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Maize quality in markets in four West African countries

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ABSTRACT

The quality of maize offered for sale in West African public markets was evaluated by analysing 281 samples collected in 24 markets in Benin, Togo, Ghana and Burkina Faso from February to March 2014. Grain moisture content ranged from 8.5 to 14.4 percent (wt/wt), while extraneous matter content ranged between 0.0 and 2.0% and the proportion of mouldy grains between 0.0 and 0.6%. Insect pest infestations were noted in about one-fourth of the samples with *Sitophilus* sp., *Cryptolestes ferrugineus* Stephens, *Tribolium* sp. and *Prostephanus truncatus* Horn found at densities varying between 0 and 2.4 individuals per 500 g of grain. Aflatoxin levels exceeding the accepted USA standard of 20 ppb were recorded in only 4.6% of the samples across the four countries. In most locations, grain moisture was within the acceptable range for aflatoxin- and insect-safe storage of maize using hermetic technology such as PICS bags.

1. Introduction

Maize is an important food crop in West Africa. Total production is estimated to be 18.5 million tonnes. Nigeria contributes about 54.5% of the total production followed by Ghana with 9.25%, Burkina Faso with 8.95%, Mali 7.88% and Benin 7.05% (FAOSTAT, 2013). Maize yields have nearly doubled over the past decade thanks to the implementation of agricultural policies that promote crop production and productivity including (1) increased use of fertilizer and (2) use of improved varieties. Almost 60% of maize production in West Africa is for human consumption (Elbehri et al., 2013).

Maize quality in markets has been a concern for decades because of aflatoxin contamination. The upper limit of acceptable aflatoxin levels in maize for human consumption is 20 ppb in the United States and 15 ppb in Ghana. From 744 maize samples collected in Benin in 1993–1994, 38.8% tested positive for aflatoxin with mean contamination of 105 ppb (Hell et al., 2003). In Ghana, in 1999, 8 of 15 maize samples studied had unacceptable levels of aflatoxin and fumonisins (Kpodo et al., 2000). Akrobortu (2008) also noted aflatoxin levels ranging between 9.5 and 153.2 ppb in different localities in Ghana. In Burkina Faso, an analysis carried out on maize-based food products showed aflatoxin B1 in 50% of the samples with a median of 23.6 ppb (Warth et al., 2012). Maize contamination by aflatoxins is a threat to human health and decreases the value of the commodity in international trade. Fungal toxins are responsible of an estimated annual loss of between USD 670–750 million to African countries (Otsuki et al., 2001; USAID and Danya International, 2013).

We conducted the present study to collect data bearing on the quality of maize for sale in some West African markets. Our results shed light on quality issues and may contribute to improving the postharvest storage management and marketing of this important cereal.

2. Materials and methods

This study was conducted in 24 markets located in Benin, Togo, Ghana and Burkina Faso (see Fig. 1 for locations). Participants were selected systematically beginning with the second maize seller in the series of sellers at the market followed by every third seller thereafter. Contact with each participant was initiated in the market or workplace and began with an explanation of the objectives of the study. Grain moisture measurements were carried out on maize stocks on display for sale or stored for later sale. Samples of 1 kg of grain were purchased to evaluate other parameters of the study, described below.

