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RESEARCH ARTICLE

MAIZE PRE-STORAGE PRACTICES AND THEIR INFLUENCE ON AFLATOXIN CONTAMINATION OF MAIZE IN MAKUENI COUNTY, KENYA

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ABSTRACT

Background: Aflatoxicosis resulting from consumption of maize contaminated with aflatoxins mainly due to poor harvesting and storage of grains, poses a significant public health problem in many countries. Furthermore Aflatoxins related disease outbreaks, associated with a degree of mortality at times have been reported in Makueni County in Kenya.

Objective: To determine maize pre-storage conditions and practices that influence development of aflatoxin in Makueni County, Kenya.

Study design: A comparative descriptive study conducted in Kibwezi and Kilome sub-counties of Makueni County, Kenya.

Methods: Four hundred and fifty households (225 from each study site) which had maize in household were randomly sampled and household heads or their representatives interviewed using interview schedules. Are presentative sub-sample of households had their maize samples taken for moisture content and aflatoxin determination.

Results: The results showed that households allowed their maize to stay for a mean period of 25 days in low altitude and 45 days in high altitude after attaining maturity, and overwhelming majority (over 90%) of households removed outer covering (husks) of maize cobs during harvesting. Majority (96.3%) of households in both study sites dried their maize in open sunshine (sun drying) after harvest with majority of them (over 75%) placing maize on top of plastic sheeting material to avoid contamination, and to make their maize dry properly and faster. The drying time for maize was shorter in low altitude (mean14 days) than in high altitude (mean17 days). The study findings further showed that duration of maize in the field before harvest was significantly positively correlated with insect pests' infestation in maize while in storage ($P<0.05$). Results further revealed significant negative correlation between duration of maize in field prior to harvest and moisture content in maize ($P<0.05$). The placing of maize on top of impervious sheeting material/layer during drying was associated with proper maize storage ($P<0.05$). Duration of drying of maize after harvest especially in higher altitude area had significant negative correlation with aflatoxin content in maize as well as in moisture content ($P<0.05$).

Conclusion: Some maize harvesting and drying practices are associated with insect pests' infestation as well as certain aspects of aflatoxin contamination in maize. Thus adoption and improvement of these practices will more likely contribute to proper maize handling and storage with subsequent reduction of aflatoxin contamination of maize.

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INTRODUCTION

Aflatoxicosis caused by aflatoxinsresulting from consumption of contaminated maize is a significant public health problem in many countries including Kenya. It is estimated that a sizable proportion of people living in developing countries could be exposed to the risk of aflatoxin in their diet (Williams *et al.*, 2004). Aflatoxins are secondary metabolites from mould of the *Aspergillus* family. The species which produce aflatoxins which contaminate cereals and other foods are *Aspergillus parasiticus* and *Aspergillus flavus* (Bennet and Klich, 2003; Claudia *et al.*, 2007). In Kenya, the eastern region particularly Makueni has been mostly affected by aflatoxicosis outbreaks resulting from consumption of aflatoxin contaminated maize. Makueniis reported to have experienced three major outbreaks since 1981 when the first major outbreak was reported (Mwihia *et al.*, 2008; Decock and Rubin, 2005). This has necessitated authorities and stakeholders to undertake numerous strategies at various levels to control aflatoxin problem. Improvement of post-harvest handling of maize which includes pre-storage practices has been known to reduce or minimize aflatoxin contamination. Moreover this can also greatly reduce maize losses resulting from post-harvest handling inefficiencies and

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storage (Mboya *et al*., 2011). Moreover in a further effort to control aflatoxin poisoning, regulatory limits of aflatoxin contamination in foods including maize have been set at10 ppb (Lewis *et al*., 2005) Studies carried out previously in Makueni, supported earlier findings that aflatoxicosis was acquired from eating contaminated maize attributed to improper harvesting, drying and storage of maize (Mwihia *et al*., 2008). Pre-harvest interventions such as proper agricultural and pest management practices can reduce the presence and growth of *Aspergillus* fungi on pre-harvested crops and consequently reduce aflatoxin levels**.** It is observed that in most communities maize is traditionally left to mature and dry in the field prior to harvesting (Fandohan *et al*., 2006). Moreover, drying crops properly before storage, as well as sorting and disposing of visibly moldy or damaged kernels before storage can prevent or reduce the development of aflatoxins in postharvest drying and storage, although not eliminating them. Although majority of farmers store most of their maize for household consumption they sell some to meet other household needs, thus underscoring the importance of proper harvesting, drying and storage of maize.

