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# Storage structures and aflatoxin content of maize in five agroecological zones of Nigeria

J.M. Udoh[a,*], K.F. Cardwell[b], T. Ikotun[c]

[a]*Forage Genetic Resources ILRI, P.O. Box 5689, Addis-Ababa, Ethiopia*
[b]*International Institute of Tropical Agriculture, Ibadan, Nigeria*
[c]*Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria*

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**Abstract**

A survey was conducted in 1994 to describe the maize storage systems, quantify the aflatoxin levels in these storage systems, and identify the main problems of maize storage recognized by both men and women farmers in five agroecological zones in Nigeria.

Maize storage in bags was the most common among all farmers. The clay *rhumbu* was used in 4 out of 5 agroecological zones by both male and female farmers. The woven *oba* was found only in the southern Guinea savanna and was used predominantly by women. Only 13% of the male farmers in the southern Guinea savanna and none in the other zones stored in an improved crib while no female farmers across all the zones used the crib system of storage.

Male and female farmers across all the zones identified insect infestation, and fungal and rodent attack as the main problems in their stored maize. Insect infestation was reported by 83% of the female farmers in the southern Guinea savanna zone who stored maize in bags. The highest fungal attack on stored maize was reported by 71% of the male farmers who stored maize in bags in the humid forest zone, while 75% of the male farmers who stored in bags in the Sudan savanna zone complained of rodent attack. Across all zones, farmers of both genders identified insects as the most common storage problem.

Farmers who reported insect problems were significantly more likely to have aflatoxin in their stores. The highest zonal mean aflatoxin level of 125.6 μg/kg was obtained from maize samples provided by male farmers in the Sudan savanna zone who stored maize in bags or in a *rhumbu*. Across the storage systems, 33% were contaminated with detectable levels of aflatoxin. No aflatoxin was detected in the storage systems of male or female farmers in the northern Guinea savanna zone in 1994. 

*Keywords:* Grain storage; Aflatoxin; Gender; Storage pests; Maize

* Corresponding author.
*E-mail address:* j.edeme@cgiar.org (J.M. Udoh).

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## 1. Introduction

Maize (*Zea mays* L.) is one of the most important cereals grown and eaten in Nigeria. In the past, its cultivation was mainly in the southern part of the country, millet and sorghum being the predominant cereal crops of the north (Opadokun et al., 1979). Today, maize has displaced sorghum and millet from all but the most arid areas (FAO, 1992). In 1992, the national maize production area in Nigeria was 1.5 million ha with an estimated grain yield of 1.3 t/h or a total production of 1.8 million t (FAO, 1992). In 1996, the maize production area totalled 4 million ha, with 0.9 million ha in the humid forest zone, 0.4 million ha in the southern Guinea savanna, 1.4 million ha in the northern Guinea savanna, 0.9 million ha in the Sudan savanna and 0.4 million ha in the Mid-altitude zone (Manyong et al., 1996).

Despite the importance of maize in the country, little is known about the various storage systems used by farmers. Meretiwon (1981) conducted a survey in the Oyo Local Government Area, which lies in the southern Guinea savanna zone of Nigeria. He identified four types of maize storage systems: (1) the traditional crib; (2) the modern ventilated crib; (3) storage in synthetic bags; and (4) storage in which the ears and grains are piled on the floor in a room. However, he made no report on the percentages of male and female farmers using these various storage systems. The preference for the different storage systems with respect to gender is an important indicator of distribution of resources within the farm family and community.

Adesuyi (1972, 1973) reported that out of a total of 8.75 million t of grains produced in Nigeria in 1970–1971, between 2.5 and 4.0% were lost to insects annually while between 1.25 and 3% were damaged by fungi. Okereke and Nwosu (1987) reported an estimated loss of 58% in 1000 t of maize due to insect and fungal attack.