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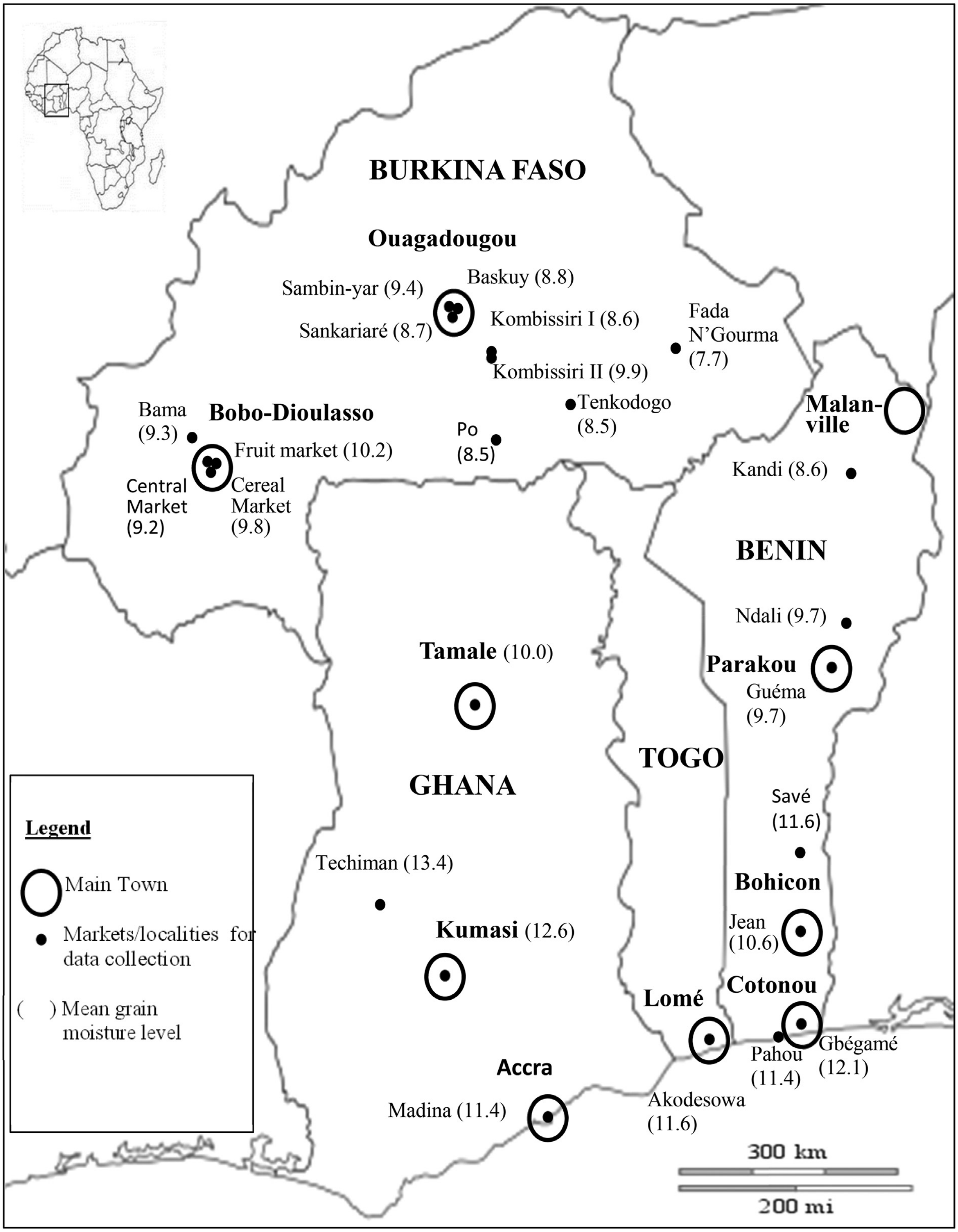

Fig. 1. Locations of cities and markets where maize samples were collected and mean grain moisture content determined; in Benin, Togo, Ghana and Burkina Faso.

Seed moisture was determined using a direct-reading portable device, the DICKEY-John mini GAC (http://www.dickey-john.com/product/mini-gac/) (DICKEY-John Corp., Auburn, IL, USA) following the company's recommended procedure and using the calibration setting for maize. Measurements were made using three separate maize samples from each of the traders or producers.

To determine total aflatoxin content, each sample was taken using a fresh pair of gloves to avoid contamination. Approximately 200 g of maize seed was collected and then divided into two samples of 100 g each. These were repackaged individually in plastic bags and labelled. Aflatoxin levels were determined by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) laboratory in Mali following the protocols of Centro Internacional de Mejoraminento de Maiz et Trigo (CYMMYT) and using the ELISA procedure (see http://www.icrisat.org/aflatoxin/elisa1.htm for details).