MATERIALS AND METHODS

Description of Study Sites

This study was conducted in Kibwezi and Kilome sub-counties of Makueni County. Kibwezi study site is a lower altitude area situated at an altitude of 916 M above sea level, while Kilome study site is a higher altitude area situated at an altitude of 1750M above sea level. Due to change in altitude, the county has climatic variations and extreme differences in temperatures. The northern part is usually cool while the southern part with low-lying areas is usually hot. The mean temperatures in Makueni range from 20.2 to 24.6°C. This county experiences two rainy seasons, namely: the long rains season occurring in March/April and the short rains season occurring in November/December of each year. Maize is the main food crop produced in Makueni.

Study design and Setting

This was comparative analytical study to determine pre-storage conditions and practices of household maize in Kibwezi and Kilome sub-counties of Makueni County, Kenya.

Sampling

Two geographically and ecologically different sub-counties namely Kibwezi and Kilome were purposefully selected for this study for comparison purposes. In each zone, one geographical location was randomly selected. Representative sample of households was then selected from Sub-locations/cluster based on method of probability proportional to size. At each of the two zones studied, households storing maize were selected to create a sample of households which had maize. Households, which were the sampling units, were then selected at random through systematic random sampling methods using a sampling frame and a table of random numbers. The households' heads who consented to participate in the study were recruited. The study population included all adults (above 18 years of age) who are household heads or their representatives within the study area and store home grown maize. It also included, agricultural and public health workers working in the area as well as community informants who consented to participate in the study. It excluded people below 18 years of age. Each study site had a sample size of 225 households. A representative sub-sample comprising 10% of sampled households drawn through systematic random sampling method provided maize samples for moisture content determination and aflatoxin analysis.

Data Collection

Interview schedules, checklists and focus group discussion guides were used to collect data from the study sites. Information collected using interview schedules included 1) socio-demographic information, 2) knowledge and awareness on aflatoxin, 3) maize pre-storage practices and 4) maize storage practices. A checklist was used as a guide for collection of information on visual assessment of condition of maize as observed during storage as well as the condition of the storage structures. Focus group discussions (FGDs) with key community opinion leaders using FGD guides and interviews with agricultural and public health workers were conducted to corroborate information collected using questionnaires/interview schedules. Two FGDs, one in each study site, were conducted each comprising 12 people. One FGD was conducted in Kibwezi area while the other was conducted in Kilome area. Each FGD comprised of selected local opinion leaders which included women group leaders, youth group leaders, village leaders and other key stakeholders in the study area. Collection of data using questionnaires and taking of maize samples were done in October/November after first season maize harvestand in May/June after second season maize harvest.

Maize sampling

Maize samples were obtained from 10 % of sub-sampled households with maize which were selected for study and interviewed using structured interview schedules. A one kg of maize sample was taken from maize found in the sub-sampled household. The sample was taken in such a way that it was a representative of the lot. Samples were collected from maize intended for human consumption found in the household. In case of maize packed in small volumes in different bags, multiple samples were taken from different parts of one bag or several bags belonging to one household and combined to produce a one kg sample for analysis. The maize samples were collected in households after first season maize using sampling tools such as scoops/probes and put in paper bags, and carried and stored in paper bags while awaiting analysis. Each sample had a sampling form filled with specific identification information pertaining to the sample.

Maize sample analysis

Moisture content was measured in the field during collection of maize samples and was determined using Portable Grain Moisture Testermodel GMK303. Maize samples were also visually inspected for insect pests' and mold infestation. The analysis of maize samples for aflatoxin was done using ELISA test to determine presence of aflatoxin contamination. The procedures for moisture content determination, and aflatoxin determination using ELISA test are described here below.

Moisture Content Determination

Seventy (70) g of maize sample was taken, well shaken and filled into moisture device to flash level and corked tightly.

The sample was then allowed to run in the device for one minute and the moisture content was then read. A new test for a different sub-sample from the same sample was repeated and an average of the two readings for the sample was determined. After each reading was noted, the reading was cleared from memory before doing a new test.

