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Factors Affecting Aflatoxin Contamination of Harvested Maize in the Three Agroecological Zones of Uganda

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Abstract: A survey was conducted in 2003 to establish aflatoxin levels in maize and the associated farmer practices in the three agroecological zones of Uganda. Maize kernels obtained from farmers in the Mid-Altitude (moist) zone had the highest aflatoxin contaminated samples (83%) and mean aflatoxin levels of 9.7 ppb followed by those from the Mid-Altitude (dry) where 70% were contaminated with a mean of 7.7 ppb, while the kernels sampled from the Highland zone had the least contaminated samples (55%) and mean aflatoxin levels of 3.9 ppb. Aflatoxin contamination in maize grain was positively related to leaving maize to dry in the field for more than three weeks, drying maize without husks, drying maize on bare ground, shelling maize by beating, heaping maize on the floor during storage and use of baskets for storage of maize. The practices that negatively impacted on aflatoxin development in maize in the agroecological zones were sorting before storage, storage of maize in shelled form, storage of maize in bags, use of improved granary as storage structures, storage of maize above fireplace and use of synthetic pesticides. Thus, those practices that reduce aflatoxin contamination of maize should be adopted by all farmers in Uganda to reduce the health hazards associated with consumption of contaminated maize grain.

Key words: Maize quality, Postharvest practices, abiotic factors, health

INTRODUCTION

Maize (*Zea mays* L.) is the most important cereal crop in Uganda, contributing to 40% of the per capita calorie intake in both rural and urban areas. As an export crop, maize is ranked third of the Non-Traditional Exports in the country. Total maize production in Uganda in 2004 was more than 1,200,000 Metric Tonnes (MT) produced on a total area of 670,000 ha (FAO, 2004). There are three agroecological zones where maize is produced in Uganda (Kyetere, 1996) These are the Mid-Altitude-900-1500 m above sea level (moist) representing 75% of production area; the Mid-Altitude-900-1500 m above sea level (dry) representing 15% of production area; and the Highland->1500 m above sea level representing 10% of production area. These areas experience varied climatic conditions and in each zone there are prevailing conditions that impact negatively on the quantity and quality attributes of maize. These include among others, farmer practices that expose the harvested crop to moisture pick-up, insect infestation and above all, fungal infection and mycotoxin production.

It is evident that maize in Uganda is contaminated by aflatoxins (Sebunya and Yourtee, 1990; Ssebukyu, 2000; Kaaya *et al*., 2005) which are potent carcinogenic and immuno-suppressing mycotoxins produced mainly by the fungus *Aspergillus flavus* (Turner *et al*., 2003; Williams *et al*., 2004). A number of traditional practices used by farmers in Uganda have been implicated in promoting aflatoxin contamination in maize. However, there have been little efforts in compiling these practices and relate them to aflatoxin contamination in maize.

The objectives of the study were two fold (i) to establish the harvest and postharvest maize farmer practices in the three agroecological zones and (ii) relate these practices to aflatoxin contamination of harvested maize grain. The findings of this study are very important in recommending practices that can be adopted by subsistence farmers to reduce aflatoxin contamination in order to improve the quality of harvested maize in the country.

MATERIALS AND METHODS

Study sites: In each of the three maize agroecological zones, two districts well-known for maize production according to Kikafunda-Twine *et al*. (2001) were purposively selected as study sites. These were

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Mayuge and Masindi districts from the Mid-Altitude (moist) zone, Nakasongola and Kasese districts from the Mid-Altitude (dry) zone and Kapchworwa and Mbale districts from the Highland zone.

Establishment of maize farmer harvest and postharvest practices: A survey was conducted during July-August, 2003 to establish harvesting, drying, shelling and storage practices of maize used by farmers in the districts of Mayuge, Masindi, Kasese, Nakasongola and Mbale; while in Kapchworwa, the survey was conducted in October 2003, the only month maize is harvested. The questionnaires used in both cases were designed according to Udoh *et al.* (2000) with slight modifications, to obtain the required information. Since practices were not likely to differ so much in each district, one parish was randomly selected and in each parish, twenty farmers from at least two villages located not less than 10 km apart, were interviewed using the questionnaire.

