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Dietary exposure to aflatoxin from maize and groundnut in young children from Benin and Togo, West Africa

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Abstract

Aflatoxins are a family of fungal toxins that are carcinogenic to man and cause immunosuppression, cancer and growth reduction in animals. We conducted a cross-sectional study among 480 children (age 9 months to 5 years) across 4 agro-ecological zones (SS, NGS, SGS and CS) in Benin and Togo to identify the effect of aflatoxin exposure on child growth and assess the pattern of exposure. Prior reports on this study [Gong, Y.Y., Cardwell, K., Hounsa, A., Egal, S., Turner, Hall, A.J., Wild, C.P., 2002. Dietary aflatoxin exposure and impaired growth in young children from Benin and Togo: cross sectional study. British Medical Journal 325, 20–21, Gong, Y.Y., Egal, S., Hounsa, A., Turner, P.C., Hall, A.J., Cardwell, K., Wild, C.P., 2003. Determinants of aflatoxin exposure in young children from Benin and Togo, West Africa: the critical role of weaning and weaning foods. International Journal of Epidemiology, 32, 556–562] showed that aflatoxin exposure among these children is widespread (99%) and that growth faltering is associated with high blood aflatoxin-albumin adducts (AF-alb adducts), a measure of recent past exposure. The present report demonstrates that consumption of maize is an important source of aflatoxin exposure for the survey population. Higher AF-alb adducts were correlated with higher *A. flavus* (CFU) infestation of maize ($p=0.006$), higher aflatoxin contamination (ppb) of maize ($p<0.0001$) and higher consumption frequencies of maize ($p=0.053$). The likelihood of aflatoxin exposure from maize was particularly high in agro-ecological zones where the frequency of maize consumption (SGS and CS), the presence of aflatoxin in maize (SGS) or the presence of *A. flavus* on maize (NGS and SGS) was relatively high. Socio-economic background did not affect the presence of *A. flavus* and aflatoxin in maize, but better maternal education was associated with lower frequencies of maize consumption among children from the northernmost agro-ecological zone (SS) ($p=0.001$). The impact of groundnut consumption on aflatoxin exposure was limited in this population. High AF-alb adduct levels were correlated with high prevalence of *A. flavus* and aflatoxin in groundnut, but significance was weak after adjustment for weaning status, agro-ecological zone and maternal socio-economic status (resp. $p=0.091$ and $p=0.083$). Ingestion of *A. flavus* and aflatoxin was high in certain agro-ecological zones (SS and SGS) and among the higher socio-economic strata due to

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higher frequencies of groundnut consumption. Contamination of groundnuts was similar across socio-economic and agro-ecological boundaries.

In conclusion, dietary exposure to aflatoxin from groundnut was less than from maize in young children from Benin and Togo. Intervention strategies that aim to reduce dietary exposure in this population need to focus on maize consumption in particular, but they should not ignore consumption of groundnuts.

Keywords: Aspergillus flavus; Aflatoxin; Dietary exposure; Maize; Groundnut; Children

1. Introduction

Aflatoxins are produced by fungi of the genus *Aspergillus*. *Aspergillus flavus* is the most common toxic species, but different strains produce different amounts of aflatoxin and some produce none. Fungal growth is facilitated by long-term storage under unhygienic, unventilated, hot and humid conditions (Williams and McDonald, 1983; Hell et al., 2000). *Aspergillus flavus* can grow on a multitude of foodstuffs, but maize and groundnut are particularly susceptible (Hesseltine, 1986). The main aflatoxins occurring naturally in foods are designated B_1, B_2, G_1, and G_2. Aflatoxin B_1 is the most toxic and usually predominant (FAO and WHO, 1997). Humans are primarily exposed to aflatoxin through dietary intake (Stoloff, 1983).

