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THE OCCURRENCE OF INSECTS AND FUNGI, AND AFLATOXIN B_1 CONTAMINATION OF STORED SORGHUM IN DEMAK AND WONOGIRI REGENCIES, CENTRAL JAVA

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ABSTRACT

The objectives of this study were to collect informations on the method of postharvest handling of sorghum and to investigate the moisture contents, insects infestation, fungal infection, and aflatoxin B_1 contents of stored sorghum grains collected from various stages of the delivery chain in Demak and Wonogiri regencies, Central Java. In Demak regency sorghum cultivation was monoculture, variety cultivated was UPC-S1. In Wonogiri regency sorghum cultivation was intercropping with secondary crop and cassava. Sorghum varieties cultivated were Kawali, Numbu, ZH30, Mandau and Hibrida hybrids. There was a difference between the method of postharvest handling of sorghum at farmer and collector levels in Demak and Wonogiri regencies. In general the method of postharvest handling of sorghum in Demak regency was more appropriate and more advance compared to that in Wonogiri regency. The moisture contents of sorghum at farmer as well as at collector level in Demak regency (13.0%) and Wonogiri regency (12.9%) were still lower that that of normal (safe) moisture content of sorghum. The number of insect species associated with sorghum in various distribution level in Demak and Wonogiri regencies was 10 and 17 species, respectively. The dominant insects species were *Sitophilus zeamais* and *Tribolium castaneum*. The number of fungal species found in sorghum at various distribution level in Demak and Wonogiri regencies was 23 species, respectively. In general, the dominant fungal species were *Aspergillus flavus*, *Fusarium semitectum* and *F. verticillioides*. In Demak regency aflatoxin B_1 contents of sorghum at farmer and collector levels were 22.50 and 15.45 ppb, respectively, while in Wonogiri regency 2.27 and 10.28 ppb, respectively.

Key words: insects, fungi, aflatoxin B_1, stored sorghum, Demak and Wonogiri regencies, Central Java

INTRODUCTION

As a foodstuff, sorghum (*Sorghum bicolor* (L) Moench) is the fifth most important cereal after rice, wheat, maize and barley in the world. In many countries, sorghum is used as food and feedstuff, industrial raw materials such as for ethanol, beer, wine, syrup, glue, paint and modification of starch. Compared to other foodcrops, sorghum can adapt to broad agroecology, resistant to dryness, high productivity, and more resistant to pests and diseases. Apart from that, sorghum has nutritional content that is almost the same with milled rice as well as maize, consequently sorghum is good to be consumed either as alternative food or feedstuff. According to Suarni (2001) protein contents in sorghum, milled rice and maize were 10.11, 9.28 and 11.02%, respectively; their lipid contents were 3.65, 1.88 and 5.42%, respectively; their carbohydrate contents were 80.42, 86.45 and 79.95%, respectively. Although in Indonesia the production of sorghum is still low, it is potential to be cultivated and developed, especially in marginal and dry areas (BP2APTP 2008). To anticipate food crisis caused by global warming, it is important to cultivate and to develop sorghum in Indonesia.

During storage grains could be infested by insects, microorganisms, mites and rats. Insects are considered as the most significant cause of losses. Among micro-organisms, fungi are the most important cause of deterioration of stored grains. The role of insects on fungal infection cannot be disregarded. Aside from injuring the grains, insects also serve as carriers of fungi. Furthermore, the metabolic activities of insects produce enough heat and moisture (especially during long-term storage) which stimulate fungal growth. Fungal infection in grains can cause discolouration, decrease in physical quality and nutritional contents, and mycotoxin contamination (Sauer *et al.* 1992). Aflatoxins are the most dangerous mycotoxins, they can cause liver cancer in human and animal. There are four kinds of aflatoxins found in food and feedstuff, i.e. aflatoxins B_1, B_2, G_1 and G_2. The most toxic of the four kinds of aflatoxins is aflatoxin B_1 (AFB1).

The objectives of this study were :

- To obtain informations on postharvest handling methods of sorghum
- To investigate the degree of insect and fungal attacks, and AFB1 contamination of stored sorghum collected from various stages of the delivery chain in Demak and Wonogiri regencies, Central Java. The moisture contents of sorghum were also determined, because moisture content is the important environmental factor for the development of insects and fungi.

MATERIALS AND METHODS

Time and location of surveys

In Demak regency, surveys and sampling of sorghum were conducted in July and August 2010, while for Wonogiri regency in April and July 2010. In Demak regency (Demak and Mijen subdistricts), surveys and sampling of sorghum were conducted at farmer and collector levels and a traditional market in the city of Demak. In

Wonogiri regency (Purwantoro, Eromoko and Pracimantoro subdistricts), surveys and sampling of sorghum were conducted at farmer level and collector level in Pracimantoro subdistrict.

In Demak regency (Demak and Mijen subdistricts), surveys and sampling of sorghum were conducted in July and August 2010 at farmer and collector levels and a traditional market in the city of Demak. In Wonogiri regency (Purwantoro, Eromoko and Pracimantoro subdistricts) surveys and sampling of sorghum were conducted during April and July 2010 at farmer level and at collector level in Pracimantoro subdistrict.

Interviews using questionnaires

Interviews were conducted during the surveys and sampling to collect information on postharvest handling of sorghum at farmer and collector levels. Number of respondents from each level distribution chain in each regency could be different depending on the field conditions during the surveys. The questionnaires contained among others questions on postharvest handling carried out by farmers and collectors and problems encountered by them.

Sampling and method to obtain working samples

The number of sorghum samples collected from **Demak** regency was 46 with the breakdown as follows : farmers (34), collectors (9) and retailers in traditional market (3). Sorghum samples collected from **Wonogiri** regency was 38 consisting of samples from farmers (23) and collectors (15) (Table 1). The samples were collected from places where the respondents stored sorghum at the time of the interview. The number of sorghum samples in each level distribution chain was determined based on the existence of sorghum at the time of interviews.

As much as 2 kg of each sample was collected randomly from each respondent, it was then placed in a clean plastic bag. Insects from each sample were separated using graded sieves, then they were preserved in vials containing ethanol 70%.

Table 1. Level of distribution chain, subdistrict origin of the sample, and the number of sorghum samples at various stages of the delivery chain in Demak and Wonogiri regenciess

Regency	Level of distribution chain	Subdistrict origin of the sample	Number of samples
Demak	Farmer	Demak and Mijen	34
	Collector	Demak and Mijen	9
	Retailer at traditional market	Demak	3
Wonogiri	Farmer	Eromoko	13
		Pracimantoro	8
		Purwantoro	2
	Collector	Eromoko	1
		Pracimantoro	14
	Total		84

Each sample was then divided three times using a sample box divider to obtain eight working samples for the determination of the percentage of sorghum grains infected by each fungal species, AFB1 content, and a reserve sample.

Determination of moisture content, insect infestation, fungal infection, and aflatoxin B_1 content

Moisture contents of sorghum grains were determined right after sample collections using Moisture Meter DELMHORST Model G-7. Two replicates were used from each sample. Insect species was identified using the publication of Haines (1991) as the main reference. The degree of insect species infestation in each sample was determined based on its number per kg of sorghum. Fungi were isolated using a plating method on Dichloran 18% Glycerol Agar (DG18) (Hocking and Pitt 1980). Two hundred sorghum grains were used from each sample. Fungal species was identified using the publication of Pitt and Hocking (2009) as the main reference. In this study only AFB1 content was determined, because it is the most dangerous aflatoxin compared to the other three kinds of aflatoxins (AFB2, AFG1 and AFG2). AFB1 content was determined according to Thin Layer Chromatography method (AOAC 2005). Two replicates were used from each sample.