In this study, a survey of the five agroecological zones was carried out to identify the maize storage systems used by male and female farmers, to measure the levels of aflatoxin in the stored maize, and to identify other storage problems.

## 2. Materials and methods

### 2.1. Agroecological zones

The agroecological zones of Nigeria as identified by Iloeje (1981) are described below.

1. The *humid forest zone* extends from the western boundary of Nigeria south-eastward to Cameroon, and lies within latitudes 6°4′ and 7°5′N and longitudes 3°5′ and 8°8′E. The annual rainfall is 130–150 cm in the west and over 200 cm in the east. The high humidity, generally over 80%, and the long wet season of 8–10 months, ensures an adequate supply of water and continuous presence of moisture in the air.
2. The *mid-altitude* plateau is a pear-shaped upland area approximately 104 km from east to west in between latitudes 4°6′ and 9°5′N and longitudes 8°5′ and 9°2′E. It rises by a 600 m escarpment from a height of 30 m to a height of 750 m above sea level. The plateau is one of the coolest parts of the country, temperatures range between 21°C and 25°C. The mid-altitude zone has an annual rainfall of approximately 140–143 cm.

3. The *southern Guinea savanna* lies within latitudes 7°4′ and 8°7′N and longitudes 4°1′ and 12°2′E. Over most of this zone, the annual rainfall varies from 100 cm and 150 cm and the dry season lasts from 4 to 6 months.
4. The *northern Guinea savanna* lies within latitudes 9°4′ and 11°5′N and longitudes 3°8′ and 13°1′E. The distribution of rainfall is unimodal with annual levels between 90 cm and 120 cm. There is a distinct wet season of about 4–6 months and a dry season of about 4–6 months when total rainfall is less than 25 mm.
5. The *Sudan savanna* is in the far north of the country between latitudes 12°2′ and 13°8′N and longitudes 3°9′ and 13°9′E. The annual rainfall is between 65 and 100 cm and the relative humidity is below 40% except in the few wet months when it averages 60%. The dry season lasts from 6–8 months.

### *2.2. Data collection and analysis*

Five villages were selected in each agroecological zone. The villages were chosen based on information obtained from the Federal Agricultural Coordinating Unit (FACU), Ibadan, Nigeria. The FACU personnel selected villages where farmers predominantly grow maize and where they were accustomed to interviews and would be likely to cooperate with the data collection. Farmers of both sexes were interviewed. Female farmers were often more involved in trading than in farming. From the list obtained from the farmers' cooperative society, it was observed that for every three male farmers, there were in effect only two female farmers. Three male and two female farmers were therefore selected in each village from the list, based on a stratified sample design. The survey was conducted 7–8 months after harvest.

Pre-tested questionnaires were administered to the farmers (Appendix A). The farmers were asked, among other things, questions on the type of storage problems they experienced, when they noticed these problems, and the storage systems they used. All categorical data were coded as discrete binomial dummy variables for subsequent analysis.

A 5 kg sample of maize was collected from each farmers' store. Frequencies of responses were calculated and correlation analysis was carried out on the survey variables. The results of the correlation analysis indicated that some of the variables were correlated, so a principal component analysis (PCA) was used to identify significant variables within each linear system. Variables with coefficients $>0.5$ were selected from the eigenvectors that explained the most variance, and these were used as independent variables in a stepwise regression analysis with aflatoxin level (μg/kg) in the maize samples as the dependent variable.

### *2.3. Aflatoxin analysis*

The method developed by Thomas et al. (1975) and modified by Singh et al. (1991) was used for the detection and estimation of aflatoxins in the maize samples collected. Fifty gram samples of maize were milled using a Romer mill. The maize sample was extracted with 60:40 methanol:water v/v solvent, separated, and re-extracted with chloroform. Thin layer chromatography (TLC) was used to quantify the extracted aflatoxin. Five, 10 and 15 μl of aflatoxin standards (SIGMA) were spotted in the bottom center of each plate and 5, 10 and 15 μl of five extracts were spotted starting from the sides of the plates to the center. The plates were viewed in a Chromatovue UV cabinet under long-wave UV light (365 nm) and the concentration of aflatoxin was calculated based on relative fluorescence (Singh et al., 1991). Confirmatory tests were also based on the methods of Singh et al. (1991).