Sampling maize for aflatoxin analysis: The farmers who responded to questions on harvest and postharvest practices of maize also provided samples for aflatoxin analysis. One maize sample, 5 cobs each (unshelled) or 1 kg (shelled) was sampled from each of the farmers' stores following the methods recommended by Juan-Lopez *et al.* (1995) and FAO (1982). Thus, in the three agroecological zones, a total of 120 samples were collected from farmers. These samples were of that current season but dried and stored in different forms (shelled or unshelled) and in different storage structures. During sampling care was taken to note the practices used by the farmer for each sample to enable relate the practices to aflatoxin contamination of the grains. The samples were transferred to the Department of Food Science and Technology, Makerere University and stored at -20°C to prevent further postharvest accumulation of moulds and aflatoxins until analysis (Anderson *et al.*, 1995).

Aflatoxin analysis: The unshelled maize samples were hand shelled to form sample lots which were analysed for aflatoxins. Each of the samples was divided into two replicate lots and aflatoxins were extracted using methanol-water solution (80:20 vol) and quantified in parts per billion (ppb) using Aflatest® Fluorometer following the manufacturer's procedures (VICAM L.P., 313 Pleasant Street, Watertown, MA 02472, USA). The detection limits were set at 0 ppb (lowest) and 50 ppb (highest). The range and mean aflatoxin content (ppb) of the samples were computed.

Data analysis: Data in questionnaires from the two districts in each agroecological zone were combined and coded. The answers to yes or no were entered as binomial values. Answers to categorical questions were entered as numbers. Stepwise multiple linear regression was used to identify the factors that significantly promote or reduce aflatoxin contamination of maize across the agroecological zones. The statistical programme used was SPSS (SPSS for Windows, Release 10.01, Standard Version 1999; SPSS Inc. 1989-1999). Aflatoxin levels were transformed using natural log to normalize the data before analysis.

RESULTS

Harvesting practices: All respondents in the three agroecological zones indicated that they harvest maize by hand; after the crop has been left to partially dry in the field. The results of the survey indicated that farmers leave maize to dry in the field for varying periods of time (Table 1). The majority of respondents in the Mid-Altitude (moist) and in the Mid-Altitude (dry) leave the crop standing in the field for more than three weeks after attaining physiological maturity. However, fewer respondents in the Highland agroecological zone indicated that they leave maize in the field for more than three weeks compared to those respondents who leave maize to dry in the field for 2 to 3 weeks (Table 1).

Table 1: Percentage of respondents leaving maize to dry in the field for different periods in the three agroecological zones of Uganda

Period	Respondents practicing (%)		
	Mid-altitude (moist)	Mid-altitude (dry)	High-altitude
1 week	5.0	2.5	5.0
2 weeks	7.5	20.0	37.5
3 weeks	27.5	30.0	37.5
>3 weeks	60.0	47.5	20.0

Table 2: Methods used by farmers to dry maize in the agroecological zones of Uganda

Method	Respondents using method (%)[a]		
	Mid-altitude (moist)	Mid-altitude (dry)	High-altitude
Bare-ground	92.5	90.0	85.0
Plastered ground	2.5	0.0	0.0
Plastic sheets	10.0	7.5	5.0
Mats	32.5	17.5	12.5
Rocks	5.0	0.0	5.0
Crib	7.5	7.5	10.0
Granary	0.0	0.0	35.0

[a]Multiple positive responses obtained

Table 3: Methods used to shell maize by farmers in the agroecological zones of Uganda

Method	Respondents using method (%)		
	Mid-Altitude (moist)	Mid-Altitude (dry)	High-Altitude
Hand shelling	32.5	10.0	37.5
Beating	52.5	77.5	47.5
Maize sheller	0.0	0.0	10.0
Both hand shelling and beating	15.0	12.5	5.0

Table 4: Storage systems and forms of maize by farmers in the agroecological zones of Uganda

		Respondents (%)[a]		
Storage system	Storage form	Mid-Altitude (moist)	Mid-Altitude (dry)	Highland
Polypropylene bags	Shelled/unshelled, dehusked	60.0	67.5	62.5
Heaping on floor	Shelled/unshelled, dehusked	35.0	37.5	27.5
Jerrican	Shelled	10.0	2.5	0.0
Above fire-place	Unshelled, with husks	2.5	5.0	7.5
Under Verandah	Unshelled, with husks	10.0	7.5	17.5
Basket	Shelled/unshelled, dehusked	2.5	10.0	0.0
Granaries	Unshelled, with husks	0.0	0.0	35.0

[a]Multiple positive responses obtained

Table 5: Aflatoxin contamination of maize kernels obtained from farmers in the three agroecological zones of Uganda

