



Farmers Perception and the Highlights of the Sources of the Chronic Aflatoxin Contamination amongst the Inhabitants of the South-Eastern Region in Kenya

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Abstract

There are factors that contribute to aflatoxin contamination like conducive ecological zones, stressed crops, virulent *Aspergillus* strains and unconventional agricultural practices. Kenyans especially in the South-Eastern region are exposed to regular doses of mycotoxins. Even after campaigns on aflatoxin mitigation in 2004, this region has had continuous cases of aflatoxin poisoning. These have not been systematically studied to identify the key entry points and contributory factors. This research was instituted to evaluate the farmers' perception of the factors which contribute to chronic aflatoxin contamination in maize grains along the pre-harvest, post-harvest and marketing stages of the production chain. We studied the moisture content of maize on seven major highway centers and found that the maize was largely within the accepted levels of moisture of 11-14%. The agri-practices investigated showed that most farmers knew the basic standard practices but were not consistent in adhering to them. We found 88% approved that close spacing of maize can stress crop, 87% agreed that poor farm plant nutrition causes stress, 78 % agreed that plant residue act as reservoirs for fungi. It was remarkable that 95 % of farmers agreed that delayed harvesting and storing of grains when the moisture content is more than 13% encouraged growth of the fungus was the main contributor of aflatoxin contamination. Furthermore, 91% indicated that, if maize combs were dropped on the soil during harvest, it increased the chances of fungal contamination. 80% of farmers agreed that the use of plastic bags to store maize in combs after harvesting could cause contamination. However, most farmers could not adequately relate contamination with the health repercussions of aflatoxin contamination. Hence, there is need to train and constantly contact understandable-sensitizations of all stakeholders; farmers, extension staff, researchers, traders, consumers, on the dangers of aflatoxin contamination along the whole maize production chain.

Key Words

Aflatoxin, Post-harvest, Maize, Production Chain, Mitigation, *Aspergillus flavus*, Animal feed, Moisture content

Introduction

The exposure of April 2004 was one of the largest documented aflatoxicosis outbreaks occurring in rural Kenya which resulted in 317 cases and 125 deaths. It was assumed that the aflatoxin contaminated maize grown and eaten on family farms was major source of the outbreak, but later studies have proved otherwise. In a survey of 65 markets and 243 maize vendors, 350 maize products were collected from most affected districts, 55 % of the maize product had aflatoxin levels greater than Kenyan regulatory limit of 20 ppb, 35 % had levels more than 100 ppb and 7 % had levels more than 1000 ppb (Lewis et al., 2005). Though many nations suffering from aflatoxin exposure have normally established maximum allowable aflatoxin standards in food; there is little if any evaluation or enforcement of these standards in many rural areas. The sources for the aflatoxin contamination has not fully been established. Food from subsistence farmers and in local markets is rarely formally inspected for aflatoxin contamination. Furthermore, there has been an increase in "confined" poultry farming in the lower eastern region. This has been due to the demand for eggs and chicken meat in the urban centers. Studies have shown that poultry is highly susceptible to aflatoxin poisoning than ruminants. Hence there is need to study the possibility of human chronic poisoning through animal feeds as a source of aflatoxin. Maize and animal feeds are hypothesized as major sources of aflatoxin if they are not properly handled.

Aspergillus flavus infection affects maize along its value chain; it can infect maize through air borne spores in the field during grain filling, during storage and handling. Pre-harvest contaminations occur when there are mechanical injuries to maize, damage by pest to the plant parts or seed. Toxins can be produced under high temperature, drought and terminal water stress prior to harvest. Post-harvest contaminations increase when the fungi continue to grow and produce aflatoxins under high moisture and warm temperatures. This process is enhanced if farm grain drying is delayed. Damage by insects or rats can facilitate mold invasion and toxin production during storage (UNIDO project report 2008). The poor storage methods used by most farmers encourage the growth of the fungus. Poor handling methods during harvest, transporting of maize to the store from the farm also expose the crop to the attack by the fungus. Currently over 5 billion people worldwide are at risk of chronic exposure to aflatoxin in food (project report Malawi, 2008).