RESULTS AND DISCUSSION

Interviews using questionnaires

Interviews using questionnaires in Demak regency

The results of interviews with farmers and collectors in Demak regency are presented in Tables 2 and 3. At **farmer** level the method of sorghum cultivation was monoculture. The variety of sorghum cultivated was UPC-S1. The range of land area for sorghum cultivation was 0.25-2 ha. Sorghum was harvested three months after planting. The method of harvesting was by cutting its panicle using a sickle. The panicles of sorghum were sun-dried on tarpaulin or cement floor. In general sorghum grains were separated from panicles using a paddy thresher. Most of sorghum was sold to collectors, although a small part was used as seeds to be replanted. Sorghum was packed in polypropylene bag. In general storage duration of sorghum collected as samples was between 0-7 days. The condition of storage was dirty. No insects and fungi were found in sorghum samples, because the duration of storage was relatively short.

The variety of sorghum bought by **collector** was UPC-S1. Sorghum was bought from farmers, collectors at village level, or from farmers and collectors at village/subdistrict levels. If they were still not dry enough, further sun-drying was conducted on cement floor. The grains were separated from panicles using a paddy thresher and packed in polypropylene bags. Sorghum samples have been stored for 0-7 days (66% of respondents) and 10-15 days (34% of respondents). The condition of storage (warehouse) was appropiate (78% of respondents) and not so appropriate (22% of respondents). Sorghum was sold to big traders in Wonosari (44% of

Table 2. Results of interviews with **farmers** on postharvest handling of sorghum in Demak and Wonogiri regencies

No.	Subject	% respondent*)	
		Demak	Wonogiri
1.	Methods of sorghum cultivation:		
	a. Intercrop with secondary crop and cassava	0	57
	b. Intercrop with secondary crop and cassava, and the use of fertilizer	0	43
	c. Monoculture	100	0
2.	Variety of sorghum cultivated:		
	a. Kawali, Numbu and ZH 30 (white colour of grains)	0	39
	b. Mandau and Hibrida (red and reddish brown of grains)	0	61
	c. UPC-S1	100	0
3.	Land area:		
	a. 0.25 ha	29	48
	b. 0.25 ha	44	13
	c. 1.00 ha	15	39
	d. 1.50 ha	3	0
	e. 2.00 ha	9	0
4.	Harvesting time (days after planting):		
	a. < 90 days	0	0
	b. 90 days	100	100
5.	Method of harvesting:		
	a. By cutting the stalk of panicle using a sickle	100	100
	b. Other method	0	0
6.	Method of drying (in the form of panicle):		
	a. Sun-drying on tarpaulin or cement floor	100	83
	b. Hanging on racks	0	13
	c. Inserted on wood located outside of the wall of the house made from zinc	0	4
7.	Method of threshing:		
	a. Manually	0	4
	b. Beaten using a coconut leaf	0	4
	c. Beaten using a piece of wood/bamboo	9	74
	d. Beaten using a hammer	0	9
	e. Beaten using a piece of stalk of tree	0	9
	f. Using a paddy thresher	91	0
8.	Harvested sorghum were:		
	a. Sold to collector	0	30
	b. Sold to collector and seed seller	100	57
	c. Usedby farmers as cattle/chicken feed	0	5
	d. Used by farmers as seeds and cattle feed	0	4
	e. b,d and consumed by farmers (by steaming)	0	4
9.	Method of storage:		
	a. Stored in plastic (polypropylene) bag	100	87
	b. Spread out on tarpaulin	0	13
10.	Duration of storage of sorghum collected as sample:		
	a. 0 -7 days	94	9
	b. 21 days	0	18
	c. 1 month	0	64
	d. 2 months	3	9
	e. 3 months	3	0
11.	Sanitation of storage:		
	a. Unappropriate (dirty)	100	100
	b. Appropriate	0	0

Table 2. Continued

No.	Subject	% respondent*)	
		Demak	Wonogiri
12.	Insect pest was found in sorghum during storage:		
	a. Yes	0	9
	b. No	100	91
13.	Based on visual observation, fungi were found in sorghum during storage:		
	a. Yes	0	0
	b. No	100	100

*) Number of respondent in Demak regency : 34
Number of respondent in Wonogiri regency : 23

respondents), big traders in other big cities (Kudus, Solo, Yogyakarta, Demak and Bantul) (34% of respondents), and entrepreneur of oyster mushroom cultivation (22% of respondents).

Interviews using questionnaires in Wonogiri regency

The results of interviews with farmers and collectors in Wonogiri regency are presented in Tables 2 and 3. In this regency, at **farmer** level the method of sorghum cultivation was intercropping with cassava (57% of respondents); intercropping with secondary crop and cassava, and using fertilizer (43% of respondents). The sorghum varieties cultivated were Kawali, Numbu and ZH 30 (ZH-30 is a mutant line from BATAN), the colour of their grains were white (39% of respondents); while for Mandau and Hibrida varieties , the colour of their grains were red and brownish-red, respectively (61% of respondents). The range of land area for sorghum cultivation was 0.25-1 ha. Sorghum was harvested three months after planting, while the method of harvesting was by cutting its panicle using a sickle. In general, the panicles of sorghum were sun-dried on tarpaulin or cement floor. The grains were separated from panicles manually (4% of respondents) or beaten using a coconut leaf (4% of respondents), a stick of wood or bamboo (74% of respondents), a hammer (9% of respondents), and a piece of tree stalk (9% of respondents). Sorghum was sold to collectors (30% of respondents), to collectors and for seeds to be replanted (57% of respondents), for feed (cattle or chicken) (5% of respondents), for seeds and cattle feed (4% of respondents); was sold to collectors, for seeds and consumption by steaming (4% of respondents). Sorghum was packed in polypropylene bag (87% of respondents) and was spread out on tarpaulin (13% of respondents). The storage duration of collected sorghum for samples was 0-2 months. In general, the storage condition was dirty. During storage, insects were found (35% of respondents), while no fungi were found.

The variety of sorghum bought by **collector** was Kawali and Numbu (53% of respondents), Mandau Hibrida varieties (47% of respondents). Sorghum was bought from farmers (65% of respondents), from collectors at village level (12% of respondents), from farmers and collectors at village/subdistricts level (23% of respondents). Panicles of sorghum were bought after sun-dried conducted by farmers (6% of respondents), after sun-dried by farmers in the form of grains (47% of respondents), after sun-dried by collector at village level in the form of panicle or grain

(47% of respondents). If sorghum bought from farmers were not yet properly dried, further sun-drying was carried out on cement floor. Grains were separated from panicles using a paddy thresher and packed in polypropylene bag. The storage duration of sorghum samples was 0-7 days (59% of respondents), 1 month (29% of respondents), and 3 months (12% of respondents). In general, the condition of storage was not so appropriate. Most of sorghum was sold to big traders in Wonosari (71% of respondents).