Pest identification, infestation level and the degree of non-maize contamination in the collected samples were determined as follows: A jar was used to collect maize samples from the top, middle and base of the container. These samples were thoroughly mixed and a 500 g sample of the mixture was taken. Each sample was sieved using 1.0 mm and 2.0 mm mesh screen sieves to separate the living adults from the intact grain and grain fragments.

Next, insects were identified and counted in each sample. Extraneous matter (i.e., non-maize organic and inorganic materials, including broken kernels, non-maize grains, plant debris, and inorganic materials such as pebbles) were separated and weighed to determine its contribution to the original sample weight; the same was done with mouldy seeds. The following formulae were used: percentage of extraneous matter = (weight of extraneous matter/total sample weight) × 100; percentage of mouldy grain = (weight of mouldy seeds/total sample weight) × 100.

Analysis of variance followed by LSD tests were used to compare means related to the moisture level, the level of extraneous matter, the proportion of mouldy grains, and the level of insect infestation. For aflatoxin, measured levels were placed in four categories, as follows: 0 ppb (below the level of detection, which is <1 ppb); 1–20 ppb; 21–99 ppb and 100 ppb and above. The correlation coefficients (Pearson R) between the levels of aflatoxin and the seed moisture level, proportion of extraneous matter, percentage of mouldy grains and insect density were calculated. Statistical analysis was done using the Statistical Package for the Social Sciences (SPSS) Version 16.0, IBM (Chicago, Illinois).

Sample collection was carried out from February 22 to March 3, 2014. This was just after the end of the second (minor) maize growing season and during the postharvest storage period for major season produced maize in Ghana, Togo and Benin. Because of its dry climate there is no second maize growing season in Burkina Faso. We visited twenty four markets in the four countries (Fig. 1) and collected 281 maize samples.

3. Results and discussion

Mean grain moisture levels all fell in the range of 8.5–14.4% (Table 1). The highest values were noted in Ghana, especially at the Kumasi market with 12.6%, in the Techiman market with 13.4%, and Medina market in Accra with 14.4%. The great preponderance of samples exhibited moisture levels well within the acceptable range for international trade. According to an FAO (1992) extension bulletin, the recommended moisture level in maize grain is 13%. According to the CODEX *Alimentarius* (http://www.codexalimentarius.org/input/download/standards/51/CXS_153f.pdf), the acceptable moisture content of maize as food is 15% or below. According to this latter standard, every sample we collected had acceptable moisture content.

As regards moisture levels and fungal growth, Lopez and Christensen (1967) indicate that a minimum moisture content of 17.5% is required for development of *Aspergillus flavus*. Magan and Aldred (2007) recommend a moisture level of 14% for safe storage of maize grain. Other studies carried out in the tropical zone indicated that moisture levels of 13% prevent the development of pathogenic fungi on maize, while a moisture level of 20%, supported extremely high levels of aflatoxin B1 (Oyebanji and Efiuvwevwere, 1999). A study of fungus growth under controlled atmospheres (20–60% CO2), Janardhana et al. (1998) showed that a moisture level of 15% prevents growth of fungus. Recently, Williams et al. (2014) demonstrated under airtight storage conditions that moisture levels between 12 and 15% do not allow the development of aflatoxin.

Our data from 24 markets in the West African region show that farmers and traders sell maize at moisture levels that do not support the growth of pathogenic fungi.

Extraneous matter levels in maize grain varied between 0.0 and 2.0% for all sites except Bascuy market in Burkina Faso where we observed a level of 4.7% (Table 1). Most markets therefore have a proportion of inedible matter below the level of 2.1% recommended for maize grain by the CODEX *Alimentarius*.

The proportion of mouldy seeds was extremely low, ranging between 0.0 and 0.6% (Table 1). This is most simply explained as the result of the low moisture content of the grain. As noted above, the development of fungi on maize seeds requires more than 15% moisture. The low percentage of mouldy seeds is consistent with the idea that farmers dry their grain successfully such that in most cases moulds don't develop.