The outbreaks of aflatoxicosis every year since the major outbreak that occurred in 2004 (Mutere and Ogana, 2005) suggests that the population is exposed to aflatoxins in their diet



Hence, this research aims at investigating the perception of farmers on the factors that can continuously cause contamination of maize and animal feeds. The consumption of the contaminated food can have both carcinogenic and hepatotoxic effects in human body, depending on the duration and level of exposure. Studies have shown that the human gastrointestinal tract rapidly absorbs aflatoxins after consumption of contaminated food, and the circulatory system transports the aflatoxins to the liver. This can manifest as hepatotoxicity or, in severe cases, fulminate liver failure and death (Etzel, 2002, Fung and Clark, 2004,). The Kenya government has been keen to follow and deal with outbreak of diseases but studies have shown that chronic intake of aflatoxins may be more serious than a onetime higher level of aflatoxin contamination (Peers and Linsell, 1973, 1997, Wogan, 1975, McGlashan, 1982).The medical expenses and economic implications of aflatoxin poisoning make it necessary to evaluate and come up with a sustainable solution Hence it is important to analyze and identify the key entry points of mycotoxins. This study has hypothesized that there are points in the production and supply chain of grains which need to be identified. Entry through animal feed is another area which needs to be investigated.

Methodology

The area of study was in the Machakos and Makueni Counties in the South-Eastern part of Kenya. The market centers which were used in this study are traversing the two counties in this order: Machakos, Kola, Mukuyuni, Kilala, Wote, Kathonweni, and Mbuvo. It covers a distance of about 200 km. The survey was done using questionnaires prepared to get farmers perception and practice in the various phases in the production value chain of maize that is pre-harvest, harvest, post-harvest and marketing and consumption where the contamination of the aflatoxin occurs. Also to find out the perceptions about how animal feeds could also be contaminated. Questionnaires were used to collect information from individual farmers and farmer groups and field agriculture and extension officers. A minimum of 30 farmers in each market and surrounding areas were interviewed. A minimum of 249 questionnaires were administered

Validity and Reliability of Research Instruments

The questionnaire was pre-tested and corrected to make it valid and realistic and to avoid bias before it is administered. The first draft of the questionnaire was made and given to a team of extension officers both agriculture and livestock in Kathonweni and Makueni districts. The officers went through the questionnaire and made corrections. The final draft was used to collect the qualitative data. The interviewers went through the questionnaire to understand the contents and also assist the farmers who had problems with English language .A questionnaire for trader and agro-vet was also done and they were interviewed.

Data sampling procedure

The samples were collected in the main towns and markets where the majority of people buy food and animal feed. This included Machakos town, Kola, Mukuyuni, Kilala, Wote, Kathonweni and Mbuvo. Random sampling of processed and non-processed food and feed for human and animals (dairy and poultry) was done. The food samples of whole maize was picked from both whole sale and retail food stores and individual farmers in the markets and in the surrounding farms. .A minimum of 30 samples per site for food was collected. The sample were selected from all sites selected at random to avoid bias depending on the size of the town/-market centers. A total of 214 samples were collected.

The moisture content analysis

The maize crop samples were collected and immediately the moisture content of each sample was measured using a moisture meter (Grain moisture meter GMK, 303RS from won Hitech co ltd Gmk® from Japan) and the readings were recorded. This was done for all the samples from the 7 market centers. A list for all the samples of maize was made with the name of the farmer or the store from where it was obtained, the moisture content and also the source of the food. Where local food from farmers or from outside like Tanzania, Busia, North Rift-valley, Shimba hills was recorded. Another list of the dairy feeds and poultry feeds was also made with name of the agro-vet or store of farmer and the name of the company or if it was locally homemade. The analysis of the data on maize and the feed was later done using the SPSS version 16.0,2007, and cross tabulation done for correlations.