Table 3. Results of interviews with **collectors** on post-harvest handling of sorghum in Demak and Wonogiri regencies

No.	Subject	% respondent*)	
		Demak	Wonogiri
1.	Variety of sorghum bought:		
	a. Kawali and Numbu (white colour of grains)	0	53
	b. Mandau and Hibrida (red and reddish brown of grains)	0	47
	c. UPC-S1	100	0
2.	Sorghum was bought from:		
	a. Farmers	44	65
	b. From collectors at village level	34	12
	c. From farmers and collectors at village/subdistrict level	22	23
3.	Sorghum was bought:		
	a. After being dried by farmer, in the form of panicle	0	6
	b. After being dried by farmer, in the form of grain	100	47
	c. After being dried by collector at village level, in the form of panicle or grain	0	47
4.	Method of drying of sorghum (not properly dried) bought from farmer :		
	a. Sun-drying on cement floor	100	100
	b. Other method	0	0
5.	Method of threshing :		
	a. Using a paddy threshing	100	100
	b. Other method	0	0
6.	Method of storage:		
	a. Stored in plastic (polypropylene) bag	100	100
	b. Other method	0	0
7.	Duration of storage of sorghum collected as samples:		
	a. 0 – 7 days	66	59
	b. 10 - 15 days	34	0
	c. 1 month	0	29
	d. 3 months	0	12
8.	Conditon of the storage(warehouse):		
	a. Not so appropriate	22	82
	b. Appropriate	78	18
9.	Sorghum was sold to:		
	a. Big traders in Wonosari	44	71
	b. Big trader s in other big cities (Kudus, Solo, Yogyakarta, Demak, and Bantul)	34	24
	c. Entrepreneur of oyster mushroom cultivation	22	6

*) Number of respondent in Demak regency: 9
Number of respondent in Wonogiri regency: 15

Moisture content

The range and mean of moisture contents of sorghum collected from farmers and collectors in Demak and Wonogiri regencies are presented in Table 4. In Demak and Wonogiri regencies the mean moisture contents of sorghum collected from farmers were almost the same with those collected from collectors, i.e. 13.0 and 12.9%, respectively, because in general the storage period of sorghum at farmer level was relatively short. The moisture contents of sorghum collected from retailers at traditional market in Demak regency were lower than those collected from farmers as well as collectors. The moisture contents of grains were always in equilibrium with the relative humidity of the storage. The moisture content will increase with the increase of the relative humidity, consequently fungal growth will be stimulated. In this study the mean moisture contents of sorghum at farmer and collector levels were still lower than the normal moisture content of sorghum. Christensen *et al.* (1990) reported, that the normal moisture content of sorghum with superior and second qualities were 13 and 14%, respectively.

Table 4. Range and mean of moisture content of sorghum collected from farmers, collectors and retailers at traditional market in Demak and Wonogiri regencies

Regency	Level of distribution chain	Range (mean) of moisture content (% wet basis)
Demak	Farmer	10.7 – 14.2 (13.0)
	Collector	12.5 – 13.8 (13.0)
	Retailer at traditional market	12.0 – 12.6 (12.2)
Wonogiri	Farmer	11.9 – 13.8 (12.9)
	Collector	11.9 – 14.2 (12.9)

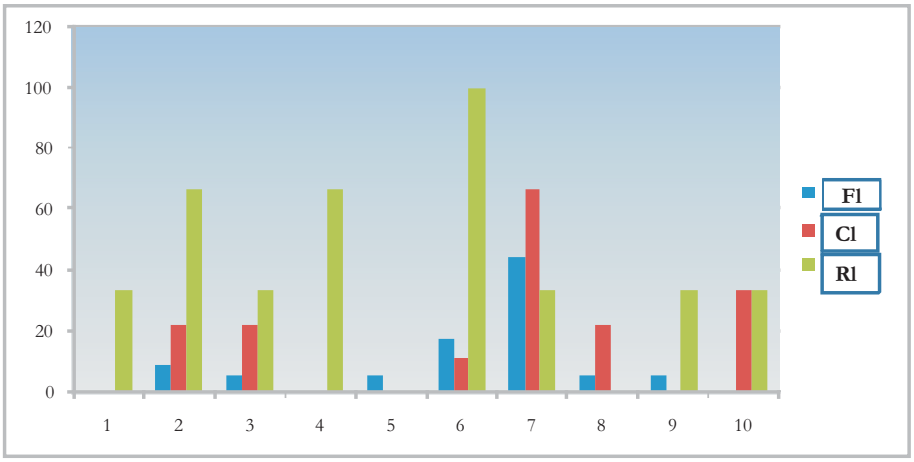
Insect infestation

Insect infestation of sorghum in Demak regency

The total number of insect species associated with sorghum at farmers, collectors and retailers at traditional market was 10 species (Table 5). The insect species belong to order Coleoptera (8 species), order Hymenoptera (1 species) and order Lepidoptera (1 species). Most of the insect species were primary and secondary insect pest, and one species was a parasit insect. *Sitophilus zeamais* and *Tribolium castaneum* were the dominant insects found (Fig. 1). *Oryzaephilus surinamensis* was only found in sorghum at retailer in traditional market and it was the dominant insect.

Insect infestation of sorghum in Wonogiri regency

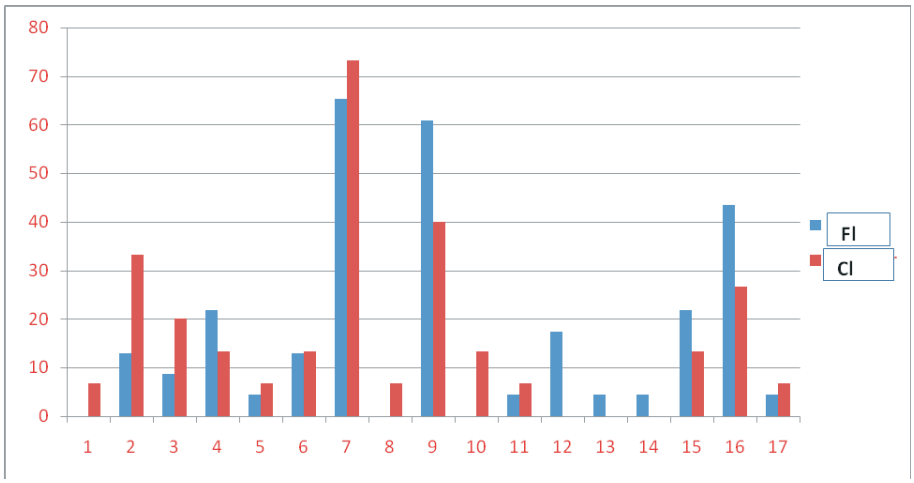
The total number of insect species associated with sorghum at farmer and collector levels was 17 species (Table 6). The insects species belong to order Coleoptera (10 species), order Lepidoptera (3 species), order Hymenoptera (2 species), order Hemiptera (1 species) and order Psocoptera (1 species). Most of the species was primary and secondary insect pests, one species as a predator, and another one was a parasitic insect. S*itophilus zeamais*, *Tribolium castaneum* and *Sitotroga cerealella* were the dominant insect species found (Fig. 2). Another insect found in some sorghum samples was *Anisoptermalus calandrae*, a parasite of *Sitophilus zeamais* egg.



Fl = Farmer level; Cl = Collector level; Rl = Retailer level

1. *Ahasverus advena*
2. *Carpophilus* sp.
3. *Cryptolestes* sp.
4. *Oryzaephilus surinamensis*
5. *Rhyzopertha dominica*
6. *Sitophilus zeamais*
7. *Tribolium castaneum*
8. *Typhaea stercorea*
9. *Anisoptermalus calandrae*
10. *Ephestia cautella*

Figure 1. Percentage of sorghum samples infested by insects at farmer, collector and retailer levels in Demak Regency



Fl = Farmer level; Cl = Collector level

1. *Ahasverus advena*
2. *Araecerus fasciculatus*
3. *Carpohilus* sp.
4. *Cryptolestes* sp.
5. *Dinoderus minutes*
6. *Rhyzopertha dominica*
7. *Sitophilus zeamais*
8. *Thaneroclerus buqueti*
9. *Tribolium castaneum*
10. *Typhaea stercorea*
11. *Xylocoris flavipes*
12. *Anisoptermalus calandrae*
13. Ants
14. *Corcyra cephalonica*
15. *Ephestia cautella*
16. *Sitotroga cerealella*
17. *Liposcelis entomophilus*

Figure 2. Percentage of sorghum samples infested by insects at farmer and collector levels in Wonogiri Regency

Table 5. Species and number of insects in sorghum at farmers, collectors and retailers in traditional market in **Demak** regency

