Indonesian Journal of Agricultural Science 9(2), 2008: 68-76

MYCOTOXIN CONTAMINATION ON CORN USED BY FEED MILLS IN INDONESIA

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ABSTRACT

Mycotoxins which are secondary metabolites of fungi contaminate agricultural products such as corn and have deleterious effects on human and animal. The objective of this study was to evaluate the mycotoxin contamination on local and imported corn samples collected from different feed mills in Indonesia. Three hundred fifty six of corn samples (0.50 kg each) were sent by several feed mills to the Indonesian Research Institute for Animal Production during 2005-2006. The background information accompanied with each sample was country/province of origins, harvesting seasons, postharvest drying methods, moisture levels, grades, and varieties. The samples were analyzed for various mycotoxins, i.e aflatoxin (AFL), ochratoxin (OCRA), zearalenone (ZEN), fumonisin (FUM), deoxynivalenol (DON), and T2 toxin using commercial kits, except for AFL which was analysed using a kit developed by the Indonesian Research Center for Veterinary Science. The results showed that average AFL level in the contaminated corn originated from Indonesia was 59 $\mu g\ kg^{-1}$, almost 7 times higher than that imported from the USA or Argentina. Among the types of mycotoxins detected, FUM was the highest with an average of 1193 $\mu g\ kg^{-1}$, followed by DON, ZEN and OCRA at level of 324, 22 and 2 $\mu g\ kg^{-1}$, respectively. Mycotoxin levels in the contaminated local corn samples varied depending on the province of origins as well as harvesting seasons, postharvest drying methods, and moisture contents. The least mycotoxin contaminations were found on corn originated from North Sumatra and Lampung with the AFL levels were < 20 and < 50 $\mu g\ kg^{-1}$, respectively, lower than those from East Java, Central Java and South Sulawesi (64-87 $\mu g\ kg^{-1}$). Mycotoxin levels, however, were less affected by grading made by feed mills and corn varieties. It is indicated that AFL was the most important mycotoxin as far as for animal feeding concerned, as it contaminated almost 50% of local corn with the level of contamination above the Indonesian National Standard, i.e. 50 $\mu g\ kg^{-1}$. The study suggests that postharvest methods of local corn must be improved to reduce mycotoxin contamination.

[***Keywords***: Corn, mycotoxins, animal feed, Indonesia]

INTRODUCTION

Corn production of Indonesia was estimated more than 11 million metric tons (mt) in 2006 (Statistics Indonesia of the Republic of Indonesia 2007). Most of the corn is used for feed, food, and seed. In 2006, feed mills required around 3.5-4.0 million mt of corn to fulfill 7.2 million mt of compound feed mainly as chicken feed. However, due to insufficient local production of corn, Indonesia imported 1.7 million mt of corn from different countries such as USA, Argentina, and China (Handiman, pers. comm.).

One of the problems in using corn for animal feed is mycotoxin contamination. Mycotoxins, which are metabolite products of certain fungus, are toxic to animal and human. There are various types of mycotoxins such as aflatoxin, fuminisin, ochratoxin, zearalenone, and deoxynivalenol. Aflatoxin (AFL), a hepatoxin, is produced by *Aspergillus flavus* and causes reduction in daily gain of chicken and egg shell weight (Zaghini *et al*. 2005). Fumonisin (FUM) which is produced by *Fusarium moniliforme*, is often found as a contaminant in corn and causes reduction of egg production in quail (Butkeraitis *et al.* 2004) and feed intake in calves (Mathur *et al*. 2001), as well as increases colonization of pathogenic *Escherichia coli* in the small and large intestines of pig (Oswald *et al*. 2003). Ochratoxin (OCRA) which is produced by *Aspergillus ochraceus,* causes mortality in chicks or broiler chicken (Gibson *et al.* 1990). Zearalenone (ZEN) produced by *Fusarium graminearum* is an estrogenic toxin hence it affects reproduction problem, embryonic mortality in eggs, and decreases antibody titers in broiler breeders (Yegani *et al*. 2006). *F. graminearum* also produces both deoxynivalenol (DON) and T-2 toxin. These toxins are included in tricotesene mycotoxin. DON or vomitoxin was less toxic (LD_{50} = 140 mg kg^{-1} body weight) than T-2 toxin (LD_{50} = 1.75 mg kg^{-1} body weight) to broiler chicken (Widiastuti 2006).