Aflatoxins are detrimental to human health. Their role in hepatocarcinogenesis often in conjunction with hepatitis B is well established (Wild and Hall, 1998; IARC, 2002; Wild and Turner, 2002). There is some evidence for associations with Reye's syndrome, Kwashiorkor, and acute hepatitis (Wild and Hall, 1996). More recently, aflatoxin exposure early in life has been associated with impaired growth, particularly stunting (Gong et al., 2002). Due to its high toxicity and carcinogenic properties, legal tolerance levels in the USA and EU are low for aflatoxin in foods that are destined for human consumption (resp. 20 parts per billion (ppb) and 4 ppb). Protective legislation is non-existent in Benin and Togo even though the traditional diet poses a potential health hazard; maize is the principal staple, groundnut is frequently consumed in snacks or sauces and climatic conditions favour development of *A. flavus* and aflatoxin (Cardwell, 2000).

In a cross-sectional study of children under five in Benin and Togo, aflatoxin-albumin (AF-alb) adducts were detected in 99% (475/479) of blood serum samples, with a geometric mean of 32.8 pg/mg and a maximum of 1064 pg/mg (Gong et al., 2002, 2003). Adduct levels varied markedly across agro-ecological zones with mean levels being approximately four times higher in the center (Southern Guinea Savannah, SGS) than in the northern Sudan Savannah (SS) (respectively 75.9 and 18.0 pg/mg). While there were differences in AF-alb levels across maternal socio-economic quartiles, there was no consistent trend between the two measures. Gong et al. (2003) earmarked food-intake as the principal source of aflatoxin exposure, because fully weaned children had approximately 2-fold higher mean AF-alb adduct levels than those receiving a mixture of breast milk and solid foods (respectively 37.7 and 21.1 pg/mg). Aflatoxins in breast milk are usually hydroxylated metabolites that are less toxic than aflatoxins in solid food (Zarba et al., 1992; IARC, 1993). Once children stop consuming breast milk, the intake of solid food and potent aflatoxins will increase.

To determine the at-risk population in Benin and Togo, a study was designed to assess whether:

1) consumption of maize and groundnut were related to aflatoxin exposure,
2) contamination of maize and groundnuts varied across socio-economic and geographical boundaries,
3) consumption frequencies of maize and groundnuts varied across socio-economic and geographical boundaries.

This report expands on data published on maize and groundnut consumption in relation to AF-alb levels in children (Gong et al., 2003). In addition to frequencies of consumption, aflatoxin contamination and *A. flavus* infestation of maize and groundnut have been taken into consideration.

2. Materials and methods

2.1. Research area

The study was conducted in the adjacent republics of Benin and Togo. From north to south four different agro-ecological zones can be distinguished on the basis of rainfall patterns and growing seasons; the SS, the Northern Guinea Savannah (NGS), the SGS and the Coastal Savannah Mosaic (CS). The CS and SGS have two maize growing seasons and average rainfall ranges from 1300–1500 mm in the CS to 1100–1300 mm in the SGS. The NGS and SS have only one maize growing season and rainfall ranges from 900–1100 mm in the NGS to <900 mm in the SS (Hell et al., 2000). Within each agro-ecological zone, four villages were selected on the basis of their proximity to a regional health center to facilitate rapid processing and temporary storage of blood samples. Ethical approval for this study was obtained from the Ministries of Health in Benin and Togo.

2.2. Subject recruitment

The study focused on children because child growth is a good indication of the general health status of children (de Onis and Blossner, 2001). Children were selected around the age of weaning because the transition from breast milk to solid food-intake highlights the importance of dietary aflatoxin exposure. Between January and April 2000, a total of 480 children aged 9 months to 5 years were randomly recruited (30/village). Storage of maize and documentation referring to the child's date of birth were mandatory criteria for selection. The household head and the mother of the selected child were informed of the nature of the study and consent was obtained. Eleven parents refused to sign and consequently their children were not included in the study.

2.3. Survey

A questionnaire was supplied to mothers of selected children. It obtained information on the household (size, composition and assets), the mother (education, position in the household, birthing history, assets, savings and revenues) and the child (age, sex, general health status, weaning status, birth order and food consumption frequencies in the week preceding the survey). Child body weight (Seca scale) and height (Shorr Board) were measured so that nutritional status could be calculated according to the median value of the international reference population recommended by NCHS/WHO (WHO working group, 1986). Socio-economic status of mother and household was defined in terms of wealth; a methodology comparable to the asset-index developed by the Worldbank in which assets are assigned a weight reflecting their economic value (HNP World Bank, 2000). The socio-economic status of the mother was based on earnings, savings and possession of land, cattle, equipment and means of transportation. The socio-economic status of the household was based on quality and ownership of housing and the means of transportation belonging to the household head. For analytic purposes, socio-economic quartiles were calculated.

