Aflatoxin in Indonesian Peanuts: How Can the Contamination within the Food Chain Be Managed?

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Abstract

Among the various raw and processed peanuts collected from different points of the delivery chain (farmer, *penebas*, collector, processor and retailer) in Pati Regency, Central Java, the highest *Aspergillus flavus* infection and aflatoxin contamination were found in raw kernels of peanuts collected from retailers in traditional markets.

Postharvest handling methods prior to peanuts being delivered to retailers and especially at the retailer level in traditional markets severely impact on the level of aflatoxin contamination in the Indonesian food chain.

Some potential initiatives to minimise aflatoxin contamination, both at the pre and postharvest stages, are discussed in this paper. Critical to the further development of this work is a concentrated effort to monitor postharvest handling methods carried out by farmers, collectors and retailers in traditional markets and identify the critical control points for potential changes needed in their procedures.

Aflatoxin is a human carcinogen that can contaminate peanuts and hence is a major food-safety problem throughout the world. It is particularly severe in developing countries such as Indonesia. It occurs when kernels become infected by *Aspergillus flavus*, *A. parasiticus* and *A. nomius*, under drought stress before harvest, during the drying phase in the field, or under unsuitable storage conditions.

Based on the report of the 23rd Session of the Joint Food and Agriculture Organization of the United Nations/World Health Organization (FAO/WHO) Food Standards Programme, held in Rome, Italy, 28 June – 3 July 1999, the Codex Alimentarius Commission adopted 15 parts per billion (ppb) as the maximum level of total aflatoxins in peanuts intended for further processing. In Australia, the maximum allowable limit of aflatoxin in peanut and peanut products is 15 ppb (QDPI 2000).

As part of an ongoing Australian Centre for International Agricultural Research (ACIAR) project on management of aflatoxin in Indonesia and Australia (PHT 97/017), a survey has been conducted to

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Agriproduct supply-chain management in developing countries
edited by G.I. Johnson and P.J. Hofman
ACIAR Proceedings No. 119e
(printed version published in 2004)

monitor aflatoxin contamination in peanuts and assess the critical hazard points along the market supply chain in the Pati Regency in Central Java. In this regency, the peanut delivery chain can be classified into five levels — farmer, *penebas* (one who buys crops before harvest), collector, processor (factory) and retailer.

Occasionally farmers may deliver the peanuts directly to a local market or collector who buys the peanuts from the farmers before harvest. To prepare flour-coated kernels, processors also buy peanut kernels from other regencies or other countries (China, India and Vietnam).

This paper describes:

- the results of interviews with farmers, *penebas*, collector/traders and factories concerning pre and postharvest handling of peanuts
- the results of a research project entitled '*Aspergillus flavus* and aflatoxin in peanuts at various stages of the delivery chain in Pati regency, Central Java'
- what initiatives should be carried out to overcome the aflatoxin problem in Indonesian peanuts.

Methodology

During the survey, interviews using questionnaires with farmers, *penebas*, collectors and processors (factories) on pre and postharvest handling of peanuts were conducted, together with random sampling of various kinds of peanuts and peanut products.

Interviews and sampling were carried out during the wet (January 2002) and dry (August 2002) seasons. The number of respondents at farmer, *penebas* and collector levels in each season was 48, 10 and 4, respectively. The number of samples of wet raw pods at farmer, *penebas* and collector levels were 48 (derived from 48 farmers), 30 (derived from 10 *penebas*) and 12 (derived from 4 collectors), respectively. The samples were obtained from the interviewed respondents. The number of interviewed farmers, *penebas* and collectors were determined in proportion to the numbers of each group in the districts where peanut samples were collected. The determination of the districts where peanut samples were collected was based on their high peanut production. This information was obtained from the Indonesian Government's Regional Office of Agricultural Crop and Animal Husbandry in Pati. In each district, peanut samples were collected from peanut farms or *penebas* located in the scattered areas. The questionnaires consisted of questions about pre and postharvest handling of peanuts. Interviews were conducted using the Indonesian language or dialect.