Reports on mycotoxin toxicity in poultry or ruminant in Indonesia were rare or limited. For example, AFL toxicity has been reported to affect ducks in West Java and South Kalimantan (Zahari and Tarmudji 1995). Bahri *et al*. (1990) reported that in 1988-1989, 40 sheep died because of DON toxicity in Bogor, West Java. Some dairy cows in Salatiga, Central Java, were ill and refused to consume feed because they were suspected to suffer from ZEN toxicity (Bahri and Maryam 2003). Most available information on mycotoxin contaminations in corn and feed was associated with AFL (Bahri *et al.* 2005; Tangendjaja and Rachmawati 2006), although FUM contamination was also reported on feed ingredient and chicken feed samples in West Java (Maryam 2000).

Mycotoxin tolerance on animal is affected by species, age or physiological state of the animals. The Indonesian Directorate General of Livestock Services recommended the maximum contamination of AFL levels for non-ruminant animal and ruminant feed as high as 50 and 200 μg kg^{-1}, respectively. There has not yet been a recommendation on the maximum tolerance level for other mycotoxins (Suparto 2004).

Most studies previously conducted in Indonesia only analysed mycotoxin contamination on limited number of corn or feed samples sent by feed mills to the laboratory without any background information on corn origin, harvesting season, variety, and method of drying process. This study aimed to evaluate the mycotoxin contamination on local and imported corn samples collected from different feed mills in Indonesia.

MATERIALS AND METHODS

Study was conducted in December 2005 to July 2006. A total of 356 corn samples were collected by several feed mills and taken to the Indonesian Research Institute for Animal Production, Ciawi-Bogor, Indonesia. The samples (0.5 kg each) were stored frozen (-20°C) until analyzed. Each sample was accompanied with its background information such as its country of origins (Indonesia, USA or Argentina). Especially for corn samples of Indonesia origin, they have additional information on growing locations (North Sumatra, Lampung, West Java, Central Java, East Java or South Sulawesi), varieties (local, hybrid or mixed variety), harvesting times (dry or wet season or unidentified), postharvest drying processes (oven drying, sun drying or combination of both), and moisture contents (grouped into four levels, i.e. < 14.0%, 14.1-16.0%, 16.1-18.0%, and 18.1-20.0%).

Since there has no standard grading for corn in Indonesia, feed millers make their own grading system. The corn was graded into three groups, i.e. KW I for the best quality of corn, KW II for intermediate, and KW III for the worst quality. Grading system was based on various criteria such numbers of broken kernels, foreign materials, damaged kernels (moldy, heat damage, insect damage, dead kernel), and appearance.

Mycotoxin contaminations on the corn were analysed in the Indonesian Research Center for Veterinary Science (IRCVS), Bogor, Indonesia. The mycotoxins analysed included AFL, FUM, DON, OCRA, T2 toxin, and ZEN. AFL was analysed using the kit developed by the IRCVS (Rachmawati 2005), while other mycotoxins were analysed using kits purchased from the Romer Lab., Pty. Ltd. Singapore. These kits were based on a direct competitive ELISA using polyclonal antibodies specific for each toxin. Analysis results were measured with ELISA reader. Due to a practical consideration, ZEN and T2 toxin were analysed to only 90 and 270 samples, respectively since there was indication that only trace levels of both ZEN and T2 toxin were detected. Simple statistical analyses to measure average, maximum and standard deviation were performed for each type of mycotoxins.

RESULTS AND DISCUSSION

Mycotoxin Level on Corn Samples Originated from Different Countries

From the total of 356 corn samples analysed, most of them (92%) originated from Indonesia, others were imported from the USA (6%) and Argentina (2%). It means that most corn sold to feed mills and used as animal feed ingredient was produced locally. When local supply is limited, feed mills imported corn from other countries such as USA and Argentina.

Average AFL contamination level on the corn samples originated from Indonesia was almost 7 times higher (58.8 μg kg^{-1}) than those imported from USA (8.8 μg kg^{-1}) and Argentina (8.5 μg kg^{-1}) (Table 1). This contamination level is above the Indonesian National Standard for corn (SNI 01-4483-1998: 50 μg kg^{-1}). Number of corn samples from Indonesia contaminated with AFL above the SNI level was 47.0% and only 22.7% was contaminated with AFL < 20 μg kg^{-1}.