## 3. Results

### 3.1. Storage systems

Twelve storage systems were identified according to the materials used in construction and how maize is stored within them (Table 1). Five of the systems were typically stocked with dehusked cobs, two systems held maize in the husk, and five held loose grain.

From Table 2 it can be seen that the most common storage system used by farmers across all agroecological zones was storage as shelled grain in polythene bags. More female than male farmers stored maize in bags in the mid-altitude and northern Guinea savanna zones (75% and 82% respectively).

Twenty-five percent of the female farmers in the humid forest zone stored maize over the fireplace compared to 12% of their male counterparts (Table 2). In all zones except the humid forest zone, male and female farmers zones stored maize in a *rhumbu* (Table 2). The oba was most common in the southern Guinea savanna zone and used predominantly by the women farmers (70%).

The highest mean aflatoxin level for maize collected from male farmers was 125.6 μg/kg. This was obtained when maize was stored in bags and in the *rhumbu* in the Sudan savanna zone (Table 3). Female farmers in the mid-altitude zone who stored maize in bags had the highest mean aflatoxin of among the female farmers (115 μg/kg). No aflatoxin was detected in the storage systems of any farmer in the northern Guinea savanna zone during the 1994 survey period.

From Table 4, it can be seen that male and female farmers across all the zones observed insect infestation, and fungal and rodent attack in their stored maize. The highest percentage of reported insect infestation was by 83% of the female farmers in the southern Guinea savanna zone who stored maize in bags. The highest reported fungal attack on stored maize was 71% by male farmers who stored maize in bags in the humid forest zone, while 75% of the male farmers who stored in bags in the Sudan savanna complained of rodent attack.

A stepwise regression of factors related to aflatoxin in the humid forest zone indicated that smoking the maize such as in storage over a fireplace which has a drying effect on the maize, was significantly related to lower levels of aflatoxin contamination. The presence of insects in the maize was significantly related to higher levels of aflatoxin (Table 5, Eq. 1).

In the mid-altitude zone, the use of fertilizer, local maize variety, harvesting maize with the husk, treating the maize seed before planting and sorting out damaged cobs were associated with reduced aflatoxin contamination (Table 6, Eq. 2).

In the southern Guinea savanna zone, sorting out cobs with poor husk cover, treating maize

Table 1
Maize storage systems

| Storage system | Description | Storage form |
| --- | --- | --- |
| Floor | A room within the house is set aside for maize and other harvested products | Dehusked |
| Tree | Maize tied in bunches on trees | Dehusked |
| Pot | 15 by 70 cm clay pots over the fire-place | Dehusked |
| Basket | Woven baskets kept over the fire-place | Dehusked |
| Crib | Improved system with rat guards, wire mesh, and corrugated iron sheet roof (FAO recommended) | Dehusked |
| Platform | Bamboo strips tied together | In husk |
| Fireplace | Maize tied over the fire in the kitchen | In husk |
| *Rhumbu* | Traditional silos made of mud and grass or stovers, elevated on stones to guard against attack by rodents | Grain |
| *Oba* | Woven grass/palm fronds or dry sorghum stalks supported on tree stumps | Grain |
| Bottle | 2.5 l glass bottles | Grain |
| Drum | 220 l barrels | Grain |
| Bag | 50 kg polythene bags | Grain |