At the farmer level, each peanut sample derived from a peanut farm. About 20 peanut plants were selected randomly; they were than pulled out manually to obtain about 2 kg of wet raw pod peanuts. At the *penebas* level, three samples (= three replicates) of wet raw pod peanuts (about 2 kg/sample) were collected randomly from each *penebas*; the peanuts had been placed in woven polypropylene bags or they were still in piles. At the collector level, three samples (= three replicates) of wet raw pod peanuts (about 2 kg/sample) were collected randomly from each collector; the peanuts had been placed in woven polypropylene bags.

Results

Results of interviews regarding pre and postharvest handling of peanuts

Interviews with farmers

Forty-eight farmers of Pati Regency were interviewed either during the wet or dry seasons. Some of the farmers interviewed during the wet season were the same individuals as interviewed during the dry season. Most of the farmers (85% and 96% of the respondents interviewed during the wet and dry seasons, respectively) sold the peanuts to *penebas* before harvest, while 15% and 4% of the respondents, respectively, harvested the crop themselves. The harvesting method was the same in either case — peanut plants were pulled out and stripped manually, and the peanuts were not dried. In the latter case, farmers sold the crop directly to the collectors. All respondents (100%) were unaware of the aflatoxin problem in peanuts.

Interviews with penebas

Ten *penebas* of Pati Regency were interviewed either during the wet or dry season. Some of the *penebas* interviewed during the wet season were the same individuals as interviewed during the dry season. Harvesting was carried out by pulling the peanut plants manually as well as by manual pod-stripping. Drying and storing of peanuts were not carried out before sending them to collectors or factories. All respondents (100%) were unaware of the aflatoxin problem in peanuts.

Interviews with collectors

Four collectors of Pati regency were interviewed either during the wet or dry seasons. Of the respondents interviewed during the wet and dry seasons, 50% and 20%, respectively, stored peanut pods before sending them to the factory. During the wet season, peanuts were stored in woven polypropylene bags for one night (25% of the respondents) or up to a maximum of 7 days (25% of the respondents). During the dry season, peanuts were stored by spreading them on a paved floor for 4–30 days. During both seasons, most peanut pods were sold to factories in the form of 'fresh' raw peanuts. All respondents (100%) were unaware of the aflatoxin problem in peanuts.

Interviews with factories (processors)

The results of questionnaires were based on a visit to the PT Garuda Food factory in Pati, Central Java (Dharmaputra and Maysra 2003). The processing steps undertaken for different products are outlined below.

Flour-coated peanut processing:

- *sorting* — peanut kernels derived from collectors are sorted according to kernel colour using 'sorteks' (machines that sort on a visual basis)
- *storage* — raw peanut kernels are stored in a grain Cooler Silo
- *coating* — peanuts are coated with a mixture of salt, tapioca flour, sugar and garlic (the garlic is imported from China) in a container made from stainless steel, fitted with a rotation system
- *frying* — peanuts are fried in palm oil (1 t flour-coated peanuts takes 30 minutes to fry); the oil is used for 24 h and then discarded
- *packing* — peanuts are packed by weight, i.e. 20 g, 100 g etc.
- *product storage* — flour-coated peanuts are stored in cardboard boxes on shelves; the maximum storage period is 7 days before the peanuts are distributed to retailers (supermarkets and traditional markets)
- *monitoring of aflatoxin contamination* — this is undertaken every 3 months using the enzyme-linked immunosorbent assay (ELISA) method.

Roasted peanut processing — peanuts (in the form of wet, raw pods) should be processed within 24 h of harvest:

- *grading* — this is conducted based on the soil attached to the pods and pod colour
- *pre-cleaning* — wet, unshelled peanuts derived from *penebas* in the Pati region are washed manually using well water, while those derived from collectors in other regions are washed in four stages
- *cooking* — the peanuts are cooked using water mixed with salt
- *drying* — the peanuts are dried at ±80°C using ovens
- *grading* — peanuts are sorted both manually and mechanically into one of three grades
  - grade I, two seeds and mature
  - grade II, two seeds and mature–young, or three seeds and mature
  - grade III, almost mature seeds
- *storage* — roasted peanuts are stored for a maximum of 7 days after processing, before they are distributed to retailers (supermarkets and traditional markets).