Insect infestations were observed in 8 of the 24 markets sampled with 22% of samples having live insects. Larger grain borer (*Prostephanus truncatus* Horn) was observed in only one market, *Sitophilus* spp. in 6, *Cryptolestes ferrugineus* (Stephens) in 5 and *Tribolium* sp. in 3. Insect densities were low, ranging from 0 to 2.4 individuals of a particular species per 500 g of maize, or 3.3 taking all species into account. This low degree of infestation is probably explained by the fact that our study mainly involved retailers who usually clean and sort their products before they put them out for sale, as consumer typically assess maize quality before they make a purchase. Major maize storage pests such as *P. truncatus* and *Sitophilus zeamais* are fairly common and have been recently reported in these ecological zones (Baoua et al., 2014).

Among the 281 samples collected, aflatoxin was undetectable in only 5 samples. However, in 93.6% of the samples the level fell in the acceptable range of 1–20 ppb (Table 2). About 1 in 20 of the samples (mean 4.6%) had total aflatoxin levels above 20 and below 100 ppb. Samples with the highest levels of aflatoxin were noted in Benin, where 7.0% had levels between 57.9 and 504.4 ppb. In Burkina Faso, 5.9% of the samples showed aflatoxin levels ranging between 26.3 and 478.3 ppb. In Togo, only two of 36 samples (5.6%) had unacceptable levels; one with 30.5 ppb and the other 100 ppb. In Ghana, only one sample out of the 83 (1.2%) exhibited an unacceptable level of 188.5 ppb.

These results indicate that within the four countries aflatoxin contamination in maize being sold for consumption is fairly common but the proportion of aflatoxin contaminated samples for each of the countries is below the rate of 38.8–68.4% reported in recent years by other studies (Kpodo et al., 2000; Akrobortu, 2008; Warth et al., 2012). The observed frequency of aflatoxin contamination in the different markets is not correlated with: (1) maize moisture levels ($R = 0.02$, $F = 0.11$, $df = 1/279$, $P = 0.73$); (2) the insect population ($R = 0.06$, $F = 1.22$, $df = 1/279$, $P = 0.27$); (3) the level of impurities in the grain ($R = 0.12$, $F = 3.85$, $df = 1/279$, $P = 0.05$); or (4) the proportion of mouldy seeds ($R = 0.11$, $F = 3.67$, $df = 1/279$, $P = 0.06$). The presence of high levels of aflatoxin in some samples could not be directly related to any of these parameters. The low moisture content of the grain as described above would not favor *Aspergillus* fungal development.

The aflatoxin levels we report here are lower than some have reported (Kpodo et al., 2000; Akrobortu, 2008; Warth et al., 2012). Low levels – only 4.6 percent above the 20 ppb standard in the USA – should perhaps not be surprising. Maize grain from sale and displayed in the open markets of the region is invariably inspected by potential buyers before purchase. Grain that has impurities, mouldy kernels, discoloration, will be rejected. Sellers accordingly

Table 1
Moisture content, extraneous matter, frequency of mouldy grains, and insect infestation levels in maize samples collected in markets of Benin, Burkina Faso, Togo and Ghana.