3. Assessment of *A. flavus* and aflatoxin in maize and groundnut

Each household donated a 100-g sample of the maize it was consuming at the time of study. If available, groundnuts were sampled as well. A total of 502 maize and 175 groundnut samples were collected. Fifty grams of each sample was ground with a Romer® mill (Romer, Union, Missouri, USA) and subsequently 10 g was diluted with distilled water into a homogenous mixture. Four replicates of 1 ml aliquots of the solution were spread on culture plates containing modified Rose Bengal medium (Cotty, 1994). The plates were incubated in the dark in an incubator (Percival, Boone, Iowa, USA) at 30 °C for a period of 4 days, after which *A. flavus* colony forming units (CFUs) could be identified and counted. Based on sclerotial colony morphology *A. flavus* L-strains and the more toxic S-strains were identified (L for large and S for small) (Cotty and Bayman, 1993). The method of Thomas et al. (1975) was employed for extraction of aflatoxin B_1, B_2, G_1, and G_2 on the basis of a 50-g sub-sample. This report will focus on aflatoxin B_1 because aflatoxin B_2, G_1, and G_2 are less toxic and

Table 1
Prevalence of *Aspergillus flavus* (CFU) and aflatoxin B_1 (ppb) in maize and groundnut

		Maize (%)	Groundnut (%)
A. flavus	L&S-strain CFUs	90.8	58.3
	L-strain CFUs	90.4	52.0
	S-strain CFUs	22.5	26.3
Aflatoxin B_1	>0 ppb	8.0	2.9
	≥20 ppb	3.6	1.7
N		502	175

less likely to result in AF-alb adducts. Aflatoxin levels were determined with a fluorescence densitometer (Shimadzu, model 9301(PC) S, Kyoto, Japan).

3.1. Assessment of child aflatoxin exposure

A 5 ml blood sample was obtained from each child, and serum was isolated by centrifugation. The levels of AF-alb adduct were determined by ELISA, with a detection limit of 3 pg AF-lysine equivalents per mg of albumin (3 pg/mg), as described in Gong et al. (2003). AF-alb adducts are a measure of cumulative exposure over the last 2 to 3 months (Chapot and Wild, 1991). They can come from any aflatoxin, such as B_1 and G_1 but not B_2 and G_2, that can be metabolised to 8,9-epoxide. AF-alb levels in the current survey population should however be regarded as a measure of the levels of aflatoxin B_1 ingested, because presence of G_1 in the contaminated food was rare. Moreover, aflatoxin G_1 forms far less epoxide than B_1 and its epoxide is less well recognised by the antibody in ELISA.

3.2. Statistical analysis

All the analyses were performed using SAS V8 software. Determinant coefficients (R^2) were computed to investigate interactions between AF-alb adducts and consumption of maize and groundnut. These interactions were subsequently verified by entering significant variables of maternal socio-economic status, agro-ecological zone and weaning status into a multivariable model. Differences between mean AF-alb adduct levels were tested by *t*-test, Wilcoxon and GLM. When differences were found means were separated with Fisher's-Least-Significant-Difference at $p \leq 0.05$. CFU, ppb and AF-alb adduct data were not normally distributed. For the purpose of analysis, these data were natural-log-transformed to normalize data (Zar, 1974), but back-transformed results are shown in tables and text.