Table 2
Distribution of maize storage systems by gender and agroecological zone

| Zone | Storage system | Male farmers (%) | Female farmers (%) |
|---|---|---|---|
| Humid forest | Platform | 41 | 12 |
| | Bag | 35 | 25 |
| | Fire place | 12 | 25 |
| | Bottle | 0 | 12 |
| | Floor | 0 | 13 |
| | Pot | 12 | 7 |
| | Basket | 0 | 6 |
| Mid-altitude | Platform | 16 | 0 |
| | Bag | 23 | 75 |
| | *Rhumbu* | 46 | 8 |
| | Floor | 0 | 17 |
| | Tree | 15 | 0 |
| Southern Guinea savanna | Bags | 38 | 12 |
| | Crib | 13 | 0 |
| | Fire place | 0 | 8 |
| | *Rhumbu* | 24 | 10 |
| | *Oba* | 25 | 70 |
| Northern Guinea savanna | Bag | 64 | 82 |
| | *Rhumbu* | 29 | 12 |
| | Floor | 7 | 0 |
| | Basket | 0 | 6 |
| Sudan savanna | Bags | 62 | 50 |
| | *Rhumbu* | 28 | 50 |
| | Drum | 10 | 0 |
| | Basket | 5 | 0 |

Table 3
Storage systems contaminated by aflatoxin by agroecological zone and farmer gender

| | | Frequency of use | | Mean aflatoxin μg/kg (range) | |
|---|---|---|---|---|---|
| Zone[a] | Storage system | Male | Female | Male | Female |
| Humid forest | Platform | 7/17 | 1/8 | 75 (0–900) | 0 |
| | Bags | 6/17 | 2/8 | | |
| Mid-altitude | Bags | 3/13 | 9/12 | 63 (0–750) | 115 (0–1380) |
| Southern guinea savanna | Bags | 5/16 | 6/9 | 56 (0–7) | 56 (0–617) |
| | Bags | 14/21 | 2/4 | 126 (0–1506) | 0 |
| Sudan Savanna | *Rhumbu* | 7/21 | 2/4 | | |

[a] No aflatoxin was detected from storage systems in the northern Guinea savanna zone.

Table 4
Male and female respondents reporting problems in their storage systems (%)[a]

| Zone | Storage systems | Male farmers (%) | | | Female farmers (%) | | |
|---|---|---|---|---|---|---|---|
| | | Fungi | Rats | Insects | Fungi | Rats | Insects |
| Humid forest | Platform | 29 | 27 | 44 | 29 | 45 | 26 |
| | Bag | 71 | 11 | 28 | 50 | 33 | 17 |
| | Fire place | 0 | 80 | 20 | 50 | 0 | 50 |
| | Pot | 0 | 18 | 7 | 0 | 33 | 0 |
| | Bottle | 0 | 0 | 0 | 0 | | 25 |
| Mid-altitude | Platform | 0 | 40 | 13 | 0 | 0 | 0 |
| | Bag | 0 | 40 | 38 | 50 | 80 | 60 |
| | *Rhumbu* | 0 | 40 | 60 | 0 | 10 | 60 |
| | Floor | 0 | 0 | 0 | 0 | 10 | 20 |
| | Tree | 0 | 20 | 0 | 0 | 0 | 0 |
| Southern Guinea savanna | Bag | 0 | 31 | 33 | 0 | 63 | 83 |
| | Crib | 40 | 15 | 13 | 0 | 0 | 0 |
| | Fire place | 0 | 0 | 0 | 0 | 13 | 0 |
| | *Rhumbu* | 0 | 8 | 20 | 0 | 25 | 17 |
| | *Oba* | 0 | 31 | 27 | 0 | 0 | 0 |
| Northern Guinea savanna | Bag | 0 | 58 | 67 | 0 | 79 | 100 |
| | *Rhumbu* | 0 | 33 | 22 | 0 | 22 | 33 |
| | Floor | 0 | 17 | 11 | 0 | 0 | 0 |
| | Basket | 0 | 0 | 0 | 0 | 11 | 20 |
| Sudan savanna | Bag | 0 | 75 | 67 | 0 | 50 | 50 |
| | *Rhumbu* | 0 | 31 | 27 | 0 | 50 | 50 |
| | Drum | 0 | 0 | 7 | 0 | 0 | 0 |
| | Basket | 0 | 0 | 7 | 0 | 0 | 0 |