Determination of Aflatoxin contamination

Determination of total Aflatoxin contamination was done using Enzyme Linked Immunoassay (ELISA) test. The test procedure was as described below:

Extraction of Sample

One kg of maize sample was ground into flour with a mill and homogenized. After which 20g of homogenized sample were weighed and 20ml of 70% Methanol were added into the sample. They were mixed for 2 hrs and filtered using Buchner funnel. The extraction jar was rinsed with 20mls of extraction solution. The total volume of the extract was then measured and recorded.

Column Preparation

Five (5) g in 25 mls (70% methanol) of extract were taken. And 10 % of methanol in Phosphate Buffered Saline (PBS) was prepared. Then 5ml of 10% methanol PBS were passed through without letting it dry. A sample comprising 1ml of extract and 6ml water was applied and let run slowly at the rate of 1 drop in 3 seconds. Distilled water-15ml was applied and passed slowly at rate of I drop per second. The air was passed to dry and the column was put to a receptacle for eluent. One (1) ml methanol (100 %) was applied and passed slowly into receptacle.

Cleaning up with Acetonitrile

Nine (9) mls of sample extract were taken and evaporated to dryness with nitrogen/rotavapour. It was consequently diluted with PBS buffer to 10mls (the amount of organic solvent did not exceed 5% of solution). The extract solution was filtered and dropped off onto the immumo-affinity column at the rate of 1-3ml/min. The Immuno-affinity column was washed with 20 ml of water and the water dropped through the column through gravity. The column was dried to ensure total Aflatoxins recovery. Derivatisation was done by evaporating all samples to dryness and then 200ul TFA were added and incubated at RT for 40 minutes, after which 800ul Acetonitrile: water (30:70) was added and dissolved using a sonicator. They were consequently filtered through a membrane filter (GHP 0.2um) into a vial.

Enzyme Linked Immunoassay (ELISA) Analysis

A sufficient number of micro-titer wells were inserted into the microwell holder for all standards and samples run in duplicate. Standard and sample positions were recorded. Then 50 µl of the standard solutions or prepared sample were added to separate duplicate wells, and 50 µl of the enzyme conjugate were added to each well. Then 50 µl of the antibody solution were added to each well and mixed gently by shaking the plate manually and incubating for 30 minutes at room temperature (20-25°C). The liquid was consequently poured out of the wells and the microwell holder tapped upside down vigorously (three times in a row) against absorbent paper to ensure the liquid from the wells was removed completely. All the wells were filled with 250 µl washing buffer 10.1 and the liquid poured out again. The the washing procedure was repeated two times. After which 100 µl of substrate/chromogen (brown cap) were added to each well and mixed gently by shaking the plate manually and incubating for 15 minutes at room temperature (20-25°C) in the dark. There after 100 µl of the stop solution were added to each well and mix gently by shaking the plate manually and the absorbance measured at 450 nm. Reading was done within 30 minutes after adding stop solution.

Data Management and Analysis

Data were cleaned, coded and entered in computer MS Windows Excel software and transferred to SPSS for Window Version 17.0 (SPSS Inc., Chicago, Illinois) for Statistical analyses. Chi-square test was used to determine association of independent variables including pre-harvest and pre-storage practices, and aflatoxin contamination in maize. Pearson Correlation coefficient was also used to analyse relationships of quantitative variables among different storage and pre-storage practices, and Aflatoxin levels. Tests of significance were at α=0.05 level of significance, and confidence levels at 95%. Quality of data was ensured by proper sampling, collection and analysis of samples in duplicate.

RESULTS

Household Socio-economic and demographic characteristics

The household respondents who were heads of households or their principal representatives had mean age of about 47 years in both study sites. Majority of respondents were female (58%) and most of them were married (74.2 %). Majority of them had attained primary education (61.7%). The main occupation of respondents was farming (79.2%) and farming was their main source of income for households (75.0%)) with majority of them (68.4%) earning less than Ksh.5000 (mean income was Ksh.4800), implying that majority of the people were poor.

Pre-Storage Practices

Pre-storage practices are practices which are undertaken before harvesting, during harvesting and drying of maize prior to storage.

Pre-harvest and harvest and drying Practices

Respondents were asked whether they removed the outer covering of maize cob during harvesting**.** In Kibwezi 218 (90.8%) said yes and 22(9.2%) said no, while in Kilome 238 (99.2%) said yes and 2(0.8%) said no. They were further asked to state how long mature maize had been in the field before harvesting. After computation of the responses given, the mean duration of maize stay in the field before harvest was found to be 24.5 (95% CI=23.55 to 26.75) in Kibwezi and 45.4 (95% CI= 41.95 to 49.53) in Kilome.