4. Results

4.1. Maize contamination

Aspergillus flavus was detected in 90.8% of the maize samples with 3.6% of the maize exceeding the U.S. legal tolerance level of 20 ppb (Table 1). The majority (90.4%) of maize samples contained *A. flavus*

Table 2
Aspergillus flavus (CFU) and aflatoxin B_1 (ppb) in maize by agro-ecological zone

		N	SS	NGS	SGS	CS
A. flavus	Prevalence of L&/S-strain CFUs	502	93.6% a	96.7% a	94.2% a	78.3% b
	Prevalence of L-strain CFUs	502	93.0% a	95.8% a	94.2% a	78.3% b
	Prevalence of S-strain CFUs	502	37.6% a	35.8% a	10.8% b	3.3 % b
	Mean[a] L&/S strain CFU[b]	455	134.0 b	279.7 a	303.9 a	142.6 b
	Mean[a] L-strain CFU[b]	454	127.5 b	268.5 a	297.9 a	140.5 b
	Mean[a] S-strain CFU[b]	113	25.1 a	42.0 a	33.3 a	23.6 a
Aflatoxin B_1	Prevalence of >0 ppb	502	2.8% b	8.3% ab	14.4% a	10.1% a
	Prevalence of ≥20 ppb	502	0.7% b	4.2% ab	8.5% a	4.2% ab
	Mean[a] ppb[b]	43	7.6 b	27.7 a	25.3 a	16.7 ab

[a] Means have been separated using LSD. Different letters within a row indicate that means are significantly different. Only positive samples have been included in this analysis.
[b] *A. flavus* (CFU) and aflatoxin content (ppb) were log($x+1$)-transformed before analysis.

Table 3
Aspergillus flavus (CFU) and aflatoxin B_1 (ppb) in groundnut by agro-ecological zone

		N	SS	NGS	SGS	CS
A. flavus	Prevalence of L&S-strain CFUs	175	61.4% a	56.9% a	56.5% a	0% n/a
	Prevalence of L-strain CFUs	175	54.3% a	48.3% a	54.4% a	0% n/a
	Prevalence of S-strain CFUs	175	37.1% a	22.4% a	15.2% a	0% n/a
	Mean[a] L&S-strain CFU[b]	102	63.6 a	81.6 a	40.8 a	–
	Mean[a] L-strain CFU[b]	91	39.4 a	63.0 a	35.0 a	–
	Mean[a] S-strain CFU[b]	46	52.2 a	76.6 a	51.2 a	–
Aflatoxin B_1	Prevalence of >0 ppb	175	2.9% a	3.5% a	2.2% a	0% n/a
	Prevalence of ≥20 ppb	175	0% a	3.5% a	2.2% a	0% n/a
	Mean[a] ppb[b]	5	12.5 a	362.8 a	528.3 a	–

[a] Means have been separated using LSD. Different letters within a row indicate that means are significantly different. Only positive samples have been included in this analysis. n/a means not applicable as only 1 sample was taken in the CS.
[b] *A. flavus* (CFU) and aflatoxin content (ppb) were $\log(x+1)$-transformed before analysis.

L-strain colonies, while only 22.5% contained S-strain CFUs (Table 1). Prevalence of infestation decreased significantly from north to south for both L- and S-strains. Among infested samples, mean S-strain CFU levels were similar across agro-ecological zones. Average L-strain CFU levels were highest in the center (NGS and SGS) (Table 2).

In maize samples, higher CFU levels were correlated with higher aflatoxin contamination ($p<0.0001$, $r=0.360$). Prevalence of aflatoxin in maize varied between 14.4% in the SGS and 2.8% in the SS. On the average, contaminated samples contained 7.6 ppb in the SS and 27.7 ppb in the NGS. One in 13 samples from the SGS exceeded the U.S. legal tolerance level of 20 ppb, while only 1 in 142 samples from the SS surpassed 20 ppb (Table 2). Aflatoxin level (AL) and CFU levels were similar across socio-economic quartiles and maternal education was not associated with AL and CFU levels (data not shown).

4.2. Groundnut contamination

Aspergillus flavus was detected in 58.3% of the groundnut samples. Aflatoxin was found in 2.9% of the samples, with 1.7% of the samples exceeding 20 ppb (Table 1). More than half (52.0%) of the groundnut samples contained *A. flavus* L-strain colonies, while 26.3% showed S-strain CFUs (Table 1). *A. flavus* was not found in the CS, but prevalence of L-strain infestation was around 50% in all other agro-ecological zones. Prevalence of S-strain infestation decreased from 3 7.1% in the SS to 15.2% in the SGS. For infested samples, mean CFU levels did not differ between agro-ecological zones (Table 3).