FUM contamination was the highest amongst all mycotoxins detected in the corn samples from Indonesia (1193 μg kg^{-1}) and USA (1504 μg kg^{-1}), but almost half in the samples from Argentina (633 μg kg^{-1}). Although FUM level seems very high (1193 μg kg^{-1} = 1.2 mg kg^{-1}), the level of contamination is still lower than FDA recommended level, i.e. 5-100 mg kg^{-1} (Carlson 2003). However, awareness should be taken as FUM level can be as high as 6100 μg kg^{-1}.

Table 1. Mycotoxin level on corn samples originated from different countries.

Type of mycotoxins		Mycotoxin level (µg kg^{-1})		
		Indonesia	USA	Argentina
Aflatoxin	Average	58.8	8.8	8.5
	Std	53.2	15.8	10.1
	Max	236.0	58.8	26.3
Fumonisin	Average	1193.0	1504.0	633.0
	Std	1159.0	1406.0	880.0
	Max	61000	4900.0	2000.0
Ochratoxin	Average	2.4	0.7	tr
	Std	9.0	1.4	
	Max	59.9	5.7	
Deoxynivalenol	Average	324.0	327.0	150.0
	Std	561.0	331.0	122.0
	Max	3800.0	1500.0	300.0
Zearalenon	Average	21.7	tr	*
	Std	61.8		
	Max	369.0		
T2	Average	5.7	2.3	26.2
	Std	61.8	9.6	42.8
	Max	1200.0	39.4	100.0

tr = trace, for FUM = < 100 µg kg^{-1}, OCRA = <19 µg kg^{-1}, DON = < 200 µg kg^{-1}, ZEN = < 20 µg kg^{-1}, T_2 = < 35 µg kg^{-1}.
* = not analysed.
Std = standard deviation; Max = maximum value.

Several studies on fungal contamination on corn in several countries such as Iran, Brazil, and Vietnam showed that *Aspergillus* species (produced AFL) was the most common contaminant, followed with *Fusarium* species (produced FUM, DON or ZEN) (Pozzi *et al.* 1995; Kosravi *et al.* 2008; Trung *et al.* 2008).

In this study, mycotoxin levels in the corn samples imported from USA and Argentina were lower compared with those originated from Indonesia. Another study by Broggi *et al*. (2007) found that corn samples from Argentina had very low AFL contamination (2 µg kg^{-1}). These may indicate that imported corn has been processed with better postharvest handling, especially using more advanced machineries for grain harvesting and processing. In addition, in both USA and Argentina, corn was grown in less favourable weather conditions for fungal development compared with that planted in the humid tropical condition of Indonesia. Furthermore, the use of genetically engineering Bt corn resistant to insect attack in most US farms significantly decreased mycotoxin contamination (Chen *et al.* 2004; Rossi *et al*. 2005) because insect attack caused open wounds on kernels which facilitated fungus infection (Hawk 2004).

Mycotoxin Level on Corn Samples Originated from Five Provinces in Indonesia

Within Indonesia, most of corn samples were originated from South Sulawesi (130 samples), followed by Lampung (87 samples), Central and East Java (49 samples each), and North Sumatra (7 samples) (Table 2). Corn samples from North Sumatra and Lampung were affected with less AFL, i.e. < 20 and < 50 µg kg^{-1}, respectively, than those from East Java, Central Java and South Sulawesi (64-87 µg kg^{-1}). FUM level was the highest in the corn samples from North Sumatra (average 1743 µg kg^{-1}), followed by those from South Sulawesi and East Java with the average content of above 1000 µg kg^{-1}. Corn samples originated from Central and East Java had the highest content of DON. Trace levels of ZEN and T2 toxin and very little OCRA (0.2 µg kg^{-1}) were detected on corn came from Lampung. Earlier study showed that quality of corn from Lampung was relatively poorer than that from East Java (Tangendjaja and Rachmawati 2006). However, due to postharvest improvement in Lampung, i.e. the use of oven drying, its quality had been improved as shown from the present study where mycotoxin contamination level on corn from Lampung was below the National Standardization Agency of Indonesia, i.e. < 50 µg kg^{-1}, better than those from East Java, Central Java or South Sulawesi.