Drying of Maize after Harvest

Respondents were also asked how long they exposed their maize to dry immediately after harvest and before storing them in their households' storage facilities for later use. After computation the mean duration of drying was found to be 14.2 days (95% CI=13.08 to 15.33) in Kibwezi and 16.6 days (95% CI=15.45 to 17.69) in Kilome. Table 3.15 below shows duration in days of maize in field before harvest and duration of drying before storage.

Methods used by Households for Drying of Maize after Harvest

Most respondents, 96.3% in Kibwezi and 96.3% in Kilome, dried their maize in open sun while 1.6% of respondents in Kilome and 0% in Kibwezi dried their maize in the shade. Other methods used included placing maize above fire place and kitchen granary which accounted for 3.8% in Kibwezi and 2.1% in Kilome (Table 1).

Table 1. Methods used by households to dry maize after harvest

	Kibwezi		Kilome	
Drying method	Frequency	Percent	Frequency	Percent
Drying in open sun	231	96.3	231	96.3
Drying in the shade	0	0	4	1.6
Others	9	3.8	5	2.1

Placing of Maize on top of any material underneath during drying

Respondents were asked whether they placed their maize on top of any material (e.g. polythene sheet, iron sheet etc.) on the ground during drying to prevent maize contact direct with the ground surface. In Kibwezi 87.5% did this, while in Kilome 76.7% did so. There was significant difference in this practice between the two study sites ($P<0.05$).

Reasons for Placing Material underneath during Drying of Maize

Respondents who placed maize on top of some material when drying were further asked to give reasons why they did so. In Kibwezi 35.4% said they did so to prevent contamination, 24.6% said to prevent rotting, 27.6% said to dry faster and 6.1% said to prevent pests. In Kilome 45.6% said they did so to prevent contamination, 21.7% said to prevent rotting, 26.6 % said to make maize dry faster and 1.1% said to prevent pests. Other reasons given include improving maize quality which accounted for 6.0% in Kibwezi and 4.9 % in Kilome (Table 2).

Table 2. Reasons for Placing Material underneath during Drying of Maize

Reason for placing material underneath during drying of maize	Kibwezi		Kilome	
	Frequency	Percent	Frequency	Percent
To Prevent contamination	74	35.4	84	45.6
To prevent rotting	52	24.6	40	21.7
To dry faster	58	27.6	49	26.6
To prevent pests	16	6.1	2	1.1
Others	10	6.0	9	4.9
Total	210	100.0	184	100.0

Reasons for drying Maize Properly

Respondents were asked to state why maize should be dried properly i.e. to attain required moisture content of less than 14%. In Kibwezi majority 55.4% said maize should be dried properly to prevent aflatoxin contamination, 34.6% said to prevent rotting, 10.8% said to avoid germination, 4.2 % said to avoid pest infestation. In Kilome majority 56.3% said maize should be dried properly to prevent aflatoxin contamination, 28.3% said to prevent rotting, 12.5% said to avoid germination, 6.3% said avoid insect/pest infestation. Other reason given in Kilome was to make maize stay longer in good condition accounting for 1.7% while in Kibwezi no other reason was given (Table 3).

Table 3. Reasons given by respondents as to why maize should be dried properly

Reasons for drying maize properly to attain moisture content of less than 14%	Kibwezi		Kilome	
	Frequency	Percent	Frequency	Percent
To prevent from rotting	83	34.6	68	28.3
To avoid germination	14	5.8	30	12.5
To prevent aflatoxin contamination	133	55.4	135	56.3
To Avoid insect/pest infestation	10	4.2	15	6.3
Others	0	0	4	1.7
Total	240	100.0	240	100.0

Cleaning of Maize Prior to Storage

Respondents were asked whether their maize was cleaned to remove broken grains, fine materials, dirt etc. prior to storage. In Kibwezi 222(92.5%) said they cleaned their maize prior to storage and 18(7.5%) while in Kilome 204(85.0%) cleaned their maize prior to storage.