Results of sampling within the supply chain

Dharmaputra et al. (2003) reported moisture contents, the incidence of *A. flavus*, and aflatoxin B_1 contamination of raw and processed peanut products collected from different points of the delivery chain in the Pati Regency in Central Java during the wet and dry seasons in 2002.

Fresh pod samples were collected from farmers' fields (48 samples), *penebas* (30 samples) and collectors (12 samples). Nine samples of roasted kernels were collected from peanut factories. Three samples of raw and flour-coated kernels, and various roasted pod samples were collected from the markets in Pati, Bogor, Yogyakarta and Malang cities. In all, during each season, 135 samples of various kinds of peanuts and peanut products were collected for analysis (Table 1).

Moisture content, the percentage of peanut kernels infected by *A. flavus*, and aflatoxin B_1 content were determined using the oven method, plating method on *Aspergillus flavus* and *parasiticus* agar (AFPA) medium, and ELISA method, respectively.

Moisture content

The results showed that moisture contents of peanuts collected from farmers' fields, *penebas* and collectors were generally very high, i.e. 46.7–48.5% (wet season) and 40.1–47.5% (dry season), roasted peanuts collected from factories or retailers were 3.1–3.8% (wet season), and 2.1–2.9% (dry season), and flour-coated kernels collected from retailers

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edited by G.I. Johnson and P.J. Hofman
ACIAR Proceedings No. 119e
(printed version published in 2004)

Table 1. Location of sampling, type and number of peanut samples collected from different stages of the delivery chain during the wet (January 2002) and dry (August 2002) seasons (Dharmaputra et al. 2003).

Stages of peanut delivery chain	Type of peanuts	Wet season					Dry season				
		Location of peanut sampling				Total no. of samples	Location of peanut sampling				Total no. of samples
		Bogor	Pati	Yogya-karta	Malang		Bogor	Pati	Yogya-karta	Malang	
Farmer	Wet raw pod	0	48	0	0	48	0	48	0	0	48
Penebas	Wet raw pod	0	30	0	0	30	0	30	0	0	30
Collector	Wet raw pod	0	12	0	0	12	0	12	0	0	12
Processor (factory)	Roasted pod	0	9	0	0	9	0	9	0	0	9
Retailer	Raw kernel	3	3	3	3	12	3	3	3	3	12
	Flour-coated kernel	3	3	3	3	12	3	3	3	3	12
	Roasted pod	3	3	3	3	12	3	3	3	3	12
Total		9	108	9	9	135	9	108	9	9	135

were 3.8% (wet season) and 2.9% (dry season). Raw kernel samples collected from retailers in traditional markets were 8.4% and 7.0% during the wet and dry seasons, respectively. Mean moisture contents of peanut kernels derived from various kinds of peanuts collected from different points of the delivery chain during the wet and dry seasons are presented in Tables 2 and 3 and Figure 1.

Incidence of A. flavus

Peanut samples from farmers' fields, *penebas* and collectors were generally significantly lower in *A. flavus* infection than those found among processors and retailers, i.e. 17–25% (wet season) and 25–40% (dry season). During the wet season, *A. flavus* infection in roasted peanut samples collected from processors and retailers was 11% and 50%, respectively, while those collected during the dry season were 89% and 17%, respectively. Raw kernel samples collected from retailers in traditional markets had 100% infection with *A. flavus* during both seasons. The highest mean percentage of kernels infected by *A. flavus* in infected samples in both seasons was found in raw kernels collected from retailers in traditional markets, i.e. 53.1% (wet season) and 30.4% (dry season) (Tables 2 and 3). The mean percentage of peanut samples infected with *A. flavus* from various types of raw and processed peanuts collected from different points of the delivery chain during the wet and dry seasons are presented in Tables 2 and 3 and Figure 2; while those mean percentages of kernels infected by *A. flavus* in infected samples are presented in Tables 2 and 3 and Figure 3.