No	Insect	Status	Number (%) of samples infested by insect			Mean average of number insects /kg sample					
						Farmer		Collector		Retailer at traditional market	
			Farmer	Collector	Retailer at traditional market	Larva	Imago	Larva	Imago	Larva	Imago
	COLEOPTERA										
1	*Ahasverus advena* (Waltl)	Pest	0	0	1 (33.33)	0	0	0	0	0	1.47
2	*Carpophilus* sp.	Pest	3 (8.82)	2 (22.22)	2 (66.67)	0-1.83 (0.61)	0-0.53 (0.35)	0	0.52-1.39 (0.96)	0	0.49-3.92 (2.21)
3	*Cryptolestes* sp.	Pest	2 (5.88)	2 (22.22)	1 (33.33)	0	8.65-36.17 (22.41)	0.47-0.54 (0.51)	0	0.49	1.47
4	*Oryzaephilus surinamensis* (Linnaeus)	Pest	0	0	2 (66.67)	0	0	0	0	0	0.98 (0.98)
5	*Rhyzopertha dominica* (Fabrichius)	Pest	2 (5.88)	0	0	0	2.88-7.45 (5.17)	0	0	0	0
6	*Sitophilus zeamais* Motschulsky	Pest	6 (17.65)	1 (11.11)	3 (100.0)	0	0.43-389.36 (111.76)	0	3.23	0	0.49-21.08 (8.50)
7	*Tribolium castaneum* (Herbst)	Pest	15 (44.12)	6 (66.67)	1 (33.33)	0-12.64 (2.40)	0-2.29 (0.32)	0-6.36 (1.69)	0-7.69 (1.36)	0	0.49
8	*Typhaea stercorea* (Linnaeus)	Pest	2 (5.88)	2 (22.22)	0	0	0.51-0.53 (0.52)	0	0.47-1.28 (0.88)	0	0
	HYMENOPTERA										
9	*Anisoptermalus calandrae* (Howard)	Parasite	2 (5.88)	0	1 (33.33)	0	52.13-55.77 (53.95)	0	0	0	0.98
	LEPIDOPTERA										
10	*Ephestia cautella* (Walker)	Pest	0	3 (33.33)	1 (33.33)	0	0	0.45-0.85 (0.59)	0	0.49	0

Table 6. Species and number of insects in sorghum at farmers and collectors in **Wonogiri** regency

No	Insect	Status	Number (%) of samples infested by insect		Mean average of number insects /kg sample			
					Farmer		Collector	
			Farmer	Collector	Larva	Imago	Larva	Imago
	COLEOPTERA							
1	*Ahasverus advena* (Waltl)	Pest	0	1 (6.67)	0	0	0	0.56
2	*Araecerus fasciculatus* (Degeer)	Pest	3 (13.04)	5 (33.33)	0	0.42-0.81 (0.64)	0-10.26 (2.20)	0.5-8.82 (3.29)
3	*Carpophilus* sp.	Pest	2 (8.70)	3 (20.0)	0	0.42-0.81 (0.62)	0	0.39-0.52 (0.44)
4	*Cryptolestes* sp.	Pest	5 (21.74)	2 (13.33)	0-12.08 (2.42)	0-3.14 (1.78)	0-0.63 (0.32)	0-1.01 (0.51)
5	*Dinoderus minutus* (Fabricius)	Pest	1 (4.35)	1 (6.67)	0	0.36	0	0.63
6	*Rhyzopertha dominica* (Fabrichius)	Pest	3 (13.04)	2 (13.33)	0	0.36-2.73 (1.30)	0	0.5-1.25 (0.88)
7	*Sitophilus zeamais* Motschulsky	Pest	15 (65.22)	11 (73.33)	0-25.53 (3.09)	0-34.68 (6.02)	0-3.53 (0.65)	0-26.50 (6.58)
8	*Thaneroclerus buqueti* (Lefevre)	Pest	0	1 (6.67)	0	0	0	0.52
9	*Tribolium castaneum* (Herbst)	Pest	14 (60.87)	6 (40.0)	0-5.12 (1.32)	0-2.05 (0.27)	0-3.75 (1.18)	0-1.0 (0.17)
10	*Typhaea stercorea* (Linnaeus)	Pest	0	2 (13.33)	0	0	0	0.52-0.63 (0.58)
	HEMIPTERA							
11	*Xylocoris flavipes* (Reuter)	Predator	1 (4.35)	1 (6.67)	0	0.36	0	0.50
	HYMENOPTERA							
12	*Anisoptermalus calandrae* (Howard)	Parasite	4 (17.39)	0	0	0.68-2.42 (1.65)	0	0
13	*Semut*	Pest	1 (4.35)	0	0	30.26	0	0
	LEPIDOPTERA							
14	*Corcyra cephalonica* (Stainton)	Pest	1 (4.35)	0	3.15	0	0	0
15	*Ephestia cautella* (Walker)	Pest	5 (21.74)	2 (13.33)	0.42-2.22 (0.98)	0	0.5-0.74 (0.62)	0
16	*Sitotroga cerealella* (Olivier)	Pest	10 (43.48)	4 (26.67)	0-17.14 (2.89)	0-12.38 (2.61)	0	0.63-3.0 (1.31)
	PSOCOPTERA							
17	*Liposcelis entomophilus* (Enderlein)	Pest	1 (4.35)	1 (6.67)	0	0.61	0	0.39

Sitophilus zeamais and *Sitotroga cerealella* were the main insect pest in sorghum, while the other insect species were also the main insect pest of other foodstuff in storage. Most collectors stored more than one kind of commodity, consequently some insect species found in other commodities were also found in sorghum. They were *Araecerus fasciculatus, Thaneroclerus buqueti, Dinoderus minutus, Ephestia cautella* and *Typhaea stercorea* . These insects were generally found in other commodities, such as milled rice, maize and mungbean. The existence of these insects was probably due to migration from one commodity to the other kinds of commodities.

In general the number of insect species found in samples collected from collectors who stored sorghum for a longer period was relatively higher than collected from farmer. Aside from sorghum, they also stored various agricultural commodities. Other insects found in sorghum were *Carpophilus* sp. and *Ahasverus advena*. These insect species were not important, but the existence of these insects gave an indication, that the moisture content of sorghum was high, consequently sorghum could be easily infected by fungi. Based on the result of inventory of insect species associated with stored sorghum at farmer and collector levels, *Sitophilus zeamais* was almost always found in all samples.

As much as eight insect species was generally found in stored sorghum in Taiwan, i.e. *Cryptolestes ferrugineus*, *Latheticca oryzae*, *Liposcelis bostrychophilus*, *Oryzaephilus surinamensis*, *Plodia interpunctella*, *Rhyzopertha dominica*, *Sitophilus zeamais* and *Tribolium castaneum*. The dominant insects were *Cryptolestes ferrugineus* and *R. dominica* (Peng 1998). According to Mendesil *et al.* (2007) in Ethiopia most farmers estimated the loss of stored sorghum caused by insect was up to 50%. Insect infestation in sorghum was due to high temperature and unappropriate sanitation of the storage.

Fungal infection

Fungal infection of sorghum in Demak regency

Percentage of sorghum grain infected by fungi in Demak regency is presented in Table 7.