Countries	Localities/Market	n	Moisture content of grain (%)	Extraneous matter level (%)	Mouldy grain (%)	Living insects per 500 g of grain			
						Sitophilus spp.	*Cryptolestes ferriginus*	*Tribolium* spp.	*Prostephanus truncatus* hhorn
Benin	Kandi	7	8.6 ± 0.2^{a}	1.0 ± 0.3^{a}	0.1 ± 0.1^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	N'Dali	6	9.7 ± 0.4^{b}	1.9 ± 0.3^{a}	0.4 ± 0.2^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Guéma Parakou	8	9.7 ± 0.2^{b}	0.8 ± 0.2^{a}	0.4 ± 0.1^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Savé	10	11.6 ± 0.2^{c}	0.8 ± 0.3^{a}	0.3 ± 0.1^{a}	1.6 ± 0.7^{b}	1.4 ± 0.9^{a}	0.3 ± 0.2^{a}	0.0 ± 0.0^{a}
	Jean de Bohicon	10	10.6 ± 0.1^{b}	1.4 ± 0.6^{a}	0.5 ± 0.3^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Gbégamé (Cotonou)	24	12.1 ± 0.2^{c}	0.5 ± 0.2^{a}	0.0 ± 0.0^{a}	0.2 ± 0.1^{a}	0.1 ± 0.1^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Pahou	6	11.4 ± 0.4^{c}	0.6 ± 0.2^{a}	0.5 ± 0.2^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	ANOVA		$F = 27.26$, df = 6/64, $P < 0.001$	$F = 2.34$ df = 6/64, $P = 0.09$	$F = 1.36$, df = 6/64, $P = 0.24$	$F = 3.44$, df = 6/64, $P < 0.01$	$F = 2.00$, df = 6/64, $P = 0.08$	$F = 2.01$, df = 6/64, $P = 0.077$	–
Togo	Akodesowa (Lomé)	36	11.6 ± 0.2	0.8 ± 0.1	0.4 ± 0.1^{a}	0.2 ± 0.1^{a}	0.2 ± 0.1	0.1 ± 0.1^{a}	0.0 ± 0.0^{a}
Ghana	Madina (Accra)	36	14.4 ± 0.3^{c}	1.1 ± 0.8^{a}	0.1 ± 0.1^{a}	1.9 ± 0.5^{a}	0.1 ± 0.1^{a}	0.1 ± 0.1^{a}	0.0 ± 0.0^{a}
	Kumasi	29	12.6 ± 0.2^{b}	0.3 ± 0.1^{a}	0.0 ± 0.0^{a}	0.7 ± 0.2$^{a,\,b}$	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Techiman	12	13.4 ± 0.2$^{b,\,c}$	1.1 ± 0.2^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Tamale	9	10.0 ± 0.2^{a}	0.5 ± 0.1^{a}	1.2 ± 0.2^{b}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	ANOVA		$F = 24.49$, df = 3/118, $P < 0.001$	$F = 0.43$, df = 3/118, $P = 0.74$	$F = 42.57$, df = 3/118, $P < 0.001$	$F = 4.78$, df = 3/118, $P < 0.01$	$F = 0.45$, df = 3/118, $P = 0.72$	$F = 1.75$, df = 3/118, $P = 0.16$	–
Burkina-Faso	Po	8	8.5 ± 0.1$^{a\,b}$	0.9 ± 0.2^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Kombissiri 1	10	8.6 ± 0.1$^{a,\,b}$	1.0 ± 0.4^{a}	0.1 ± 0.1	0.0 ± 0.0^{a}	0.1 ± 0.1^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Koumbissiri 2	10	9.9 ± 0.3^{d}	0.6 ± 0.2^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Sambin Yar (Ouagadougou)	3	9.4 ± 0.3$^{bc\,d}$	1.1 ± 0.2^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Sankariare (Ouagadougou)	6	8.7 ± 0.2^{abc}	0.9 ± 0.7^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Bascuy (Ouagadougou)	11	8.8 ± 0.2^{abc}	4.7 ± 0.9^{b}	0.2 ± 0.1	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Central (Bobo-Dioulasso)	10	9.2 ± 0.1^{bcd}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Cereal (Bobo-Dioulasso)	3	9.8 ± 0.8^{cd}	0.4 ± 0.2^{a}	0.11 ± 0.11^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Fruit (Bobo-Dioulasso)	10	10.2 ± 0.2^{d}	0.1 ± 0.1^{a}	0.0 ± 0.0^{a}	0.1 ± 0.1^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Bama	11	9.3 ± 0.2$^{b,\,c,\,d}$	2.2 ± 0.6^{a}	0.3 ± 0.3	2.4 ± 2.3^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.3 ± 0.3
	Tenkodogo	3	8.5 ± 0.2^{ab}	0.6 ± 0.3^{a}	0.6 ± 0.1^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Fada N'Gourma	3	7.7 ± 0.2^{a}	0.8 ± 0.5^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	ANOVA		$F = 8.03$, df = 11/76, $P < 0.001$	$F = 6.30$, df = 11/76, $P < 0.001$	$F = 1.00$, df = 11/76, $P = 0.46$	$F = 0.65$, df = 11/76, $P = 0.781$	$F = 0.68$, df = 11/76, $P = 0.753$	$F = 0.60$, df = 11/76, $P = 0.83$	$F = 0.61$, df = 11/76, $P = 0.82$
All countries	Benin	71	10.9 ± 0.2^{b}	0.9 ± 0.1^{a}	0.3 ± 0.1^{b}	0.3 ± 0.129^{a}	0.2 ± 0.1^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	Togo	36	11.6 ± 0.2^{c}	0.8 ± 0.1^{a}	0.4 ± 0.1^{b}	0.25 ± 0.083^{a}	0.2 ± 0.1^{a}	0.1 ± 0.1^{a}	0.0 ± 0.0^{a}
	Ghana	86	13.2 ± 0.2^{d}	0.7 ± 0.3^{a}	0.2 ± 0.5^{a}	1.07 ± 0.228^{a}	0.0 ± 0.0^{a}	0.1 ± 0.0^{a}	0.0 ± 0.0^{a}
	Burkina-Faso	88	9.2 ± 0.1^{a}	1.3 ± 0.2^{a}	0.1 ± 0.0^{a}	0.31 ± 0.29^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	ANOVA		F = 111.49, df = 2/278, P < 0.001	F = 1.11, df = 2/278, P = 0.34	F = 4.00, df = 2/278, P < 0.01	F = 2.85, df = 2/278, P = 0.16	F = 1.97, df = 2/278, P = 0.12	F = 0.31, df = 2/278, P = 0.82	F = 0.73, df = 2/278, P = 0.54
	Total	281	11.2 ± 0.1	0.9 ± 0.1	0.2 ± 0.0	0.5 ± 0.1	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