Associations/Correlations of Maize Pre-Storage Practices with Variables Related to Aflatoxin Contamination

Pre-storage practices were analysed with variables related to aflatoxin occurrence to determine their associations/ correlations. In Kilome duration of maize in field before harvest and before storage was significantly correlated with maize affected by pests/insects while in storage (Correlation r, $_{238}$=0.181, $P<0.05$), while in Kibwezi the correlation was not significant (Correlation $r_{,238}$=0.024, $P>0.05$). In Kilome the placing of maize on top of any material during drying was associated with Proper storage of maize ($\chi2_{,3}$=7.849, $P<.05$), while in Kibwezi it was not ($\chi2_{,3}$ =0.02, $P>0.05$). Duration of drying of maize after harvest and before storage had negative correlation with aflatoxin content in maize but not significant in Kibwezi (Correlation r, $_{22}$ = -0.325, $P>0.05$), and Kilome (Correlation $r_{,22}$ = -0.341, $P>0.05$). However duration of maize in field before harvest and before drying/storage had significant negative correlation with moisture content in maize in Kibwezi (Correlation r, $_{22}$ = -0.382, $P<0.05$), and in Kilome though correlation was not significant (Correlation r, $_{22}$ = -0.341, $P>0.05$).

Results for Maize Analysis

The sub-samples of household maize grains collected from Kibwezi and Kilome for first and second season maize harvest were analyzed for aflatoxin contamination using ELISA test with detection cut-off point of 1.75µg/Kg. The results showed that out of 24 samples from Kibwezi 6 (25.0 %) tested positive for aflatoxin, and out of 24 samples from Kilome 1 (4.2%) tested positive for aflatoxin. There was high aflatoxin positivity rate for maize harvested in low altitude (Kibwezi) than maize harvested in high altitude (Kilome). The mean moisture content for first maize harvest season in Kibwezi was 12.78% while in Kilome it was 12.85%. The low altitude maize had higher moisture content than high altitude maize. However in both areas, the mean moisture content was within the recommended limit of 12 to 14.0 %. Regarding maize physical conditions of first season maize, in Kibwezi, mouldy condition was observed in 5(20.8 %) of maize samples and insect/pest infestation was observed in 6(25.0%) of maize samples while in Kilome, mouldy condition was observed in 3(12.5 %) and insect/pest infestation was observed in 5(20.8 %). Mould and insect infestation was higher in low altitude maize (Kibwezi) than high altitude maize (Kilome). Maize harvested in second season was also analyzed for aflatoxin contamination using ELISA test with detection cut-off of 1.75µg/Kg. The results showed that out of 24 samples from Kibwezi 8 (33.3%) tested positive for aflatoxin, and out of 24 samples from Kilome 3(12.5%) tested positive for aflatoxin. There was high aflatoxin positivity rate for maize harvested in low altitude (Kibwezi) than maize harvested in high altitude (Kilome). The mean moisture content for second maize harvest season in Kibwezi was 13.63% whereas Kilome it was 13.48%. The low altitude maize had higher moisture content than high altitude maize. In both areas the mean moisture content was also within the recommended limit of 12 to 14.0 %. Regarding maize physical conditions for second season maize, in Kibwezi, mouldy condition was observed in 9(37.5%) of maize samples, and insect pest infestation was observed in 11(45.8 %) of maize samples while in Kilome, mouldy condition was observed in 6 (25.0 %), and insect pest infestation was observed in 10 (41.7%). Mould and insect infestation was higher in low altitude maize than high altitude maize.

DISCUSSION

Afaltoxin causing fungal *Aspergillus* species can infect maize during pre-harvest and harvest periods. Proper pre-harvest and harvest practices of maize can effectively reduce aflatoxin contamination during these periods. In this study, households in both high and low altitude areas were found to undertake various practices before harvesting, during harvesting and after harvesting their maize. The pre-harvest practices undertaken included allowing maize in the field inorder to mature before harvest, and harvest practices included removal of outer cover of maize cob during harvest (de-husking). The vast majority of farmers left their maize to mature before harvesting. This is a good harvesting practice as most communities traditionally also left their maize to mature and dry in the field prior to harvesting (Thamanga-Chitja *et al*., 2004). This is a proper harvest practice for allowing maize to attain maturity, that's moisture content of about 20 to 30 %, prior to immediate harvesting and drying as this will reduce field exposure to *Aspergillus* fungi. Duration of leaving maize in the field to attain maturity prior to harvest is therefore important in reducing moisture content which will go a long way in preventing aflatoxin of maize. This is corroborated by finding elsewhere which noted that maize cobs may be left in the field for several weeks after attaining maturity in order to reduce moisture content (Udoh *et al*., 2000). In this study farmers in higher altitude area left their maize in the field for a mean duration of 45 days which was nearly two times longer than farmers in lower altitude area where the mean duration was 25 days. This could be due to prevailing cooler climate in higher altitude area than in lower altitude area. During focus group discussion (FGD) it was reported that theft of maize while in field discouraged farmers from leaving their maize longer in the field prior to harvest. Equally of concern was damage of maize by wild animals thereby causing loses. As a result of this finding, improving general security in the community as well as controlling wild life will therefore go a long way in improving length of stay of maize in the field prior to harvest. This will enable maize to be harvested when it's properly mature and dry. The practice of removing outer covering of maize cob was done by vast majority of households in both high and low altitude areas. It was observed that overwhelming majority of respondents (over 90%) both in low altitude and high altitude areas removed outer covering of maize cob during harvest. However there were more in higher altitude area removing outer coverings of maize cob during harvesting than those in low altitude area. This indicates removal of outer covering of maize during harvest is a common practice among households. The practice of removing outer covering of maize cob is worthwhile since it might remove pests/insects which could have been embedded in coverings and thus contribute to reduction of infestation and by extension aflatoxin contamination. This will also go a long way in ensuring that damage to seed coat which could permit ease entrance of molds and fungi to grains is minimized.