[a] Multiple positive responses possible.

seeds before planting, and storing maize in a crib were associated with decreased aflatoxin contamination in the stored maize. The presence of insects was a significant contributing factor in increased aflatoxin levels (Table 7). Although the male and female farmers in the northern Guinea savanna zone also perceived insect infestation of their maize (Table 4), no aflatoxin was detected in any of the maize samples obtained (Table 3). Factors associated with reduced aflatoxin levels in the Sudan savanna zone were the use of recommended pesticides, storage in bags or in the *rhumbu* and using local plant leaves as a storage treatment (Table 8, Eq. 4).

## 4. Discussion

The most common method of maize storage in all the agroecological zones was storage in polythene bags. Both male and female farmers reported storing maize this way because the

Table 5
Summary of stepwise regression analysis on aflatoxin for the humid forest zone. $Y_{HF} = 2.667 - 2.00X_1 + 2.33X_2$. ($R^2 = 0.75$) (eqn 1)[a]

| Variable | Parameter estimate | $t$ | $p > t$ |
|---|---|---|---|
| Intercept | 2.667 | 2.84 | 0.012 |
| $X_1$ | −2.000 | 4.51 | < 0.001 |
| $X_2$ | 2.333 | 2.56 | 0.021 |
| $X_3$ | −0.667 | 1.54 | 0.144 |
| $X_4$ | −1.333 | 2.13 | 0.049 |
| $X_5$ | −0.667 | 1.78 | 0.094 |
| $X_6$ | 0.667 | 1.50 | 0.152 |

[a] where: $X_1$ = use of smoke as a storage treatment of maize; $X_2$ = presence of storage problems; $X_3$ = use of fertilizer; $X_4$ = storage of maize in baskets; $X_5$ = storage of maize on a raised platform; $X_6$ = storage of maize dehusked; $Y_{HF}$ = aflatoxin levels (μg/kg) in humid forest zone.

bags were able to hold a large quantity of grain, and because the bags were cheap and easy to handle and label. The bags were also where the majority of the aflatoxin was found and in some areas this storage system was not particularly effective in keeping out insects. Thus, this practice appears to be detrimental to the long-term quality of the stored grain. Nigeria is a producer of plastic, and there has obviously been widespread adoption of this practice in the country. It is not common in the neighboring country Benin (Hell et al., in press), but it is being recommended by extension agents in northern Cameroon (Z. Ngoko, personal

Table 6
Summary of stepwise regression analysis on aflatoxin for the mid-altitude zone. $Y_{MA} = 4.247 - 1.003X_1 - 0.933X_2 - 0.730X_3 - 0.750X_4 - 0.686X_5$. ($R^2 = 0.70$) (eqn 2)[a]

| Variable | Parameter estimate | $t$ | $t > p$ |
|---|---|---|---|
| Intercept | 4.247 | 8.31 | < 0.001 |
| $X_1$ | −1.003 | 2.43 | 0.027 |
| $X_2$ | 2.151 | 3.91 | 0.001 |
| $X_3$ | −0.933 | 2.95 | 0.009 |
| $X_4$ | −0.730 | 3.22 | 0.005 |
| $X_5$ | −0.750 | 2.94 | 0.010 |
| $X_6$ | −0.686 | 2.54 | 0.022 |
| $X_7$ | −0.346 | 1.52 | 0.148 |
| $X_8$ | 0.268 | 1.08 | 0.298 |

[a] where: $X_1$ = use of fertilizer; $X_2$ = maize storage in drum; $X_3$ = use of local maize variety; $X_4$ = harvesting with the husk; $X_5$ = treating the maize seed before planting; $X_6$ = sorting out damaged cobs; $X_7$ = leaving maize to dry at home for 4 months before storing; $X_8$ = leaving maize to dry in the field for 2 months before harvesting; $Y_{MA}$ = aflatoxin levels (μg/kg) in mid-altitude zone.