Effect of Corn Varieties on Mycotoxin Level

From the data collected, most of corn planted in Indonesia was local varieties although hybrid or mix varieties were also grown. The average AFL contamination level on the local varieties was slightly lower than that on the hybrid or mixed varieties. Nevertheless, the mixed varieties were contaminated with higher level of mycotoxins, especially FUM, OCRA and DON, compared with the local and hybrid ones (Table 3). This study indicated that corn variety was not significantly related with the mycotoxin contamination. The result is in contrast with the report that some types of corn are resistant to fungus, meaning that some varieties of corn may have less AFL contamination (Betran *et al*. 2002; Chen *et al.* 2004).

Effect of Harvest Seasons on Mycotoxin Level

Most (68%) of corn samples from Indonesia were harvested during the wet season and the other 32% in the dry season. Corn samples harvested during the

Table 2. Mycotoxin levels on corn originated from five provinces in Indonesia.

Type of mycotoxins		Mycotoxin level (µg kg^{-1})				
		North Sumatera	Lampung	East Java	Central Java	South Sulawesi
Aflatoxin	Average	19.1	26.0	64.0	87.4	72.6
	Std	27.3	34.4	49.6	57.1	53.1
	Max	79.3	164	201	236	197.0
Fumonisin	Average	1743.0	902.0	1224.0	863.0	1476.0
	Std	2010.0	821.0	1139.0	845.0	1337.0
	Max	6100.0	3400.0	4500.0	4200.0	5900.0
Ochratoxin	Average	1.1	0.2	2.3	8.9	1.2
	Std	1.0	0.7	9.9	16.1	5.5
	Max	2.1	3.3	59.9	58.5	43.5
Deoxynivalenol	Average	386.0	176.0	500.0	788.0	183.0
	Std	273.0	165.0	776.0	994.0	234.0
	Max	900.0	800.0	3000.0	3800.0	1100.0
Zearalenon	Average	56.3	tr	10.8	*	33.2
	Std	100.0		24.1		74.8
	Max	272.0		53.9		369.0
T2	Average	*	tr	tr	24.5	2.0
	Std				171.0	9.3
	Max				1200.0	50.8

tr = trace, for FUM = < 100 µg kg^{-1}, OCRA = <19 µg kg^{-1}, DON = < 200 µg kg^{-1}, ZEN = <20 µg kg^{-1}, T_2 = < 35 µg kg^{-1}.
* = not analysed.
Std = standard deviation; Max = maximum value.

Table 3. Mycotoxin levels on corn of different varieties.

Type of mycotoxins		Mycotoxin level (µg kg^{-1})		
		Local	Hybrid	Mixed
Aflatoxin	Average	64.1	77.1	89.6
	Std	53.0	57.3	57.3
	Max	197.0	236.0	175.0
Fumonisin	Average	1171.0	1075.0	1367.0
	Std	1146.0	956.0	1248.0
	Max	6100.0	4500.0	4200.0
Ochratoxin	Average	0.9	3.6	18.9
	Std	3.7	11.0	23.4
	Max	34.1	59.9	56.4
Deoxynivalenol	Average	182.0	705.0	984.0
	Std	223.0	893.0	1186.0
	Max	1100.0	3200.0	3800.0
Zearalenon	Average	16.6	70.5	tr
	Std	51.2	148.0	
	Max	272.0	369.0	
T2	Average	tr	18.2	tr
	Std		148.0	
	Max		1200.0	

tr = trace, for FUM = < 100 µg kg^{-1}, OCRA = <19 µg kg^{-1}, DON = < 200 µg kg^{-1}, ZEN = <20 µg kg^{-1}, T_2 = < 35 µg kg^{-1}.
Std = standard deviation; Max = maximum value.

wet season had higher level of AFL, OCRA, and DON than those harvested in the dry season (Table 4). As far as for AFL, this result was in agreement with previous study reported by Widiastuti (2006) that AFL contamination level on the corn harvested in wet season (March and April) was higher than that harvested in the dry season. The problem is farmers do not have facility to dry the corn, therefore, the moist corn is proned to fungal infection during storage.