Twenty three fungal species were isolated from sorghum collected from **farmer**, i.e. *Aspergillus candidus*, *A. flavus*, *A. niger*, *A. tamarii*, *A. wentii*, *Cladosporium cladosporioides*, *Colletotrichum* sp., *Curvularia lunata*, *C. pallescens*, *Endomyces fibuliger*, *Eurotium chevalieri*, *E. repens*, *E. rubrum*, *Fusarium proliferatum*, *F. semitectum*, *F. vercillioides*, *Lasiodiplodia theobromae*, *Penicillium citrinum*, *Pestalotiopsis guepinii*, isolates 3, 7, 8 and 10. Eight out of 23 fungal species belong to field fungi, i.e. *Cladosporium cladosporioides*, *Curvularia lunata*, *C. pallescens*, *Fusarium proliferatum*, *F. semitectum*, *F. vercillioides*, *Lasiodiplodia theobromae*, and *Pestalotiopsis guepinii*. The existence of these fungi was probably due to optimum temperature or relative humidity for fungal growth before or after harvest.

Twenty fungal species were isolated from sorghum collected from **collector**, i.e. *A. flavus*, *A. niger*, *A. tamarii*, *A. wentii*, *Colletotrichum* sp., *Curvularia lunata*, *C. pallescens*, *Endomyces fibuliger*, *Eurotium chevalieri*, *E. repens, E. rubrum*, *F. proliferatum*, *F. semitectum*, *F. vercillioides*, *Lasiodiplodia theobromae*, *Penicillium citrinum*, *Pestalotiopsis guepinii*, isolates 3, 8 and 10. Field fungi were also still found in sorghum collected from collectors, because at farmer level sorghum was stored in a short period. It was also assumed, that the condition of storage was suitable for fungal growth.

Table 7. Fungal infection in sorghum collected from farmers, collectors and retailers at traditional market in **Demak** regency

No	Fungi	Number (%) of samples infected by fungi			Range (mean) percentage of sorghum infected by fungi in infected samples		
		Farmer	Collector	Retailer at traditional market	Farmer	Collector	Retailer at traditional market
1	*Aspergillus candidus*	2 (5.88)	0 (0.00)	1 (33.33)	1.0-2.5 (1.75)	0	1.50
2	*A. flavus*	30(88.24)	9 (100.00)	3 (100.00)	0.5-100.0 (71.7)	2.0-99.5 (74.28)	13.5-87.5 (61.50)
3	*A. niger*	26 (76.47)	7 (77.78)	3 (100.00)	0.5-52.5 (6.35)	1.0-43.0 (14.29)	0.5-3.5 (2.00)
4	*A. tamarii*	17 (50.00)	7 (77.78)	1 (33.33)	0.5-46.0 (7.21)	1.0-9.0 (3.50)	1.5
5	*A. wentii*	7 (20.59)	2 (22.22)	0 (0.00)	0.5-2.5 (1.36)	0.5 (0.5)	0
6	*Cladosporium cladosporioides*	4 (11.76)	0 (0.00)	1 (33.33)	0.5-1.5 (0.88)	0	11.5
7	*Colletotrichum* sp.	18 (52.94)	8 (88.89)	3 (100.00)	0.5-23.5 (6.50)	0.5-13.0 (4.25)	3.0-10.0 (6.00)
8	*Curvularia lunata*	19 (55.88)	8 (88.89)	3 (100.00)	0.5-22.5 (7.39)	4.0-16.5 (10.88)	1.0-7.0 (4.83)
9	*C. pallescens*	29 (85.29)	8 (88.89)	3 (100.00)	1.0-43.5 (12.05)	4.5-24.0 (10.81)	4.5-17.0 (11.17)
10	*Endomyces fibuliger*	2 (5.88)	1 (11.11)	2 (66.67)	3.5-80.5 (42.0)	5.0	1.0-4.0 (2.50)
11	*Eurotium chevalieri*	9 (26.47)	1 (11.11)	3 (100.00)	0.5-12.0 (2.61)	1.0	0.5-17.5 (7.00)
12	*E. repens*	6 (17.65)	1 (11.11)	1 (33.33)	0.5-2.5 (1.08)	0.5	0.5
13	*E. rubrum*	5 (14.71)	1 (11.11)	2 (66.67)	0.5-9.0 (2.60)	1.5	0.5-1.5 (1.0)
14	*Fusarium proliferatum*	1 (2.94)	2 (22.22)	0 (0.00)	17.5	0.5-1.0 (0.75)	0
15	*F. semitectum*	26 (76.47)	9 (100.00)	3 (100.00)	1.5-67.5 (19.77)	1.0-29.5 (12.06)	2.5-8.0 (3.0)
16	*F. verticillioides*	25 (73.53)	8 (88.89)	3 (100.00)	0.5-9.5 (3.68)	1.5-22.5 (6.25)	1.0-4.5 (2.83)
17	*Lasiodiplodia theobromae*	20 (58.82)	7 (77.78)	3 (100.00)	0.5-7.0 (1.65)	0.5-4.0 (1.71)	0.5-1.0 (0.67)
18	*P. citrinum*	29 (85.29)	9 (100.00)	3 (100.00)	0.5-62.5 (15.72)	1.0-21.5 (6.89)	3.5-6.0 (4.5)
19	*Pestalotiopsis guepinii*	16 (47.06)	5 (55.56)	2 (66.67)	0.5-5.5 (2.06)	0.5-2.5 (1.40)	0.5-1.0 (7.50)
20	Isolate 3	9 (26.47)	2 (22.22)	0 (0.00)	0.5-9.5 (2.39)	0.5-1.0 (0.75)	0
21	Isolate 7	1 (2.94)	0 (0.00)	1 (33.33)	0.5	0	2.0
22	Isolate 8	1 (2.94)	1 (11.11)	1 (33.33)	0.5	1.0	1.0
23	Isolate 10	8 (23.53)	1 (11.11)	0 (0.00)	2.0-8.0 (4.38)	12.5	0

Number of samples at farmer level: 34
Number of samples at collector level: 9
Number of samples at retailer in traditional market: 3

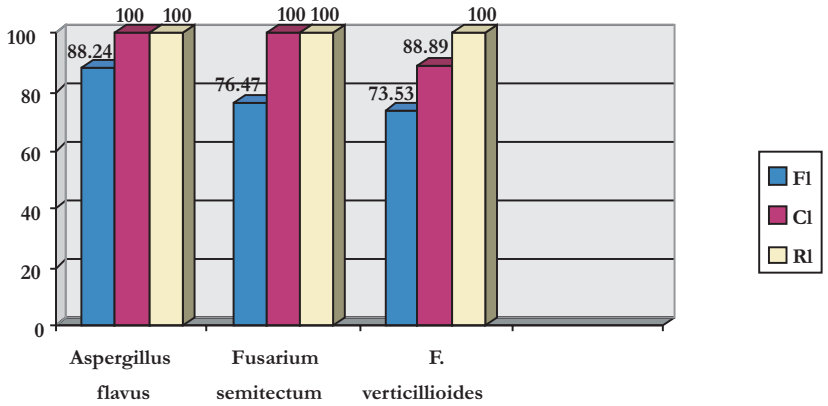
Nineteen fungal species were isolated from sorghum collected from **retailer at traditional market**, i.e. *A. candidus*, *A. flavus*, *A. niger*, *A. tamarii*, *Cladosporium cladosporioides, Colletotrichum* sp., *Curvularia lunata*, *C. pallescens*, *Endomyces fibuliger*, *Eurotium chevalieri*, *E. repens, E. rubrum*, *F. semitectum*, *F. vercillioides*, *Lasiodiplodia theobromae*, *Penicillium citrinum*, *Pestalotiopsis guepinii*, isolates 7 and 8.

Fungi which were often isolated from 34 sorghum samples collected from **farmer** were *A. flavus* (88.24% of samples), *Curvularia pallescens* and *Penicillium citrinum* (85.24%, respectively), *A. niger* and *F. semitectum* (76.47%, respectively) and *F. verticillioides* (73.53%). *Aspergillus flavus* caused highest percentage of infection (71.7%), with the range of 0.5 - 100.0%, while the lowest were isolates 7 and 8 (0.5%, respectively).

