau of Agricultural Commodity and Food Standards (ACFS) of Thailand is a government agency. One of the core functions is to establish food standard to ensure the safety of products produced in the country.

Regulations for mycotoxins are generally based on toxicological data, occurrence and distribution including epidemiological data (CAST, 2003). Global harmonization of mycotoxin regulation would protect human in every country from this unavoidable toxin. However the differences among countries both in political and economical aspects make this idea impractical. The harmony of mycotoxins regulation has been established in some regional communities such as EU, MERCOSUR (Argentina, Brazil, Paraguay and Uruguay) and Australia/New Zealand (FAO, 2004 b). In Thailand, the regulatory limit has been set for aflatoxins (AFB_1, B_2, G_1, G_2) at 20 ppb in food (FAO, 2004b). The regulation has not been established for the other mycotoxins. As the food exporter, the agricultural commodities have to meet the regulation of the importing countries. However, with the strict action of those countries may lead to the difficulties of exporter to maintain the quality especially the year of extreme weather, drought and flood. It is possible that the low-grade quality product will leave for the local people instead of destroying or diverting products. CAST (2003) noted that people in the developed countries expose to mycotoxins less than people in the developing countries. This could be due to the strict regulative action, standard of living and consumer protection policy. Moreover the results from the study of prevalence and level of human exposure to aflatoxins showed the chronic exposure of 4.5 billion people in developing countries to uncontrolled level of aflatoxins (Williams *et al*., 2004). Recent study showed a positive association between mycotoxin-prone food (maize) consumption and HIV transmission frequency in sub-Saharan Africa (Williams, 2010). This is another evidence to link health effect to mycotoxins exposure.

Conclusions

Data of mycotoxins contamination in Thailand from 2000-2010 is rather limited. Most of reports show low level of mycotoxins in food. Aflatoxins have occupied the major area of mycotoxins investigation in Thailand. Aflatoxins contamination of peanut and peanut products has been a problem in the country. Interestingly, highly susceptible crop like corn has not been sufficiently examined. This may be due to the limitation of availability of local reports on the database. Occurrence data of mycotoxin of food in Thailand on a regular basis are needed and the data should be published. Regulation on more mycotoxins is required for a safer food. Harmonization of directive in Southeast Asia should be considered as the countries in the region will become the ASEAN Community in 2015. As the food exporter, high quality products are usually sent to the importing countries. Local people expect to consume safe food as well even though the regulation in the country has not covered all of the major mycotoxins.

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