Effect of Drying Techniques on Mycotoxin Level

Based on the background information accompanied to each sample, it can be concluded that most of the corn samples were dried using oven drying. As the result, mycotoxin contamination was lower than using sun drying, except for FUM (Table 5). Oven drying reduced AFL contamination on corn since almost 50% of the total corn samples harvested in the dry season and 30% in the wet season had very low AFL level. There were only about 5% of oven dried corn samples contaminated with AFL above the SNI level (100-200 µg kg^{-1}). Using an oven drying, corn was dried faster, therefore, had less opportunity for fungal contaminants such as *Aspergillus* spp. to grow on the kernels

Table 4. Mycotoxin levels on corn harvested at different seasons.

Type of mycotoxins		Mycotoxin level (µg kg^{-1})		
		Wet season	Dry season	Unidentified season
Aflatoxin	Average	66.4	36.5	131
	Std	55.2	40.9	65.6
	Max	236.0	202.0	177.0
Fumonisin	Average	1139.0	1445.0	700.0
	Std	1030.0	1430.0	566.0
	Max	4900.0	6100.0	1100.0
Ochratoxin	Average	2.8	1.2	18.3
	Std	9.7	5.3	25.9
	Max	59.9	43.5	36.6
Deoxynivalenol	Average	409.0	217.0	100.0
	Std	671.0	246.0	141.0
	Max	3800	1300.0	200.0
Zearalenon	Average	5.0	46.3	
	Std	20.8	89.4	
	Max	135.0	369.0	
T2	Average	0.0	20.5	
	Std		147.0	
	Max		1200.0	

tr = trace, for FUM = < 100 µg kg^{-1}, OCRA = <19 µg kg^{-1}, DON = < 200 µg kg^{-1}, ZEN = <20 µg kg^{-1}, T_2 = < 35 µg kg^{-1}.
Std = standard deviation; Max = maximum value.

Table 5. Mycotoxin levels on corn dried with different techniques.

Type of mycotoxins		Mycotoxin level (µg kg^{-1})		
		Oven drying	Sun drying	Mixed drying
Aflatoxin	Average	52.4	79.1	187.0
	Std	49.4	61.9	31.8
	Max	197.0	236.0	209.0
Fumonisin	Average	1263.0	1091.0	550.0
	Std	1191.0	1181.0	354.0
	Max	5900.0	6100.0	800.0
Ochratoxin	Average	1.4	5.9	7.4
	Std	7.0	13.3	10.5
	Max	59.9	58.5	14.8
Deoxynivalenol	Average	262.0	682.0	800.0
	Std	426.0	923.0	849.0
	Max	3000.0	3800.0	1400.0
Zearalenon	Average	17.5	56.3	*
	Std	55.6	100.0	
	Max	369.0	272.0	
T2	Average	0.9	25.0	tr
	Std	6.4	173.0	
	Max	50.8	1200.0	

tr = trace, for FUM = < 100 µg kg^{-1}, OCRA = <19 µg kg^{-1}, DON = < 200 µg kg^{-1}, ZEN = <20 µg kg^{-1}, T_2 = < 35 µg kg^{-1}.
Std = standard deviation; Max = maximum value.
* = no sample.

than those dried using sun drying (Noomhorm and Cardona 1989).

Corn which was dried using mixed drying, in which a combination of sun drying and oven drying, produced higher level of mycotoxins. This probably related with the initial process of sun drying on the harvested corn which does not completely reduce water from the kernels. Prolonged storage of corn with high moisture content prior to oven drying might result in fungal infestation resulting in increased mycotoxin production. However, based on the information collected, mixed drying was not commonly practiced as the corn samples dried using this techniques were very few.

Effect of Moisture Contents on Mycotoxin Level

Only 101 out of 356 total samples (28.37%) were accompanied with moisture content data. Among these samples, 31 samples had 14% moisture content and only one sample showed a peculiar one since it had a very high moisture content (18-20%) (Table 6). Mycotoxin levels on the corn samples having very low moisture content (< 14%) were low, for examples AFL was < 50 µg kg^{-1}, DON was 603 µg kg^{-1}, and only traces of T2. There was a trend of decrease in AFL and OCRA contamination on corn having less moisture content.