In groundnut samples, higher *A. flavus* infestation (CFU) was correlated with higher AL ($p<0.0001$, $r=0.317$), with no significant differences in AL between agro-ecological zones (Table 3). AL and CFU levels were similar across socio-economic quartiles

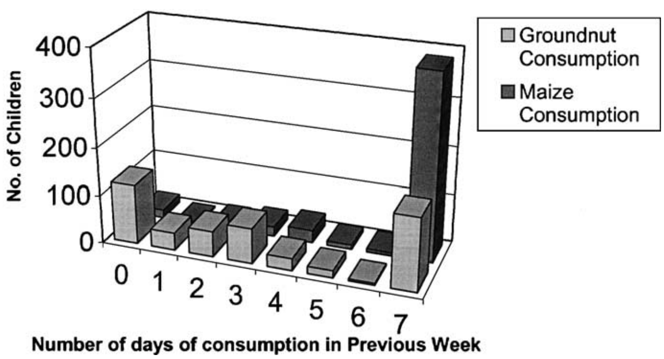

Fig. 1. Frequency of maize and groundnut consumption in days during the week prior to survey.

Table 4
Average frequencies of maize and groundnut consumption by agro-ecological zone in the week prior to survey

	SS	NGS	SGS	CS
Average[a] maize consumption (days/week)	5.7 b	5.6 b	6.8 a	6.6 a
Average[a] groundnut consumption (days/week)	4.8 a	2.6 b	4.6 a	1.4 c
N	120	120	120	120

[a] Averages have been separated using LSD. Averages followed by different letters within a row are significantly different.

and were not associated with maternal education (data not shown).

4.3. Consumption frequencies of maize and groundnut

Maize consumption in the week preceding this survey was frequent and fairly uniform among the survey population, while consumption of groundnut was variable and relatively low. The average frequency of maize consumption was 6.2 days a week and 80% of the children consumed maize on a daily basis, while 3.6% consumed none. Groundnuts were consumed an average of 3.4 days a week; 31.5% of the children consumed groundnut every day while 25.6% did not consume any (Fig. 1).

The consumption of maize and groundnuts showed marked regional variation (Table 4). The average frequency of maize consumption in the north (SS and NGS) was less than 6 days a week, whereas it was rare for children in the south (SGS and CS) to do without maize for a single day ($p<0.0001$, $t=6.82$). Groundnut consumption was at least twice as frequent among children in the SS and SGS, than among children in the NGS and CS ($p<0.0001$, $t=12.13$). Outside of the SS, higher socio-economic status was correlated with a higher frequency of groundnut consumption (Table 5). Maternal education did not affect the frequency of groundnut consumption and the frequency of maize consumption was similar across socio-economic quartiles. Within the SS, however, children with uneducated mothers consumed maize significantly more frequent than children whose mothers had received some formal education (resp. 5.9 versus 3.7 days a week; $p=0.001$, $X^2=10.5$). Maternal education and the frequency of maize consumption were not correlated in other agro-ecological zones.

4.4. Factors responsible for AF-alb adducts in blood

A higher frequency of maize consumption was correlated with higher AF-alb adducts in blood, even after adjustment for maternal socio-economic status, agro-ecological zone and weaning status. Similarly, higher AL and CFU levels (*A. flavus* infestation) in maize were associated with higher AF-alb adduct levels (Table 6). Aflatoxin contamination of maize explained 6% of inter individual variation in AF-alb adducts. CFUs and the frequency of consumption explained 2% of inter individual variation each (Table 6).