			Aflatoxin content (ppb)	
Production zone	No. of samples	Positive (%)	Range	Mean
Mid-altitude (moist)	40	82.5	0-25	9.73
Mid-altitude (dry)	40	70	0-18	7.72
Highland	40	55	0-10	3.92
LSD (p = 0.05)				2.334

Drying practices: The survey revealed that, after harvest, the majority of farmers in each agroecological zone remove husks from maize before home drying. Various methods of drying maize across the zones were also reported (Table 2). The methods included drying on bare ground, plastered ground, mats, plastic sheets, rocks, cribs and granaries. Four or more methods are practiced by farmers in the same agroecological zone. More than 80% of the respondents in each zone indicated that they dry their maize on bare ground. Use of granaries was only reported in the Highland zone, in the district of Kapchworwa, where some farmers dry maize on bare ground for a very short time followed by drying in granaries.

Shelling methods: Three methods of shelling maize were reported to be used in the maize agroecological zones surveyed (Table 3). Of these, beating cobs were reported to be used by the majority of farmers. Use of hand-operated maize shellers was only reported by respondents in the Highland zone and their use was limited to 10% of the respondents. Respondents reported that those farmers who shell by hand do so for kernels intended for sowing. Kernels for selling to markets are mainly shelled by beating.

Storage practices: During the survey, it was established that 100, 97.5 and 97.5% of the respondents from the Mid-Altitude (moist), Mid-Altitude (dry) and High-Altitude ecological zones respectively store maize after drying and sorting. The basis for sorting grain was according to discolouration, dirtiness, degree of moulding and broken grain as well as removal of foreign matter. The majority of farmers can store more than 20 bags of maize, for a period of 1-4 months.

Several storage practices of maize in use by farmers across zones were reported by respondents and are presented in Table 4. Maize was stored with the husks, without the husks or as loose grain (shelled), depending on storage method. The storage methods included use of polypropylene bags of capacity 50-100 kg, heaping grain or ears on plastered or unplastered floor in the house, use of old *jerricans* (20 L plastic containers that originally were used to fetch water), storage of cobs in husks above the fire-place in the kitchen or main house, use of verandah where the cobs are individually placed under the roof, storage in baskets woven with plant materials and storage in granaries. The majority of respondents across the zones (60% or more) reported that they use polypropylene bags to store maize either shelled or unshelled. Heaping maize on the floor is also a common storage practice. Use of granaries was reported in only the Highland zone. In addition, no *jerricans* and baskets were reported to be used for maize storage in the Highland zone (Table 4).

During storage, farmers face several problems but rodents and insects were reported to be the most common. In order to manage these, farmers use several strategies including redrying, poisons (rodenticides) and traps to control rodents and synthetic insecticides to control insects. In addition the majority of respondents (55, 92.5 and 77.5%) in the Mid-Altitude (moist), Mid-Altitude (dry) and Highland zones respectively, indicated that they clean their storage structures before storing new crop. Across the agroecological zones, sweeping to remove waste materials and old stock grains was the commonest cleaning method and was reported to be used by more than 90% of the respondents.

Aflatoxin contamination of maize: The results of aflatoxin contamination of maize kernels obtained from farmers in the three maize agroecological zones of Uganda are presented in Table 5. There were significant differences

Table 6: Harvest and postharvest practices that are significantly related to aflatoxin levels (Y) in agroecological zones ($Y = 4.001 + 21.690X_1 + 21.682X_2 +\ldots -19.196X_{13}$; $R^2 = 0.85$)[a]; F= 44.56

Factor/variable	Parameter estimate	t	p>t
Intercept	4.001	4.04	<0.001
X_1	21.690	4.73	<0.001
X_2	21.682	4.70	<0.001
X_3	22.781	4.79	<0.001
X_4	19.505	4.07	<0.001
X_5	-6.824	2.09	0.042
X_6	-24.810	5.40	<0.001
X_7	-5.934	2.78	0.037
X_8	20.845	4.50	<0.001
X_9	-21.264	4.33	<0.001
X_{10}	-19.470	3.65	0.032
X_{11}	-30.796	6.66	<0.001
X_{12}	18.535	3.64	0.034
X_{13}	-19.196	4.04	<0.001