Aflatoxin contamination

In general, the aflatoxin B_1 content of peanuts collected from farmers' fields, *penebas*, and collectors and processed samples were low (less than 15 ppb). The highest aflatoxin B_1 contents were found in peanuts collected from retailers in the traditional markets, with the range of 2–124 ppb and <4–342 ppb during the wet and dry seasons, respectively (Table 4). The percentage of raw kernel samples contaminated with aflatoxin B_1 (exceeding 15 ppb) collected during the wet and dry seasons was 33% and 25%, respectively (Table 4, Figures 4 and 5).

Discussion and Conclusions

Potentially there are some strategic areas where efforts could be carried out to overcome the aflatoxin problem in Indonesian peanuts. This is regardless of whether the problem is generated via pre and/or postharvest handling practices, or from domestic versus imported production. The high incidence of *A. flavus* infection immediately postharvest and the subsequent high levels of contamination of *all* peanuts after processing in local markets or retailing operations suggest that much of the problem is of local Indonesian origin.

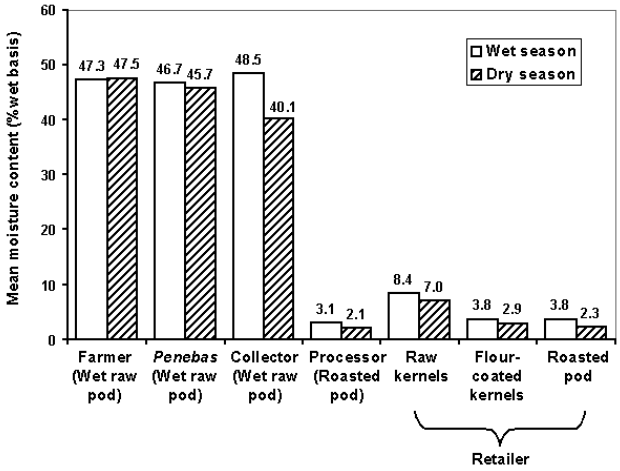

Figure 1. Mean moisture content of peanut kernels derived from various types of peanuts collected from different points of the delivery chain during the wet and dry seasons (Dharmaputra et al. 2003).

Table 2. Moisture content, *Aspergillus flavus* infection, and aflatoxin B_1 content of peanut kernels derived from various types of peanuts collected from different points of the delivery chains during the **wet** season (January 2002) (Dharmaputra et al. 2003).

Chain level	Type of peanuts	Number of samples	Range (mean) of moisture content (% wet basis)	Number (%) of sample infected with *A. flavus*	Range of % infection in infected samples	Mean % of infected kernels in infected samples	Range of aflatoxin B_1 content (ppb)
Farmer	Wet raw pod	48	36.98–58.63 (47.27)	10 (20.8)	1–2	1.10	<3.6–9
Penebas	Wet raw pod	30	37.33–51.89 (46.69)	5 (16.7)	1–5	2.00	<3.6–11.4
Collector	Wet raw pod	12	45.72–51.78 (48.50)	3 (25.0)	1–2	1.33	<3.6–6.2
Processor (factory)	Roasted pod	9	2.50–3.56 (3.06)	1 (11.1)	Only one infected sample with 4% of infected kernels	Only one infected sample with 4% of infection	<3.6
Retailer	Raw kernels	12	6.71–11.56 (8.43)	12 (100)	17–100	53.08	1.7–124
	Flour-coated kernels	12	3.43–4.08 (3.79)	10 (83.3)	1–33	8.60	<3.6–5.7
	Roasted pod	12	2.94–4.84 (3.75)	6 (50)	1–7	2.83	<3.6–4.5

Table 3. Moisture content, *Aspergillus flavus* infection, and aflatoxin B_1 content of peanut kernels derived from various types of peanuts collected from different points of the delivery chain during the **dry** season (August 2002) (Dharmaputra et al. 2003).