Fungi which were always isolated from 9 sorghum samples collected from **collector** were *A. flavus*, *F. semitectum* and *Penicillium citrinum* (100%, respectively), while fungi which were often isolated were *Colletotrichum* sp., *Curvularia lunata*, *C. pallescens* and *F. vercillioides* (88.89%, respectively), *A. niger*, *A. tamarii* and *Lasiodiplodia theobromae* (77.78%, respectively). *Aspergillus flavus* caused highest percentage of infection (74.28%), with the range of 2.0 - 99.5%, while the lowest were *A. wentii* and *E. repens* (0.5%, respectively).

Fungi which were always isolated from three sorghum samples collected from **retailer at traditional market** were *A. flavus*, *A. niger*, *Colletotrichum* sp., *Curvularia lunata*, *C. pallescens*, *Eurotium chevalieri*, *F. semitectum*, *F. vercillioides*, *Lasiodiplodia theobromae* and *Penicillium citrinum* (100%, respectively), while *Endomyces fibuliger*, *Eurotium rubrum*, and *Pestalotiopsis guepinii* (66.67%, respectively) were often isolated. *Aspergillus flavus* caused highest percentage of infection (61.50%), with the range of 13.5 - 87.5%, while the lowest was *E. repens* (0.5%).

In general, the dominant fungal species infecting sorghum grain collected from various stages of the delivery chain in Demak regency were *A. flavus*, *F. semitectum* and *F. verticillioides* (Fig. 3).



Fl = Farmer level; Cl = Collector level; Rl = Retailer level

Figure 3. Percentage of sorghum samples infected by *Aspergillus flavus, Fusarium semitectum*, and *F. verticillioides* at farmer, collector and retail levels in Demak regency

Table 8. Fungal infection in sorghum collected from farmers and collectors in **Wonogiri** regency

No	Fungi	Number (%) of samples infected by fungi		Range (mean) percentage of sorghum infected by fungi in infected samples	
		Farmer	Collector	Farmer	Collector
1	*Aspergillus flavus*	18 (78.26)	14 (93.33)	0.5-99.5 (17.44)	0.5-86.5 (23.21)
2	*A. niger*	11 (47.83)	14 (93.33)	0.5-7.0 (2.91)	0.5-17.5 (4.79)
3	*A. tamarii*	11 (47.83)	9 (60.00)	1.0-56.5 (9.55)	1.0-21.5 (6.72)
4	*A. wentii*	9 (39.13)	14 (93.33)	0.5-19.0 (7.17)	0.5-81.5 (9.96)
5	*Cladosporium cladosporioides*	9 (39.13)	0 (0.00)	0.5-14.5 (3.00)	0
6	*Colletotrichum* sp.	14 (60.87)	2 (13.33)	1.0-12.0 (6.43)	1.0-3.5 (2.25)
7	*Curvularia lunata*	10 (43.48)	1 (6.67)	0.5-13.5 (7.95)	5.0
8	*C. pallescens*	19 (82.61)	9 (60.00)	2.0-18.0 (7.26)	0.5-9.5 (3.44)
9	*Endomyces fibuliger*	6 (26.09)	1 (6.67)	1.0-89.5 (30.67)	87.0
10	*Eurotium chevalieri*	7 (30.43)	4 (26.67)	0.5-9.0 (3.14)	2.0-3.0 (2.50)
11	*E. repens*	6 (26.09)	0 (0.00)	0.5-1.5 (0.92)	0
12	*E. rubrum*	8 (34.78)	9 (60.00)	0.5-60.0 (13.63)	0.5-18.5 (4.83)
13	*Fusarium proliferatum*	18 (78.26)	11 (73.33)	0.5-46.0 (15.17)	2.0-45.0 (15.64)
14	*F. semitectum*	22 (95.65)	14 (93.33)	2.0-75.5 (24.48)	1.0-29.0 (7.18)
15	*F. verticillioides*	22 (95.65)	14 (93.33)	1.0-70.5 (29.09)	1.5-95.5 (51.64)
16	*Lasiodiplodia theobromae*	1 (4.35)	2 (13.33)	6.5	1 (1)
17	*Penicillium* sp.1	3 (13.04)	8 (53.33)	2.0-6.5 (4.50)	0.5-47.0 (14.69)
18	*Penicillium* sp.2	4 (17.39)	7 (46.67)	1.5-30.5 (11.00)	9.5-49.0 (28.07)
19	*P. citrinum*	23 (100)	12 (80.00)	0.5-97.0 (30.24)	1.5-90.5 (32.33)
20	*P. islandicum*	2 (8.70)	2 (13.33)	1-2.5 (1.75)	2.5-3.5 (3.0)
21	*Pestalotiopsis guepinii*	21 (91.30)	12 (80.00)	0.5-11.1 (2.86)	1.0-5.5 (2.8)
22	Isolate 3	15 (65.22)	9 (60.00)	0.5-17.5 (4.67)	0.5-17.0 (4.28)
23	Isolate 7	9 (39.13)	0 (0.00)	0.5-9.5 (3.38)	0

Number of samples at farmer level: 23
Number of samples at collector level : 15

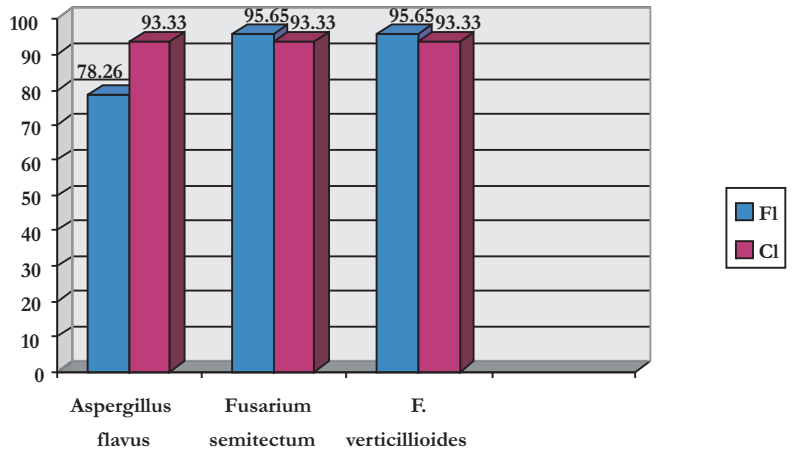
Fungal infection of sorghum in Wonogiri regency

Percentage of sorghum infected by fungi in Wonogiri regency is presented in Table 8.

Twenty three fungal species were isolated from sorghum collected from **farmer**, i.e. *Aspergillus flavus*, *A. niger*, *A. tamarii*, *A. wentii*, *Cladosporium cladosporioides*, *Colletotrichum* sp., *Curvularia lunata*, *C. pallescens*, *Endomyces fibuliger*, *Eurotium chevalieri*, *E. repens*, *E. rubrum*, *Fusarium proliferatum*, *F. semitectum*, *F. vercillioides*, *Lasiodiplodia theobromae*, *Penicillium citrinum*, *P. islandicum*, *Penicillium* sp. 1, *Penicillium* sp. 2, *Pestalotiopsis guepinii*, isolates 3 and 7. Eight out of 23 fungal species were belong to field fungi, i.e. *Cladosporium cladosporioides*, *Curvularia lunata*, *C. pallescens*, *Fusarium proliferatum*, *F. semitectum*, *F. vercillioides*, *Lasiodiplodia theobromae*, and *Pestalotiopsis guepinii*.