AF-alb adducts were not associated with the frequency of groundnut consumption. Aflatoxin and CFU levels in groundnut did not correlate with AF-alb adduct levels either. New variables were created representing the intake of aflatoxin and CFUs in the week preceding the survey by multiplying ppb and

Table 5
Socio-economic status and average[a] consumption frequencies for groundnut by agro-ecological zone in the week prior to survey

Variable	Category	SS (days)	NGS (days)	SGS (days)	CS (days)
Maternal socio-economic status	1st quartile(poorest)	4.4 a	1.5 b	3.4 b	1.1 c
	2nd quartile	5.0 a	3.2 a	4.7 ab	0.9 bc
	3rd quartile	5.0 a	2.9 a	4.3 ab	2.0 ab
	4th quartile(richest)	4.7 a	3.8 a	5.6 a	2.9 a
Household socio-economic status	1st quartile(poorest)	4.7 a	2.0 b	3.7 c	0.8 b
	2nd quartile	5.7 a	2.3 b	4.0 bc	1.6 ab
	3rd quartile	4.7 a	3.3 ab	5.6 a	1.9 ab
	4th quartile(richest)	4.8 a	4.1 a	5.1 ab	2.1 a
N		117	118	118	117

[a] Averages have been separated using LSD. Averages followed by different letters within a column are significantly different.

Table 6
Aflatoxin albumin adducts correlated with maize and groundnut consumption (frequency of consumption, aflatoxin B_1 and *A. flavus* content and intake)

		N	Regression		Multivariate model[a]
			P	R^2	P
Maize	Frequency of consumption (days/week)	478	0.0012	0.02	0.053
	Aflatoxin B_1 content (ppb[b])	476	<0.0001	0.06	<0.0001
	A. flavus content (CFU[b])	478	0.0007	0.02	0.006
Groundnut	Frequency of consumption (days/week)	479	0.193	0.00	0.217
	Aflatoxin B_1 content (ppb[b])	174	0.338	0.01	0.478
	A. flavus content (CFU[b])	174	0.328	0.01	0.102
	Aflatoxin B_1 intake (ppb[b]/week)	174	0.038	0.03	0.091
	A. flavus intake (CFU[b]/week)	174	0.061	0.02	0.083

[a] Adjusted for significant variables of maternal socio-economic status, agro-ecological zone and weaning status.
[b] AF-alb adducts (pg/mg), aflatoxin content (ppb) and *A. flavus* content (CFU) were $\log(x+1)$-transformed before analysis.

CFU levels by the frequency of consumption. Higher AF-alb adduct levels were associated with higher CFU and ppb intake, but significance became weak after adjustment for maternal socio-economic status, agro-ecological zone and weaning status (Table 6). Aflatoxin intake through groundnut (ppb/week) explained 3% of inter individual variation in AF-alb adducts whereas *A. flavus* intake (CFU/week) explained 2% (Table 6).

5. Discussion

The current study demonstrated that maize consumption was highly correlated with aflatoxin exposure as measured in blood serum among children less than 5 years of age in Benin and Togo. Groundnut consumption also contributed to aflatoxin exposure among this group of children, but its importance was less. Difference could be due to lower frequencies of consumption as compared to maize (resp. 3.4 and 6.2 days/week) and relatively low prevalence of aflatoxin in groundnut (2.9% as compared to 8.0%). One should also bear in mind that maize, as the principle staple, is consumed in larger quantities than groundnuts that are consumed in small quantities in the form of snacks, as groundnut oil and in sauces that accompany the family meal.