[a]Where: X_1, Leaving maize to dry in the field for more than three weeks; X_2, Drying maize without husks; X_3, Drying maize on bare ground; X_4, Shelling maize by beating; X_5, Sorting before storage; X_6, Storage of maize in shelled form; X_7, Storage of maize in bags; X_8 Heaping maize on floor during storage; X_9, Cleaning storage structures before storage; X_{10}, Use of improved granary as storage structure; X_{11}, Storage of maize above fireplace; X_{12}, Use of baskets for storage of maize; X_{13}, Use of synthetic pesticides (Actellic Super or Malathion, 2%); Y = Aflatoxin levels (ppb)

($p \leq 0.05$) among the aflatoxin levels in maize kernels obtained from farmers in the three agroecological zones. Maize obtained from farmers in the Mid-Altitude (moist) zone had the highest aflatoxin contaminated samples (83%) and mean aflatoxin levels of 9.7 ppb while the kernels sampled from the Highland zone had the least contaminated samples (55%) and mean aflatoxin levels of 3.9 ppb.

Farmer practices that affect aflatoxin contamination of maize: Thirteen major factors significantly affecting aflatoxin contamination of maize were identified across the agroecological zones (Table 6). A stepwise linear regression analysis of the factors gave a coefficient of determination (R^2) of 0.85 an indication that the model used was able to explain 85% of the variation in aflatoxin contamination of maize.

Aflatoxin development in maize grain was positively related to leaving maize to dry in the field for more than three weeks, drying maize without husks, drying maize on bare ground, shelling maize by beating, heaping maize on the floor during storage and use of baskets. The practices that negatively impacted on aflatoxin development in maize across zones included sorting before storage, storage of maize in shelled form, storage of maize in bags, use of improved granary as storage structures, storage of maize above fireplace and use of synthetic pesticides (Table 6).

DISCUSSION

The results of this study have revealed that there are several farmer harvest and postharvest practices of maize in each agroecological zone. Although the mean aflatoxin levels of maize from each agroecological zone was less than the 20 ppb FDA/WHO regulatory upper limit (Mphande *et al*., 2004), some of the farmer practices influence maize aflatoxin contamination.

Across the agroecological zones, leaving maize to dry in the field for more than three weeks was found to be among the most important factors associated with higher aflatoxin levels in the sampled maize supporting the findings from previous authors. Harvest time is very crucial as regards the subsequent storage quality of grain. Early harvesting has been advocated as a means of reducing the risk of aflatoxin contamination (Bankole and Adebanjo, 2003). According to Agona *et al*. (1999) the most suitable maize harvest period is at physiological maturity. FAO (1999) emphasizes that delayed harvest is one of the factors that enhance preharvest aflatoxin contamination. Sauer (1978) reported that the longer the crop is left to dry in the field after attaining maximum dry matter, the higher the chances of mycotoxin contamination due to enhanced conditions that favour insects, fungi, birds, lodging and shuttering. Although many farmers are aware of the need for early harvesting, market and labour constraints as well as unpredictable weather often compel them to harvest later in the season (Bankole and Adebanjo, 2003).

Drying on bare ground is the most common traditional practice of drying cereals and legumes in Uganda (Odogola, 1994). However, when dried on bare ground maize grain can be contaminated with soil, moulds and foreign matter thus adversely affecting its quality (Odogola and Henriksson, 1991). This could explain why drying maize on bare ground was positively associated to aflatoxin contamination. This problem is exacerbated by farmers who dry shelled or maize without husks on bare ground. Good husk cover serves as a barrier against insect, fungal and bird attack as well as water seepage. Udoh *et al.* (2000) reported that drying maize with the husk in the southern zones of Nigeria was associated with reduction in aflatoxin contamination of stored maize.

Shelling maize grain by beating was in this study, related to increased aflatoxin contamination. Shelling maize by hand is a common practice in Uganda for grain intended for seed since beating the kernels off the cob results in damage to the grain which would reduce germination (Kikafunda-Twine *et al*., 2001). However, this practice is labour intensive and time consuming thus not suitable for maize intended for commercial purposes. Beating inflicts physical or mechanical damage to the grain making them prone to fungal invasion including *A. flavus/parasiticus* and therefore mycotoxin production (Tuite *et al*., 1985; Bankole and Adebanjo, 2003). Possibly use of hand shellers should be promoted in Uganda since grain shelled by these simple equipments is often clean with no mechanical damage.