Twenty fungal species were isolated from sorghum collected from **collector,** i.e. *A. flavus*, *A. niger*, *A. tamarii*, *A. wentii*, *Colletotrichum* sp., *Curvularia lunata*, *C. pallescens*, *Endomyces fibuliger*, *Eurotium chevalieri*, *E. rubrum*, *F. proliferatum*, *F. semitectum*, *F. vercillioides*, *Lasiodiplodia theobromae*, *Penicillium citrinum*, *P. islandicum*, *Penicillium* sp. 1, *Penicillium* sp. 2, *Pestalotiopsis guepinii*, and isolate 3. Field fungi were still found in sorghum collected from collectors, because the duration of storage was relatively short. It was also assumed, that the storage condition was suitable for fungal growth.

Penicillium citrinum (100% of samples) was always isolated from 23 sorghum samples collected from **farmer**, while *F. semitectum* and *F. verticillioides* (95.65%, respectively), *Pestalotiopsis guepinii* (91.30%), *Curvularia pallescens* (82.61%), *A. flavus* and *F. proliferatum* (78.26%, respectively) were often isolated. *Endomyces fibuliger* caused highest percentage of infection (30.67%), with the range of 1.0 - 85.5%, while the lowest was *Eurotium repens* (0.92%), with the range of 0.50 - 1.50%.



Fl = Farmer level; Cl = Collector level

Figure 4. Percentage of sorghum samples infected by *Aspergillus flavus, Fusarium semitectum* and *F. verticillioides* at farmer and collector levels in Wonogiri regency

Fungi which were often isolated from 15 sorghum samples collected from **collector** were *A. flavus*, *A. niger*, *A. wentii*, *F. semitectum* and *F. verticillioides* (93.33%, respectively), and *Penicillium citrinum* (80%). *Endomyces fibuliger* caused highest percentage of infection (87.0%), while the lowest was *Lasiodiplodia theobromae* (1.0%). *Fusarium semitectum* and *F. verticillioides* are field fungi, while *A. flavus, A. niger A. wentii* are post-harvest (storage) fungi.

In general, the dominant fungal species infecting sorghum grain collected from various stages of the delivery chain in Wonogiri regency were also *A. flavus*, *F. semitectum* and *F. verticillioides* (Fig. 4).

Aflatoxin B_1 content

Aflatoxin B_1 content of sorghum in Demak regency

Percentage of samples contaminated by AFB1 in sorghum collected from farmers (61.76%) was higher than that of collected from collectors (55.56%). The mean of AFB1 content of sorghum collected from farmes (22.50 ppb, with the range of 4.54 - 90.78 ppb) was higher than those of collected from collectors (15.45 ppb, with the range of 13.62 - 22.73 ppb) (Table 9). This might be due to more toxigenic strains of *A. flavus* available in sorghum collected from farmers compared to those collected from collectors. According to Pitt and Hocking (2009) aflatoxin production among others depend on the certain strains of *A. flavus* and the existence of other fungal species which are antagonistic to aflatoxigenic *A. flavus*. Dharmaputra *et al.* (2001) reported that *in vitro Aspergillus niger* was able to inhibit *A. flavus* growth, consequently aflatoxin production was also inhibited as much as 80%.

Aflatoxin B_1 content of sorghum in Wonogiri regency

Percentage of samples contaminated by AFB1 in sorghum collected from collectors (40%) was higher than collected from farmers (4.35%) (Table 9). It was probably due to the duration of storage at collectors was longer than that of at farmers, or the existence of aflatoxigenic *A. flavus* found in sorghum collected from farmers was lower that that of in sorghum collected from collectors. The main and range of AFB1 content in sorghum samples at farmers was 2.27 and 2.27 ppb, respectively, while at collectors was 10.28 ppb (4.57 - 22.85 ppb) (Table 9).

Da Silva *et al.* (2004) reported that 59 *A. flavus* strains were found from 10 fresh sorghum samples collected from farmers and 130 sorghum samples collected from

Table 9. Aflatoxin B_1 content in sorghum collected from farmers, collectors and retailers at traditional market in Demak and Wonogiri regencies

Regency	Level of distribution chain	Number (%) of samples contaminated by AFB_1	Range (mean) of AFB_1 content (ppb) in contaminated samples
Demak	Farmer	21 (61.76)	4.54-90.78 (22.50)
	Collector	5 (55.56)	13.62-22.73 (15.45)
	Retailer at traditional market	0	0
Wonogiri	Farmer	1 (4.35)	2.27
	Collector	6 (40.0)	4.57-22.85 (10.28)

collector in Brazil. As much as 38 (64.4%) of 59 strains were able to produce AFB_1+AFB_2 with the range of 12,00-3,282.50 ppb.

Aflatoxin production was affected among others by the kind of substrates, moisture content and relative humidity, water activity, damaged grains, concentration of oxygen and carbondioxide, temperature and the duration of storage, interaction among microorganisms and the existence of insects (Diener & Davis 1969).

Pitt and Hocking (1996) stated that aflatoxin content exceeding 1 000 ppb toxic to animal and human. FAO (2004) reported that in Russia AFB1 content in sorghum should not exceed 5 ppb, while in Taiwan total aflatoxin content (AFB1 + AFB2 + AFG1 + AFG2) should not exceed 10 ppb. In Indonesia there are no regulations concerning the maximum tolerable limit of aflatoxin content in sorghum.

Although in general sorghum at farmer and collector levels were not contaminated by aflatoxin, post-harvest handling in each level of distribution chain should be conducted appropriately to prevent aflatoxin contamination. The method of post-harvest handling will affect fungal infection (including *A. flavus*) and aflatoxin contamination.

In Brazil the dominant fungi found in fresh harvested sorghum (10 samples) and stored sorghum (130 samples) were *Phoma* (57.1%), *Aspergillus* (42.7%), *Fusarium* (25.1%), *Rhizopus* (21.4%) and 9 genera of other fungi with mycelia. *Fusarium*, *Aspergillus* and *Penicillium* were important fungi, because certain species of these fungi can produce toxin. The population range of these fungi were 1×10^3 - 36×10^3, 1×10^3 - 295×10^3 and 1×10^3 - 20×10^3 *cfu*/g, respectively. The most often fungi found was *Aspergillus flavus* and *Fusarium moniliforme*. As much as 12.8% of the samples was contaminated by AFB1. Their range was 7 - 33 ppb (da Silva *et al*. 2000).

In Nigeria nine pathogenic and saprophytic fungi were found in stored sorghum (*Sorghum guineense*) which were previously air-dried. Pathogenic fungi found were *Cladosporium vignae*, *Macrophomina phaseolina* and *Helminthosporium turcicum*, while most of saprophytic fungi belong to *Aspergillus*, especially *A. flavus*, *A. fumigatus* and *A. niger* (Ogundero 2007). *Fusarium* was the important fungus of sorghum in Argentine in 1991, 1992 and 1993. The dominant fungus was *Fusarium moniliforme*, while the most often fungi isolated were *Alternaria alternata*, *Phoma sorghina*, *Penicillium funiculosum* and *Aspergillus flavus* (Gonzales *et al*. 1997). The percentage of sorghum infected by *Alternaria alternata*, *Fusarium moniliforme*, *Colletotrichum graminicol;a*, *Acremonium strictum*, *Phoma sorghina*, *Macrophomina phaseolina* and *Pestalotia guepinii*, i.e. 93.75, 75.0, 62.75, 62.50, 62.50, 56.25 and 37.5%, respectively (Hemanth *et al*. 2007). Schroeder and Boller (1973) reported that aflatoxin was found in sorghum samples collected in two of three periods in Texas. In 1970, 6% of 114 sorghum samples were contaminated by aflatoxin. Their range and mean of contents were 3 - 20 ppb and 10 ppb, respectively. In 1971, 16% of 25 sorghum samples were contaminated by aflatoxin. Their range and mean of contents were 4 - 9 ppb and 6 ppb, respectively.