Chain level	Type of peanuts	Number of samples	Range (mean) of moisture content (% wet basis)	Number (%) of samples infected with *A. flavus*	Range of % infection in infected samples	Mean % of infected kernels in infected samples	Range of aflatoxin B_1 content (ppb)
Farmer	Wet raw pod	48	38.04–62.67 (47.48)	17 (35.4)	1–5	1.65	<3.6–196.5
Penebas	Wet raw pod	30	40.14–52.28 (45.66)	12 (40.0)	1–4	1.33	<3.6–19.6
Collector	Wet raw pod	12	15.23–50.25 (40.07)	3 (25.0)	Three infected samples with 1% of infected kernels, respectively	1.00	<3.6–6.9
Processor (factory)	Roasted pod	9	1.40–2.40 (2.08)	8 (88.9)	1–5	2.75	<3.6
Retailer	Raw kernels	12	6.50–9.41 (7.01)	12 (100)	1–100	30.42	<3.6–342.1
	Flour-coated kernel	12	2.59–3.23 (2.89)	2 (16.7)	1–6	3.50	<3.6–141.2
	Roasted pod	12	1.40–2.96 (2.30)	2 (16.7)	1–4	2.50	<3.6–11.4

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ACIAR Proceedings No. 119e
(printed version published in 2004)

The results of the survey showed that the highest percentages of samples infected by *A. flavus* and mean percentages of infected kernels in infected samples, and the highest aflatoxin B_1 contamination were found in raw kernels collected from retailers in traditional markets in Pati, Bogor, Yogyakarta and Malang cities. The raw kernels may have been sourced from farmers or collectors in their respective regencies. There is, however, the possibility that contaminated raw kernels were imported from other countries, such as China, India and Vietnam, and it is difficult to determine the exact source. Despite this possibility, it is clear that in Indonesia, both pre and postharvest handling methods prior to peanuts being delivered to retailers (and especially at the retailer level in traditional markets) severely impact on the level of aflatoxin contamination in the Indonesian food chains.

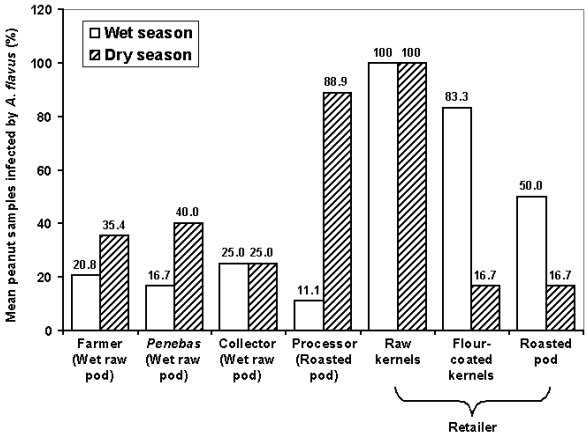

Figure 2. Mean percentage of peanut samples infected with *Aspergillus flavus*. Samples were derived from various types of peanuts collected from different points of the delivery chain during the wet and dry seasons (Dharmaputra et al. 2003).

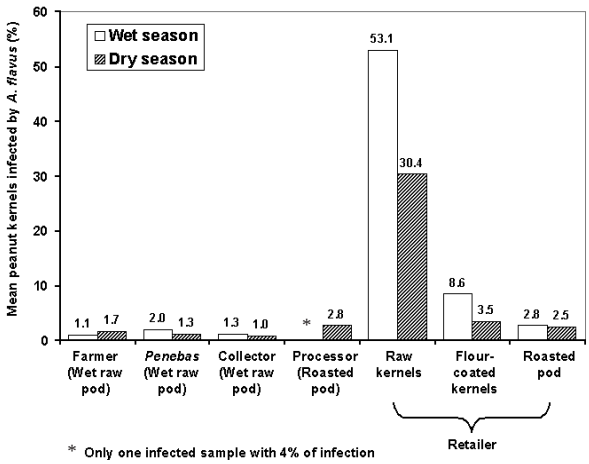

Figure 3. Mean percentage of kernels infected by *Aspergillus flavus* in infected samples. Samples were derived from various types of peanuts collected from different points of the delivery chain during the wet and dry seasons (Dharmaputra et al. 2003).