Heaping maize on the floor during storage was positively associated with aflatoxin contamination as compared to storage in bags which was associated with a reduction in aflatoxin contamination as reported by Udoh *et al.* (2000). Heaping maize grain during storage promotes mould and insect proliferation especially when the grain is inadequately dried due to heat build-up. This however, depends on the size of the heap and whether grain is heaped on bare ground, plastered/cemented floor or raised platform. The larger the size of the heap, the more likely the heat build-up due to inadequate aeration. Grain heaped on bare ground is also more likely to be contaminated than that heaped on plastered floor. The majority of farmers and traders in Uganda use inter-woven polypropylene bags as packages for storage and transportation of maize. These bags are easy to handle, are durable and have been reported to protect the grain to some degree, against moisture pick-up as long as they are stacked off the floor using stones or pallets.

Storage of maize in baskets was associated with an increase in aflatoxin contamination. These are woven storage containers which are not covered during storage and therefore do not protect grain against insects, rodents, moulds and moisture pick-up which are factors that promote aflatoxin contamination. In Nigeria, Udoh *et al.* (2000) associated baskets with reduced aflatoxin contamination because they are kept over the fire place which is not the case in Uganda. Similarly, in the current study storage of maize above the fire place was related to lower aflatoxin contamination of maize. Smoking significantly reduces levels of weevil damage and moisture content in maize which subsequently leads to a reduction in aflatoxin levels (Daramola, 1991). However, according to Bankole and Adebanjo (2003) the problem with smoking is that if not carefully applied, it may discolour the product and change the taste. In Uganda, although smoking as a storage method is easily affordable by resource-poor farmers, it may not be suitable for commercial farmers who are the majority of maize producers.

Sorting out diseased, damaged and discoloured maize kernels as well as cleaning before storage were associated with reduced aflatoxin levels across agroecological zones. Similar results were reported by Hell *et al.* (2000) and Udoh *et al.* (2000) in Benin and Nigeria, respectively. These practices help to reduce the fungal inocula load and infected substrates. This reduces chances of mould proliferation by infecting health kernels and subsequent production of mycotoxins as confirmed by Martin *et al.* (1999) and Galvez *et al.* (2003). Since more than 80% of the respondents across the production zones indicated that they sort maize before storage, this should be encouraged to be practiced by all maize handlers in the country to reduce aflatoxin contamination of the crop.

Storage of maize in a shelled form was negatively related to aflatoxin development as was established by Hell *et al.* (2000) in Benin, West Africa. This is probably attributed to the ease with which loose grain can easily be dried to safe storage moisture content compared to grain on cob. According to results obtained in this study, several farmers in all agroecological zones reported as storing maize on cobs, husked or dehusked agreeing with (Kikafunda-Twine *et al.*, 2001), who reported that most farmers in Uganda store maize on cobs until there is need for it either for sale, seed or to mill for family use. Higher development rates of insects on maize stored on cobs than that stored in shelled form have been reported (Kyamanywa, 1994) which would have an aflatoxin-increasing effect (Dunkel, 1988; Sétamou *et al.*, 1998). Probably, where possible, farmers in Uganda should be advised to store maize in a shelled form, in polypropylene bags, to reduce aflatoxin contamination.

Use of improved granaries was also related to a reduction in aflatoxin contamination. These are recommended improved storage structures adopted by farmers from Kawanda Agricultural Research Institute (KARI) and therefore may be better in terms of maintaining the quality of maize grain during storage compared to traditional granaries. In Kapchworwa district, more than 50% of the farmers have adopted these granaries (Mutyaba, unpublished data). However, use of granaries in Uganda to store high value crops like maize has of recent become less popular due to theft. The materials used for construction are weak and therefore easy to destroy by thieves and also allow entry of insects.

Use of synthetic pesticides like Actellic Super and Malathion (2%) was another practice that significantly reduced aflatoxin development. These pesticides control insect pests that have a direct effect on mould and aflatoxin contamination. In a study by El-Kady *et al.* (1993) it was observed that Actellic® did not have any direct effect on *A. flavus* development in maize grain, thus it was concluded that the aflatoxin-reducing effect of these insecticides is a secondary effect through the reduction of insect infestation. However, fewer farmers in Uganda can afford to use synthetic pesticides during storage of maize due to economies of scale and the lack of knowledge on use of such pesticides.

All practices established in this study as reducing aflatoxin contamination of maize should be adopted by all maize farmers in Uganda to reduce the health hazards associated with consumption of contaminated grain.

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