Maize and groundnut consumption is possibly the most important sources of aflatoxin exposure in Benin and Togo, but in this study, determination coefficients explained no more than 9% of the inter individual variability in AF-alb adducts. Other sources of dietary aflatoxin exposure such as dried fish, yam and cassava chips (FAO, 1979; Wheatley, 1984; Bassa et al., 2001) might explain the remaining variability, but these commodities are usually consumed less frequently than maize. Bois et al. (1995) and d'Errico et al. (1996) have suggested that genetic differences affecting the metabolism of aflatoxin might be at the root of inter-individual variation in AF-alb adducts. But Wild et al. (2000) found no evidence of this effect, at least in Gambian adults. It is most likely that factors related to the survey method are responsible for the modest impact of maize and groundnut consumption on AF-alb adduct levels in this study. First, AF-alb adducts are a measure of cumulative exposure over the last 2 to 3 months (Chapot and Wild, 1991), while the current study only focused on consumption during the week preceding the survey. Second, the actual quantity of consumption was never measured and the frequency of consumption was used as a proxy for quantity instead. Third, objective assessment of the relation between consumption and AF-alb adducts might have been hampered by the fact that no prepared foods were sampled. Several dishes involve wetted maize and groundnut that are often allowed to stand in ambient temperatures during the day. Under optimal conditions *A. flavus* can produce aflatoxin within 24 h after infestation (Gwinner et al., 1996) and aflatoxin can increase by 6% an hour (Univ. of Illinois, 1997). Finally, the prevalence of aflatoxin in maize and groundnuts might have been underestimated as a result of the sampling methods used. The distribution of aflatoxin in stored grains is not uniform (Whitaker et al., 1979; Francis et al., 1988). Davis et al. (1980) came to the conclusion that approximately 4500 g of shelled produce is needed to determine the average aflatoxin distribution in a lot. In order to prevent depletion of the family larder, the current study took 100-g samples only. Consequently, prevalence of aflatoxin in maize and groundnut might have been higher than presented in this study. Higher prevalence rates would be easier to reconcile with the high prevalence (99%) of AF-alb adducts in child blood.

AF-alb adducts increased with more frequent consumption of maize (Table 2 and see also Gong et al., 2003). Maize consumption was particularly high in the southern agro-ecological zones (CS and SGS) whereas it was particularly low among children in the SS whose mothers had received some formal education (3.7 days/week). Educated mothers are possibly more aware of the beneficial health effects related to diversification of food consumption.

In this study, prevalence of aflatoxin in maize varied between 3.9% in the SS and 14.4% in the SGS. Prevalence in a prior 2-year survey in Benin varied between 5.0% in the SS and 72.5% in the NGS. Differences between seasons and years were considerable, but consistently higher ppb levels were found in the SGS (Hell et al., 2003), the same zone that showed a higher risk of aflatoxin exposure in the presented study.

Aspergillus flavus can be divided into S- and L-strains, S-strain isolates produce greater quantities of aflatoxin than do L-strain isolates (Garber and Cotty, 1997). In Benin, Cardwell and Cotty (2002) observed an increase in the distribution of *A. flavus* S-strains from south to north, while they reported a declining occurrence of L-strains along this gradient. In the current study, prevalence of infestation increased from south to north, for both L- and S-strains. These data may be affected by sampling period, because samples in the north were taken during the dry months of January and February, while samples in the south were taken at the onset of the rainy season in March and April times that might have been more favourable for *A. flavus* development.

Higher frequencies of groundnut consumption were correlated with higher socio-economic status in most of the survey area. People with higher disposable income are probably more inclined to buy a groundnut snack (kulikuli), a product that is notoriously contaminated with aflatoxin (Bankole et al., 2005). Also they might often choose to prepare their food with groundnut oil instead of cheaper alternatives like palm-oil and shea-butter. No regional variation was observed for development of *A. flavus* and aflatoxin in groundnut, although theoretically, relative humidity and temperature are considered important factors (ICRISAT, 1991).

The current survey has been the first to measure the effect of individual maize and groundnut consumption on aflatoxin exposure among children. For a more exact appreciation, it is recommendable that future studies closely monitor and quantify consumption over a period of 3 months. Such a study would explain variability of AF-alb adducts in greater detail and unexplained variability could subsequently be attributed to other sources of exposure and possibly to genetic differences affecting the metabolism of aflatoxin. The current study can only indicate that maize is an important source of aflatoxin exposure in Benin and Togo and that the effect of groundnut consumption is limited. Consumption of both commodities was frequent across socio-economic and regional boundaries while contamination was nationwide. It is recommended that awareness campaigns in Benin and Togo inform people of the risks associated with consumption of groundnut and particularly maize. These campaigns must provide feasible alternatives to the consumption of contaminated produce through improved production, harvesting and storage techniques (Hell et al., 2000, 2003). Adoption of these techniques holds the potential to reduce aflatoxin exposure without compromising demand for major food supplies.

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