In general, Bandyopadhyay *et al*. (2000) stated that some species of *Aspergillus*, *Alternaria*, *Cladosporium*, *Diplodia*, *Fusarium*, *Curvularia*, *Phoma*, and *Penicillium* were pathogenic fungi in sorghum seeds. Hemanth *et al*. (2007) reported, that five (*Fusarium semitectum, F. verticillioides, F. proliferatum*, *C. pallescens*, and *A. flavus*) fungal species often isolated were able to inhibit the germination of sorghum. Aside from that,

the diversity of fungi in sorghum collected from 10 regions in Karnataka, India depended on the variety of sorghum, the structure and the location of the storage.
According to Schroeder and Boller (1973) in 1969 and 1971 the percentage of sorghum samples collected in Texas and infected by *A. flavus* was 100%, respectively, while the percentage of samples contaminated by aflatoxin was 24 and 40%, respectively. Reddy *et al.* (2002) reported that in India 2, 2, 0 and 2 out of 29 sorghum samples were contaminated by aflatoxin with the range of 10 - 29 ppb, 30 - 49 ppb, 50 - 100 ppb, and >100 ppb, respectively.

CONCLUSIONS

There was a slight difference in the method of postharvest handling of sorghum at farmer and collector levels in Demak and Wonogiri regencies, especially the method of threshing sorghum grain. In Demak and Wonogiri regencies the farmers sun-dried sorghum in the form of panicles on tarpaulin or cement floor, while the collectors sun-dried the sorghum only on cement floor. In Demak regency most of farmers threshed sorghum using a paddy thresher, while in Wonogiri regency most of farmers threshed sorghum using a stick of wood. In these two regencies collectors threshed sorghum using a paddy thresher. In Demak regency farmers and collectors stored sorghum grain in polypropylene bags. Only in Wonogiri regency most farmers and collectors stored sorghum in polypropylene bags.

The moisture contents of sorghum at farmer and collector levels in Demak and Wonogiri regencies were still lower compared to normal moisture content of sorghum.

Various insect species associated with sorghum was found at various stages of the delivery chain in Demak and Wonogiri regencies. The dominant insects species were *Sitophilus zeamais* and *Tribolium castaneum*.
Various field and postharvest storage fungi were isolated from sorghum at various stages of the delivery chain in Demak and Wonogiri regencies. The dominant fungal species found were *Aspergillus flavus*, *Fusarium semitectum* and *F. verticillioides*.
Generally, AFB1 content in sorghum at various stages of the delivery chain in Demak and Wonogiri regencies were low, i.e. ≤ 22.5 ppb.

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REFERENCES

[AOAC] Association of Official Analytical Chemist. 2005. Natural toxins. *In* Horwitz W, editor. Official methods of Analysis of AOAC International. 18th ed. Ch.49, p. 11. Gaithersburg : AOAC.

Bandyopadhyay, R., Butler, D.R., Chandrasekhar, A. Reddy, R.K., and Navi, S.S. 2000. Biology, epidemiology, and management of sorghum grain mold. In Chandrashekar A, Bandyopadhyay R., Hall AJ, editor. Technical and Institutional Options for Sorghum Grain Mold Management: Proceedings of an International Consultation; Patancheru, 18-19 May 2000. India : International Crops Research Insitute for the Semi-Arid Tropics (ICRISAT). p. 34-71.

[BP2APTP] Balai Pengembangan Perbenihan Produksi Tanaman Pangan dan Hortikultura. 2008. Pengembangan Teknologi dan Produksi Perbenihan Tanaman Sorghum. Yogyakarta: BP2APTP.

Christensen CM, Miller BS, Johnston JS. 1990. Moisture and its measurement. *In*: Sauer DB, editor. Storage of Cereal Grains and Their Products. 4th edition. St Paul: American Association of Cereal Chemist, p. 39-54.

Dharmaputra OS, Putri ASR, Retnowati I, Ambarwati S. 2001. Soil mycobiota of peanut fields in Wonogiri regency, Central Java: Their effect on the growth and aflatoxin production of Aspergillus flavus in vitro. Biotropia, 17: 30-58.

Diener UL, Davis ND. 1969. Aflatoxin formation by Aspergillus flavus. *In* Goldblatt LA, editor. Aflatoxin. Scientific Background, Control and Implications. New York: Academic Press. p. 13-54.

FAO. 2004. Worldwide Regulations for Mycotoxins in Food and Feed in 2003. FAO Food and Nutrition Paper 81. Rome: Food and Agriculture Organization of the United Nations.

Gonzalez HHL, Martinez EJ, Resnik SL. 1997. Fungi associated with sorghum grain from Argentina. Mycopathologia, 13 (1): 35 - 41.

Haines CP. 1991. Insects and Arachnids of Tropical Stored Products : Their Biology and Identification (A Training Manual). Kent: Natural Resources Institute.

Hemanth RM, Niranjana SR, Nayaka SH. 2007. Health status of farmers saved paddy, sorghum, sunflower and cowpea seeds in Karnataka, India. WJ Agricultural Science, 3(2): 167 - 177.

Hocking AD, Pitt JI. 1980. Dichloran-glycerol medium for enumeration of xerophilic fungi from low-moisture foods. Applied and Environmental Microbiology, 30: 448 - 492.

Mendesil E, Abdeta C, Tesfaye A, Shumeta Z, Jifar H. 2007. Farmers perceptions and management practices of insect pests on stored sorghum in Southwestern Ethiopia. Crop Protection, 26 (12): 1817-1825.

Ogundero VW. 2007. The fungal flora of post-harvest grains of Sorghum guineense Stapf and their importance in pathogenicity. Journal of Basic Microbiology, 26 (6); 359-363.

Peng WK. 1998. Insects in domestic corn and sorghum stored in steel silos in Taiwan. Plant Protection Bulletin, 40: 309-314.

Pitt JI, Hocking AD. 1996. Current knowledge of fungi and mycotoxins associated with food commodities in Southeast Asia. In Highley E, Johnson GI, editor. Mycotoxin contamination in Grains. Paper presented at the 17th ASEAN Technical Seminar on Grain Postharvest Technology, Lumut, Malaysia, 25-27 July 1995. Canberra: Australian Centre for International Agricultural Research. p. 5-10.

Pitt JI, Hocking AD. 2009. Fungi and Food Spoilage. New York: Springer.

Reddy DVR et al. 2002. Estimation of aflatoxin levels in selected foods and feeds in India. *In* Hanak E, Boutrif E, Fabrie P, Pineiro, editor. Food Safety Management in Developing Countries. Proceedings of the International Workshop, CIRAD-FAO; Montpellier, 11-13 December 2000. France: CIRAD FAO. p. 1-4.

Sauer DB, Meronuck RA, Christensen CM. 1992. Microflora. In Sauer DB (editor). Storage of Cereal Grains and Their Product. 4th ed. Minnesota: American Association of Cereal Chemistry. p. 313 - 340.

Schroeder HW, Boller RA. 1973. Aflatoxin production of species and strains of the *Aspergillus flavus* group isolated from field crops. Applied Microbiology, 25 (6): 885 - 889.

da Silva JB, Pozzi CR, Mallozzi MAB, Ortega EM, Correa B. 2000. Mycoflora and occurrence of aflatoxin B_1 and Fumonisin B_1 during storage of Brazilian sorghum. Journal of Agricultural and Food Chemistry, 48(9): 4352-4356.

da Silva JB, Dilkin P, Fonseca H, Correa B. 2004. Production of aflatoksin by Aspergillus flavus and of fumonisin by Fusarium species isolated from Brazilian sorghum. Brazilian Journal of Microbiology, 35:182-186.

Suarni. 2001. Tepung komposit sorgum, jagung dan beras untuk pembuatan kue basah (cake). Risalah Penelitian Jagung dan Serealia. Maros: Balai Penelitian Jagung dan Serealia. p. 55-60.