Most of corn samples had moisture content above the Indonesian National Standard requirement (14%). However, some feed mills still accepted the corn with moisture content of 16-18% because they have corn drying machine that is able to reduce the moisture content.

It is clear in this study that moisture is one of the most important factors affecting the level of mycotoxin contamination. Since moisture content of corn is closely related with the drying process, application of postharvest technology such as oven drying must be done as fast as possible and then be kept at low moisture content to prevent mycotoxin contamination (Noomhorm and Cardona 1989; FAO 2001).

Mycotoxin Level Based on Different Grades of Corn

The study revealed that feed mills graded most of corn samples into the KW II (77% from total sample) and only 8% graded as KW I and 15% as KW III. The

Table 6. Mycotoxin levels on corn with different moisture contents.

Type of mycotoxins		Mycotoxin level (µg kg^{-1})			
		18-20%	16-18%	14-16%	< 14%
Aflatoxin	Average	74.4	81.3	69.8	38.9
	Std	0.0	82.5	50.9	42.1
	Max	74.4	236.0	201.0	164.0
Fumonisin	Average	3300.0	1540.0	1182.0	1687.0
	Std	0.0	1447.0	1069.0	1391.0
	Max	3300.0	6100.0	4200.0	4900.0
Ochratoxin	Average	tr	6.12	5.92	3.77
	Std		12.46	15.10	12.01
	Max		52.0	59.9	56.4
Deoxynivalenol	Average	1200.0	761.0	740.0	603.0
	Std	0.0	781.0	1001.0	711.0
	Max	1200.0	2200.0	3800.0	2700.0
Zearalenon	Average		56.3	4.84	6.74
	Std		100.0	12.8	19.1
	Max		272.0	33.9	53.9
T2	Average	tr	92.3	tr	tr
	Std		333.0		
	Max		1200.0		

tr = trace, for FUM = < 100 µg kg^{-1}, OCRA = <19 µg kg^{-1}, DON = < 200 µg kg^{-1}, ZEN = <20 µg kg^{-1}, T_2 = < 35 µg kg^{-1}.
Std = standard deviation; Max = maximum value.

best corn quality (KW I) contaminated with higher mycotoxin levels followed with the KW II and KW III (Table 7).

Although mycotoxin is an important factor in determining corn quality, there is no standard corn grading system in Indonesia. The Indonesian National Standard of corn (SNI 01-4483-1998) stated only the maximum levels of mycotoxins such as AFL 50 µg kg^{-1} and OCRA 5 µg kg^{-1} (National Standardization Agency of Indonesia 1998). This national standard is hardly applied to many feed mills, therefore, they developed their own corn grading system based on the US corn grading system which measured broken corn, foreign materials, and damaged kernels due to fungi or physical damage. The AFL level is not a grading factor in the US system, but some Indonesian feed mills measured the contamination level of AFL using "a UV light" for the incoming corn. Besides AFL, moisture has been used as one of the grading factors for corn although US system does not consider it in its grading system.

The present study indicated that the grading system in feed mills was not related to the level of mycotoxins. Grade III (KW III) had slightly lower mycotoxin level compared with grade II (KW II) or grade I (KW I). This suggests that the corn grading system made by some feed mills which based on the physical appearances cannot be used to estimate the mycotoxin level in the corn samples. Therefore, if mycotoxin is one of the important factors for corn quality, it should be aware when selecting corn based on the feed mill's grading system.

In the past few years, several laboratories in the Asian region analyzed and reported results of mycotoxin assays (Chin *et al*. 2007). For example, the Optimal Laboratory in the Philippines reported as high as 103 µg kg^{-1} of AFL contaminated the corn and 650 µg kg^{-1} in the corn barn, while the Romer Laboratory of Singapore which analyzed corn samples originated from Asia and Oceania feed mills from 2005 to 2006 showed that corn samples were contaminated by AFL at the level of < 80 µg kg^{-1}, OCRA 12 µg kg^{-1}, ZEN < 500 µg kg^{-1}, FUM 1.7 µg kg^{-1}, DON < 1 µg kg^{-1}, and T2 toxin was undetected. Recent result reported by Alltech Company showed that corn samples sent by some feed mills from Asian region were contaminated by AFL of < 30 µg kg^{-1}, OCRA < 10 µg kg^{-1}, ZEN < 100 µg kg^{-1}, FUM 1.2 µg kg^{-1}, DON < 1 µg kg^{-1} and T2 toxin < 25 µg kg^{-1} (Chen 2007, unpubl.).