Table 4. Percentage of peanut samples collected during the wet (January 2002) and dry (August 2002) seasons, and contaminated with different levels of aflatoxin B_1 (Dharmaputra et al. 2003).

Peanut delivery chain	Type of peanuts	Wet season			Dry season		
		Number of samples	Aflatoxin B_1 content (range in ppb)	Percentage (%)of peanut samples contaminated with aflatoxin B_1	Number of samples	Aflatoxin B_1 contents (range in ppb)	Percentage (%) of peanut samples contaminated with aflatoxin B_1
Farmer	Wet, raw pod	48	≤5	81.25	48	≤5	72.92
			>5 ≤ 15	18.75		>5 ≤ 15	10.42
			>15 ≤ 50	0		>15 ≤ 50	12.50
			>50 ≤ 124	0		>50 ≤ 342	4.16
Penebas	Wet, raw pod	30	≤5	86.67	30	≤5	70.00
			>5 ≤ 15	13.33		>5 ≤ 15	23.33
			>15 ≤ 50	0		>15 ≤ 50	6.67
			>50 ≤ 124	0		>50 ≤ 342	0
Collector	Wet, raw pod	12	≤5	91.67	12	≤5	66.67
			>5 ≤ 15	8.33		>5 ≤ 15	33.33
			>15 ≤ 50	0		>15 ≤ 50	0
			>50 ≤ 124	0		>50 ≤ 342	0
Processor (factory)	Roasted pod	9	≤5	100	9	≤5	100
			>5 ≤ 15	0		>5 ≤ 15	0
			>15 ≤ 50	0		>15 ≤ 50	0
			>50 ≤ 124	0		>50 ≤ 342	0
Retailer	Raw kernels	12	≤5	25	12	≤5	58.33
			>5 ≤ 15	41.67		>5 ≤ 15	16.67
			>15 ≤ 50	16.67		>15 ≤ 50	8.33
			>50 ≤ 124	16.67		>50 ≤ 342	16.67
	Flour-coated kernels	12	≤5	91.67	12	≤5	83.34
			>5 ≤ 15	8.33		>5 ≤ 15	8.33
			>15 ≤ 50	0		>15 ≤ 50	0
			>50 ≤ 124	0		>50 ≤ 342	8.33
	Roasted pod	12	≤5	100	12	≤5	91.67
			>5 ≤ 15	0		>5 ≤ 15	8.33
			>15 ≤ 50	0		>15 ≤ 50	0
			>50 ≤ 124	0		>50 ≤ 342	0

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Preharvest practices

Preharvest management plays an important role in reducing the risk of aflatoxin contamination in Indonesian peanuts. It is well known that although the aflatoxin-producing fungus, *A. flavus*, is widely distributed in soils, it invades peanut pods/kernels only when the shell is physically ruptured, either mechanically via splitting during severe end-of-season drought stress, or as a result of injury via soil-insect damage. Even though the *A. flavus* fungus is present in pods and kernels, aflatoxin contamination will only occur under very special conditions of kernel moisture content (below about 30%, Mehan et al. 1986) and temperature. Cole et al. (1985) and Sanders et al. (1985) reported that preharvest aflatoxin contamination will only occur when pod-zone soil temperatures are in the range of 25–32°C, with associated drought conditions during the last 30–50 days of the growing season.

To maintain healthy peanuts that can resist *A. flavus* infection and subsequent aflatoxin production, it is therefore important that a series of agronomic management practices are implemented in farmers' fields, including the following:

- Pods should be grown with adequate soil moisture during the last 30 days of pod growth to avoid pod splitting arising from drought stress. Where irrigation is available, watering should be undertaken every 10–15 days, depending on the evaporative demand.