Drying of maize after harvest prior to storage is crucial in improving the quality of maize to be stored as well as prevention of aflatoxin. The traditional practice of grain drying has been by spreading maize on the ground and thus exposing it to the effects of sun and wind to dry. The sun supplies heat to evaporate moisture from the grain, and the velocity of wind removes the evaporated moisture, thus drying the grains (Kaaya *et al*., 2005). In this study farmers exposed their maize to dry in varying length of time (duration) before storage. They exposed their maize to dry immediately after harvest for mean duration of 17 days in higher altitude area and 14 days in lower altitude area, before storing them for later use. These results indicate that farmers in lower altitude area dried their maize for significantly shorter time than those in higher altitude area. This variation in drying time could be attributed to households in higher altitude harvesting their maize early than their counterparts in lower altitude, hence the need for them to dry their maize for a longer time. It could also be attributable to prevailing cooler climate in the higher region than in the lower region. This finding is consistent with findings of another study (Kaaya and Kyamuhangire, 2006). Proper drying of maize in order to attain moisture content of less than 14% before storage as well as sorting and disposing of moldy or damage grains can prevent or minimize insects' infestation, mold growth and development of aflatoxins. There are various options available to farmers for drying their maize immediately after harvest. These include sun drying, drying in shade, solar drying and artificial drying among others. This study revealed two main methods/options used by households to dry their maize after harvest before storage. These were 1) drying in open sun which entailed placing maize in the open directly exposed to sunlight and 2) drying in the shade in which maize is placed in a shade shielded from direct sunlight and left to dry naturally. However vast majority (over 95%) of households in both high and low altitude areas placed their maize in the open exposed directly to sunshine to dry while only a few in high altitude area placed their maize in the shade to dry.

However there were a few households which used other methods such as placing maize above fire place or kitchen granary or drying by hanging to house rafters (maize cobs tied by tassels into small bundles and hung). Although maize can be dried using solar or artificially, these methods were not found in use. In addition although drying in the field may also be carried out after harvest with the harvested plants laid in stacks with the grains, or maize cobs with stems raised above the ground and exposed directly to the sun, this practice was not observed or reported during focus group discussions. Relying predominantly on sun drying could be attributed to the fact that this being a tropical region with plenty of sunshine, sun drying of maize could be the most appropriate and convenient way of drying maize. However, when temperatures are as high as 60% under clear skies the rate of drying can be extremely high and grains may crack and result in losses. Thus covering grains or drying under shade has an advantage of preventing Kernel cracking. It has also been noted that, drying temperature has an effect on the development of aflatoxin on stored grain. A study done previously elsewhere showed that slow drying with low heat over long periods of time promotesaflatoxin development (Walker and Davies, 2013). Thus ideally maize should be dried with moderate heat over short period of time to discourage aflatoxin development. Maize should ideally not be placed directly on the ground during drying to avoid being contaminated with dirt, debris, germs, fungi spores and other contaminants. The *Aspergillus flavus* which produce aflatoxin is a common fungus/mold found in soil and debris (Claudia *et al*., 2007). It has further been noted that drying on flat exposed surfaces has been the most convenient way of drying grains after threshing, but contamination with dirt cannot be avoided with this method and thus cleaner grains can be obtained by drying grains on plastic sheets, preferably black (Hell *et al*., 2000). Plastic sheets will provide suitable intervening impervious layer that will prevent maize from being in direct contact with the ground surface, hence avoid contamination of grains. This is more proper and hygienic way of drying maize since apart from mold and aflatoxin prevention, it also prevents against other health hazards. This study had revealed that over three-quarters of respondents dried their maize by placing them on top of sheet material such as polythene, and not directly on the ground.