Table 7
Summary of stepwise regression analysis on aflatoxin for the southern Guinea savanna zone. $Y_{SGS} = 2.967 - 2.886X_1 - 0.694X_2 - 2.431X_3 + 2.631X_4$ ($R^2 = 0.95$) (eqn 3)[a]

| Variable | Parameter estimate | $t$ | $p > t$ |
|---|---|---|---|
| Intercept | 2.967 | 3.39 | 0.005 |
| $X_1$ | −2.886 | 11.81 | < 0.001 |
| $X_2$ | −0.694 | 3.00 | 0.011 |
| $X_3$ | −2.431 | 7.49 | < 0.001 |
| $X_4$ | 2.631 | 6.95 | < 0.001 |
| $X_5$ | −1.187 | 2.90 | 0.013 |
| $X_6$ | 0.244 | 1.32 | 0.211 |
| $X_7$ | −1.083 | 3.55 | 0.004 |
| $X_8$ | 1.274 | 4.32 | < 0.001 |

[a] where: $X_1$ = sorting cobs with poor husk cover; $X_2$ = treating maize seed before planting; $X_3$ = storage of maize in a crib; $X_4$ = storage problems; $X_5$ = sorting of damaged cobs in the field; $X_6$ = use of pesticides; $X_7$ = use of local maize variety; $X_8$ = harvesting maize with the husk; $Y_{SGS}$ = aflatoxin levels (μg/kg) in the southern Guinea savanna.

communication). Research on suitable bag materials should be conducted and extended in the region.

Female farmers constituted the largest percentage of farmers who stored maize over the fireplace. They reported that they store maize this way because (a) the smoke from the fire helps to keep the cobs dry and repel insects and (b) as they have less access to fertile soils than the male farmers, they usually had less maize.

Smoking/heating of maize was related to lower levels of aflatoxin contamination of maize. Smoking significantly reduces levels of weevil damage and moisture content in maize (Daramola, 1991), which subsequently leads to a reduction in aflatoxin levels. Storing maize

Table 8
Summary of stepwise regression analysis on aflatoxin for the Sudan savanna zone. $Y_{SS} = 4.986 - 1.586X_1 - 2.030X_2 - 2.816X_3 - 0.876X_4$ ($R^2 = 0.89$) (eqn 4)[a]

| Variable | Parameter estimate | $t$ | $p > t$ |
|---|---|---|---|
| Intercept | 4.986 | 9.22 | < 0.001 |
| $X_1$ | −1.586 | 7.89 | < 0.001 |
| $X_2$ | −2.030 | 7.24 | < 0.001 |
| $X_3$ | −2.816 | 9.05 | < 0.001 |
| $X_4$ | −2.816 | 6.02 | < 0.001 |
| $X_5$ | 0.674 | 5.11 | < 0.001 |
| $X_6$ | −0.876 | 2.76 | 0.015 |

[a] where: $X_1$ = use of pesticides; $X_2$ = storage of maize in bags; $X_3$ = storage of maize in rhumbu; $X_4$ = storage of maize in drum; $X_5$ = harvesting maize with husk; $X_6$ = use of local plant leaves as a storage treatment of maize; $Y_{SS}$ = aflatoxin levels (μg/kg) in the Sudan savanna.

over a fireplace compared favorably with the use of stored products pesticides such as pirimiphos-methyl. Besides being very effective, this method is also easily affordable for resource-poor farmers. In related work in Benin, farmers who used smoke to protect their maize were also found to have a lower risk of aflatoxin contamination in their maize (K. Hell, personal communication, 1998).