The US Food and Drug Administration (FDA) and Canadian Government recommended the maximum level (depending on the species and physiological state

Table 7. Mycotoxin level in different grades of corn samples based on the feed mill grading classification.

Type of mycotoxins		Mycotoxin levels (μg kg^{-1})			
		KW I	KW II	KW III	Not identified
Aflatoxin	Average	81.6	55.3	47.4	107.0
	Std	62.5	52.1	49.4	145.0
	Max	201.0	209.0	236.1	209.0
Fumonisin	Average	1504.0	1282.0	925.0	550.0
	Std	1171.0	1242.0	921.0	354.0
	Max	4200.0	6100.0	4500.0	800.0
Ochratoxin	Average	12.7	1.7	0.9	25.2
	Std	20.2	7.3	3.8	14.7
	Max	58.5	59.9	26.1	35.6
Doexynivalenol	Average	1056.0	260.0	230.0	700.0
	Std	1114.0	438.0	390.0	990.0
	Max	3800.0	3000.0	2000.0	1400.0
Zearalenon	Average	19.5	25.2	0.0	*
	Std	30.1	68.4	0.0	
	Max	81.1	369.0	0.0	
T2	Average	0.0	0.9	0.0	0.0
	Std	0.0	6.4	0.0	0.0
	Max	0.0	50.8	0.0	0.0

tr = trace, for FUM = < 100 μg kg^{-1}, OCRA = <19 μg kg^{-1}, DON = < 200 μg kg^{-1}, ZEN = < 20 μg kg^{-1}, T_2 = < 35 μg kg^{-1}.
Std = standard deviation; Max = maximum value.
* = no sample.

of animal) as follows: AFL 20-200 μg kg^{-1}, OCRA 250-2000 μg kg^{-1}, ZEN 1-200 mg kg^{-1}, FUM 5-100 mg kg^{-1}, DON 1-10 mg kg^{-1}, and T2 toxin 1 mg kg^{-1} (Carlson 2003; Hawk 2004). Based on these data, the most important type of mycotoxins in Indonesian corn would be AFL as the average level observed was 58.8 μg kg^{-1}, ranged from 0 to 236 μg kg^{-1}, and AFL is the most toxic contaminant to animal. The Indonesian National Standard determined that the AFL level in corn and in broiler or layer chicken feed should not be more than 50 μg kg^{-1} (Rachmawati 2005), while almost 50% of corn samples collected in Indonesia have AFL level of more than 50 μg kg^{-1}. Other type of mycotoxin concern would be DON, but it was found only in few batches of corn. FUM level was lower than the FDA tolerance level, however, the maximum value of FUM was quite high. Therefore, it is suggested that the Indonesian National Standard for corn for animal feed should be revised. Tolerance level for other mycotoxins for different animals should be included. The level can be adopted from FDA or Canadian recommendations. It is also recommended to include grading system of corn into the Indonesian National Standard as the quality of corn is not only determined by mycotoxin level. Corn damaged should also be included in the grading system since damaged corn will expose higher possibility of fungal infection, hence, mycotoxin contamination.

CONCLUSION

Several mycotoxins included AFL, OCRA, ZEN, FUM, DON, and T2 toxin have been detected in corn used for animal feed in Indonesia. Corn imported from the USA and Argentina contaminated with less mycotoxins level than the local ones.

The levels of mycotoxin contamination in the local corn varied depending on province of origins, harvesting seasons, and postharvest drying methods. The least contaminated corn samples were originated from North Sumatra and Lampung with the AFL levels were < 20 μg kg^{-1} and < 50 μg kg^{-1}, respectively, than those from Central Java and South Sulawesi (64-87 μg kg^{-1}).

AFL is the most common mycotoxin found in the local corn; 47% of the local corn samples contained AFL above the Indonesian National Standard (> 50 μg kg^{-1}).

All necessary means to prevent mycotoxin contamination on corn for animal feed must be applied such as improvement of postharvest drying processes and storage, as well as preharvest control methods.

ACKNOWLEDGEMENT

The authors wish to thank US Grains Council for supporting this study.

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