Majority of respondents who were small scale (subsistence) farmers in both high and low altitude areas cited prevention of contamination as the main reason for placing impervious material underneath of maize during drying. Further a sizable proportion of respondents said they did so to make maize dry faster and to prevent maize from rotting. Besides, a few respondents did so to improve maize quality in general. Similar views were expressed during community focus group discussions as well as in depth interviews with technical officers in the field. This was an indication that previous as well as ongoing awareness campaigns appeared to have an impact on positive behavior change on proper maize drying. Sustaining this positive practice will go along in enhancing impact not only on improvement of maize drying but also on reduction of aflatoxin contamination as well as prevention of other contaminants getting into contact with maize. Respondents gave various reasons for proper drying of maize before storage which were almost similar to reasons given for placing material underneath during drying, i.e. to make maize attain moisture content of less than 14 percent before storage. For instance majority of respondents in low altitude and in high altitude said the main reasons for proper maize drying were 1) to prevent to make maize dry properly, 2) to prevent aflatoxin contamination and 3) to prevent maize from rotting. Given that these reasons were important in prevention of aflatoxin contamination; this is an indication that awareness level was quite high in these areas. However there is need to continuously intensify awareness campaign so as to sustain this momentum since there were quite a number of people who did not know the importance of drying maize properly. A notable pre-storage practice revealed by this study was that about 90% of households in both high and low altitude areas winnowed (cleaned) their maize prior to storage so as to remove broken grains, fine materials, dirt etc. However there were more households owners in high altitude area than in low altitude area who cleaned their maize before storage. Although the difference was small, this nonetheless indicates an enhanced up take of this important practice. This practice is very important as it reduces contaminated materials which could have found their way in maize and thus enhance spoilage of maize when stored. It is therefore important that this positive practice is encouraged and enhanced because of its beneficial effects on potential reduction of aflatoxin contamination.

The study findings showed that duration of maize in the field before harvest in higher altitude was significantly positively correlated with maize affected by pests/insects while in storage, implying that the longer maize is left in field the more likely for it to be infested with insect pests. Length of stay of maize in field was also found to be significantly negatively correlated with aflatoxin content in maize, implying that the longer the duration of maize in field the lessor the aflatoxin content in maize. Results further indicated that duration of maize in field before harvest and before drying/storage had significant negative correlation with moisture content in maize both for lower altitude and higher altitude maize. This finding implied that when maize is kept longer in the field to dry it had lower moisture content than maize left in the field for a shorter period. The placing of maize on top of impervious material/ layer during drying was associated with proper maize storage. This meant that those household owners who placed their maize on top of impervious material during drying were more likely to store their maize properly than those households which did not place any material underneath during drying of maize. Duration of drying of maize after harvest especially in higher altitude area had negative correlation with aflatoxin content in maize, implying that the longer the drying of maize after harvest the lower the aflatoxin contamination. This was also negatively correlated with moisture content in maize, implying that the longer the drying of maize after harvest the lower the moisture content in maize. Besides the association of maize pre-storage practices with aflatoxin contamination, low altitude maize had higher mould and insect infestation, moisture content and aflatoxin positivity rate than high altitude maize. This could be likely attributed to prevailing warmer climate in the low region compared to the high region which is relatively cooler and likely less favorable for aflatoxin development (Cotty and Jaime-Garcia, 2007; Patterson and Lima, 2010). Maize harvested in second season also had higher mould and insect infestation, moisture content and aflatoxin positivity rate than maize harvested in first season. This could also be likely attributed to prevailing warmer climate in second season compared to first season which is relatively cooler and likely less favorable for aflatoxin development.

Conclusion

The findings of this study have revealed that inadequate drying period of maize prior to crop harvest and post-harvest storage is highly associated with insect infestation, high moisture content and aflatoxin development in maize. More time for pre-harvest and post- harvest drying is required in the higher altitude area as this is more likely to reduce moisture content as well as aflatoxin contamination in maize.

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