In the northern agroecological zones, the traditional *rhumbu* and *oba* were used. Farmers claimed that they preferred these traditional storage structures because they were simple and cheap to construct. The farmers in the northern Guinea savanna also claimed that they always sorted their maize cobs before storing and continued sorting periodically throughout storage. Since this survey was conducted 7–8 months after harvest, and the farmers reported sorting their maize prior to storage and periodically after storage, it could not be determined if aflatoxin could have been found in the maize at the time of harvest. This is probably an important factor explaining why aflatoxin was not detected in the maize samples obtained from this zone. The maize sorted and removed prior to storage is usually fed to livestock. Also, the northern Guinea savanna zone had the highest use of maize storage pesticides (Udoh et al., 2000). In this zone, 82% of the female farmers reported dusting their stored maize with the fungicide Thiram.

Maize storage in cribs is the farm and village maize storage method recommended by FAO (FAO, 1979; NSPRI, 1982). Although the male farmers interviewed in the southern Guinea savanna zone had been exposed to this method for some time, they were unwilling to utilize it because they believe it is not cost effective. The farmers also believed that they would incur additional expenses in terms of purchase of pesticides. These were also the reasons given by the male farmers in all other zones. No female farmers were found to be using a crib storage structure.

The female farmers often stated that they rarely had access to new technologies or innovations since these were usually targeted towards the male farmers whom, it was assumed, would pass on the information to them. Fortmann (1978) reported that husband to wife communication of extension messages in Tanzania was ineffective, and it is possible that this break in communication flow is occurring in Nigeria as well, particularly if the woman's enterprise is seen as conflicting or competing with other responsibilities (Amartya, 1990). Although the women farmers complained of not obtaining information concerning new technologies, currently used technologies were gender neutral. For example, polythene bags were a purchased input used almost equally by men and women. The *oba* was used predominantly by women since it is essentially a large woven basket that the women could construct themselves. The *rhumbu* was used more by men in the southern Guinea savanna zone (where women were using the *oba*) but it was a gender-neutral storage structure in the northern Guinea savanna zone with both men and women using it. Both genders had management practices that helped reduce the risk of aflatoxin production.

Insects have been known to be associated with spread of the fungus *Aspergillus flavus* and grain contamination by aflatoxin (Widstrom et al., 1976; McMillian et al., 1980, 1987; Barry et al., 1985; Beti et al., 1995; Setamou et al., 1998). A reduction in insect numbers can contribute significantly to the reduction of aflatoxin in stored maize (Lillehoj et al., 1978; Sinha and Ranjan, 1989). Specifically the maize weevil, *Sitophilus zeamais*

Motschulsky, has been reported to contribute significantly to *A. flavus* infection in maize and subsequent production of aflatoxin (McMillian et al., 1981; Miller, 1995). Weevils facilitate the growth of *A. flavus* and aflatoxin production in maize by increasing surface area susceptible to fungal infection and increasing moisture content as a result of weevil metabolic activity (Beti et al., 1995). Therefore efforts must be intensified to reduce insect infestation in stored maize in Nigeria.

Harvesting maize with the husk in the southern zones was associated with reduction in aflatoxin contamination of stored maize. Local maize varieties often have more complete husk cover than improved varieties, and less infestation with *S. zeamais* (Kossou et al., 1992, 1993). One of the reasons why farmers store maize in the husk is because it gives protection against weevils.

Sorting of damaged cobs and cobs with poor husk covering was another practice that led to a significant reduction in aflatoxin contamination. The use of local plant leaves/extracts such as bitter leaf (*Vernonia amygdalina* Delile) and ginger (*Zingiber officiale* Rosx and Holl) to control storage problems also significantly reduced aflatoxin contamination. Many plant extracts have been shown to possess fungitoxic properties (Cardwell and Dongo, 1994; Awuah, 1995). Nevertheless, caution must be exercised, because some plant materials are a natural medium for *A. flavus* and may make the situation worse. K. Hell, (personal communication, 1998) found that use of *Khaya senegalensis* (Desr., A. Juss) as a storage protectant significantly increased the risk of maize contamination with aflatoxin in Benin.