Means followed by the same letter are not significantly different (LSD, 5%).

Table 2
Aflatoxin levels in maize samples collected in markets in Benin, Burkina Faso, Togo and Ghana. Total aflatoxin levels are given.

Countries	Markets/localities	Total aflatoxin level (ppb)				Total
		0	1–20	21–100	101 and plus	
Benin	Kandi	0	7	0	0	7
	N'Dali	0	5	1	0	6
	Guéma (Parakou)	0	8	0	0	8
	Savé	0	8	0	2	10
	Jean de Bohicon	0	9	0	1	10
	Gbegame (Cotonou)	0	24	0	0	24
	Pahou	0	5	0	1	6
Togo	Akodesowa (Lomé)	3	31	2	0	36
Ghana	Accra	0	35	0	1	36
	Kumasi	2	27	0	0	29
	Techiman	0	12	0	0	12
	Tamale	0	9	0	0	9
Burkina Faso	Po	0	8	0	0	8
	Kombissiri 1	0	9	0	1	10
	Kombissiri 2	0	10	0	0	10
	Sambin Yar (Ouagadougou)	0	3	0	0	3
	Sankariaré (Ouagadougou)	0	6	0	0	6
	Bascuy (Ouagadougou)	0	10	1	0	11
	Central (Bobo-Dioulasso)	0	10	0	0	10
	Cereal (Bobo-Dioulasso)	0	3	0	0	3
	Fruit (Bobo-Dioulasso)	0	9	0	1	10
	Bama	0	10	1	0	11
	Tenkodogo	0	2	1	0	3
	Fada N'Gourma	0	3	0	0	3
Total 4 countries		5	263	6	7	281

commonly sort out debris, mouldy grain, etc. to make their offering more appealing. Another major factor is the dryness of the grain; virtually all of our samples had moisture contents at or below the levels that support aflatoxin accumulation. Other researchers who sampled maize grain in bulk may have used unsorted grain, which might tend to have much higher levels of fungal toxins. Another mitigating factor was the low level of insect pests, which are known to transport pathogenic fungal spores in infested grain stores (McMillian, 1987; Hell et al., 2000). In the present study 78.0% of the samples were free of insect pests.

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