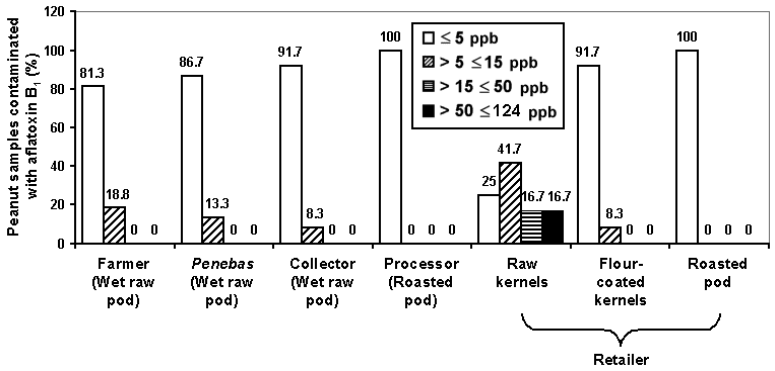

Figure 4. Percentage of peanut samples contaminated with different levels of aflatoxin B_1 during the wet season 2002. Samples were derived from various types of peanuts collected from different points of the delivery chain (Dharmaputra et al. 2003).

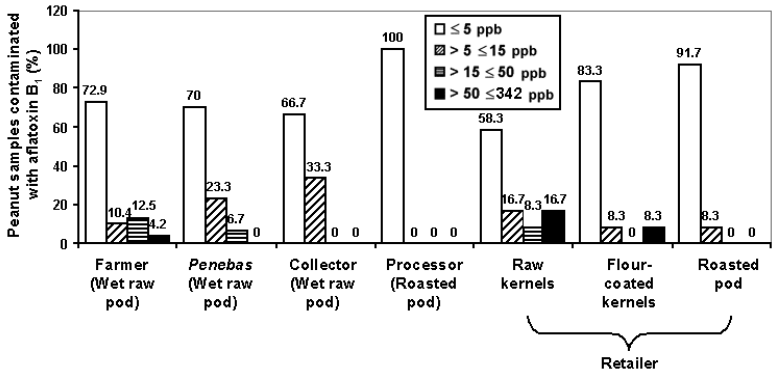

Figure 5. Percentage of peanut samples contaminated with different levels of aflatoxin B_1 during the dry season 2002. Samples were derived from various types of peanuts collected from different points of the delivery chain (Dharmaputra et al. 2003).

- Pods should be free from mechanical injury resulting from field implements such as weeding equipment. In Indonesia, this practice is relatively rare, as farmers usually conduct weeding operations around 20–40 days after sowing. Care should be taken during the harvesting operation to prevent pod injury when plants are pulled manually.
- Pods should be free of soil-pest infection, such as white grubs, in a range of peanut cropping systems. Some farmers broadcast the pesticide Carbofuran onto the soil and then apply irrigation water. Most farmers, however, tend to leave crops without doing any pest management.
- Pods should be harvested at optimal maturity. Late harvesting will result in higher susceptibility of kernels and shells to fungal invasion (McDonald and Harkness 1967). Under very hot and severe end-of-season drought conditions, it is recommended that crops even be harvested 1–2 weeks early to avoid crop water deficits and the associated high risk of aflatoxin contamination (Nageswara Rao et al. 2002; Rahmianna et al. 2003).

Postharvest practices

To overcome, or at least minimise, aflatoxin contamination in Indonesian peanuts, effort is warranted in the following areas:

- obtain more information on postharvest handling of peanuts in other peanut-growing areas in Indonesia
- monitor postharvest handling methods carried out by farmers, collectors and retailers (especially in traditional markets)
- obtain more information on the supply chain for imported peanuts and ensure that regulators have the knowledge and capacity to reduce the importation of inferior-quality product
- monitor the quality of imported peanuts, especially their aflatoxin content, in an effort to help define the extent of the problem and contribution being made by domestic versus imported production
- identify the most effective means of informing the postharvest-handling industry sectors about aflatoxin and its potential management
- develop information and training packages for processors and retailers to inform them about the dangers of aflatoxin and the handling methods that can reduce the problem
- encourage collectors and processors to place emphasis on improved production and handling techniques by farmers and *penebas*
- publicise to the wider community the potential health problems associated with consuming poor-quality peanuts.

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