## 5. Conclusions

Since farmers are not eager to accept the 'improved' crib storage structure, work needs to be done on improving the efficacy of the new and traditional systems of storage that are being used. Particularly, the desirability of continued use of plastic bags should be investigated.

Extension messages for resource-poor farmers, who constitute the largest percentage of the farmers, can include recommendations to sort out damaged cobs and cobs with poor husk cover at the time of harvest, and to smoke their stored maize to achieve a drying effect. If pesticides are used to reduce insect damage, extension agents must make sure that appropriate pesticides are used (Udoh et al., 1998).

Extension programs should endeavor to work directly with female farmers to improve their access to new technologies and innovations.

Alternative solutions for control of insects and mycotoxic fungi should continue to be a research priority.

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## Appendix A. Questionnaire on farmers' maize harvesting and storage practices

Agroecological zone:
Village:
Name of farmer:

Section 1 Maize production

| | | | |
|---|---|---|---|
| 1. | Do you grow maize during the rainy season? | Yes | No |
| 2. | Do you grow maize during the dry season? | Yes | No |
| 3. | What seed do you use? | Own seed | Bought gift |
| 4. | Which variety do you use? | Local | Improved |
| 5. | Do you treat the seed with insecticide? | Yes | No |
| 6. | If yes, give the name of the product used: (show bag of product used) | | |
| 7. | Do you use fertilizer? | Yes | No |
| 8. | If yes, which fertilizer? | | |
| 9. | Do you use pesticides when the maize was still on the field? | Yes | No |
| 10. | If yes, which ones? | | |

Section 2 Harvest practices

| | | | |
|---|---|---|---|
| 1. | Are the damaged cobs separated out in the field? | Yes | No |
| 2. | If so, what attacks the maize in the field?<br>Insects<br>Mice/rats<br>Birds<br>Fungi | | |
| 3. | Are the cobs, which are not well covered, separated in the field? | Yes | No |
| 4. | Does the variety you used have good husk cover? | Yes | No |
| 5. | Are the cobs harvested with the husk? | Yes | No |
| 6. | How long do you leave your maize to dry on the plant before harvest? | | |
| 7. | How long do you dry your maize at home before storing? | | |

Section 3 Sorting of maize

| | | | |
|---|---|---|---|
| 1. | Do you sort the maize before storage? | Yes | No |
| 2. | If yes, on what basis did you sort the "good" maize?<br>Color<br>Cob size<br>Other | | |
| 3. | After sorting, what do you do with the "good" maize "bad" maize? | | |

Section 4. Storage practices

1. How long do you usually store?
2. What storage method do you use?

On a raised platform on the farm
In bags in a room in the house
In a constructed crib
Over the fire-place
On the ceiling
In a "*rhumbu*"
In an "*oba*"
In a bottle
Others

| | | | |
|---|---|---|---|
| 3. | Why do you store maize this way? | | |
| 4. | Do you use the storage for other foodstuffs? | Yes | No |
| 5. | If yes, which ones? | | |
| 6. | Do you have problems with storage? | Yes | No |
| 7. | What are the problems? | | |
| | Insects | | |
| | Mice/rats | | |
| | Fungi | | |
| | Theft | | |
| | Others | | |
| 8. | What do you do? | | |
| 9. | Do you clean the storage structure before storage? | Yes | No |
| 10. | If you treat the storage structure before use, what method did you use? | | |
| | Ash + pepper | | |
| | Smoke (fumigation) | | |
| | Local leaves | | |
| | Pesticides (specify) | | |
| | Others | | |
| 11. | Are the treatments that you use successful? | Yes | No |
| 12. | How do you store your maize? | | |
| | Grain | Yes | No |
| | In the husk | Yes | No |
| | Dehusked | Yes | No |

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