From each sample of maize collected few grains were picked at random. The grains were placed into the moisture meter instrument where the maize grains were ground and measurement of the MC done by pressing a button written measure. The readings of the M.C was repeated 2 to 3 times and the average obtained by pressing the button written average. This was recorded and the procedure repeated for all the samples. For animal feeds which are formulated having high cereal content the procedure is the same. The feed was already processed so there was no need of grinding.

Data analysis techniques

Data analysis for the questionnaires was done using SPSS® version 16.0, 2007. and data analysis for moisture content of maize and animal feeds was done using SPSS ® version 16.0,2007.

After the maize samples were collected the MC was measured and recorded poultry feeds and dairy feeds. The MC figures were entered to the SPSS for analysis and the statistics were obtained through one way ANOVAs. The responses



on farmers' perception on various agronomic practice of pre-harvest, harvest, post-harvest, The chi-square test was done to determine level of significance. If the level is less than 5 % ($P < 0.05$). It is significant different if the level is more than 5% ($P > 0.05$) then there is no significant difference.

Results

Perception of farmers on agronomic practices

In this study, farmers were asked to give their perception on the influence of different agronomic practices on aflatoxin contamination and their responses were measured on a 5 point Likert type scale ranging from strongly disagree to strongly agree.

Farmers' perception of Pre harvest Agronomic practices in maize

The findings on farmers' perception on the influence of different pre harvest agronomic practices on aflatoxin contamination are presented in table 3.

Table 1 Farmers' perception of Pre- harvest Agronomic practices

Activity	Strongly disagree		Disagree		Do not know		Agree		Strongly agree		X ²	P value
	F	%	F	%	F	%	F	%	F	%		
Very close spacing of maize	7	3	11	5	9	4	137	57	75	31	276.6	0.000
Plant residue acts as a reservoir for the fungi	7	3	23	10	24	10	148	62	37	16	272.0	0.000
Poor plant nutrition causes stress	9	4	12	5	11	5	152	64	55	23	314.9	0.000
Late planting reduces increases maize crop stress	7	3	12	5	21	9	157	66	42	18	326.8	0.000
Late weeding of maize causes stress	4	2	5	2	16	7	157	66	57	24	350.9	0.000

The results showed that majority of the respondents agreed that pre harvest agronomic practices influences aflatoxin contamination in maize (Table 4.1). For instance, 62% of the respondents agreed that maize plant residue acted as a reservoir for the fungi which causes contamination. Chi square analysis showed significant association between farmers' perceptions and the different pre harvest agronomic practices ($p < 0.000$).

Farmers' perception about harvest agronomic practices

The findings on farmers' perception about harvest agronomic practices in maize are presented in table 4. The results showed that majority (over 60%) of the respondents agreed that different harvest agronomic practices carried out by farmers had an influence to aflatoxin contamination in maize (median = 4). Chi square analysis showed a significant association between the farmers' perceptions and the activities ($p < 0.000$)



Table 2.Farmers’ perception of harvest agronomic practices

Agronomic practices	Strongly disagree		Disagree		Do not know		Agree		Strongly agree		Median	X ²	P value
	F	%	F	%	F	%	F	%	F	%			
Delayed harvesting of maize when moisture content is more than 15% MC	3	1	6	3	5	2	147	62	78	33	4	341.8	0.000
Farmers harvest maize cobs and throw them on the ground(soil).	1	0	18	8	3	1	155	65	62	26	4	351.0	0.000
Farmers use plastic bags (jute bags) to store harvested maize	9	4	36	15	4	2	141	59	49	21	4	256.3	0.000
Farmers’ first cut and heap maize crop with stoppers before harvesting	4	2	36	15	7	3	136	57	56	23	4	242.0	0.000

Farmers’ perception on Post-harvest Agronomic practices

Results show that majority of farmers agreed to most of post-harvest practices (median = 4) on maize. Although most farmers (53%) disagree that most farmers use canvas when drying their maize (Table 5). Chi square results show a significant association between farmers’ responses and the post-harvest activity (p = 0.000).

Table 3. Farmers’ perception of Post- harvest Agronomic practices

Agronomic practices	Strongly disagree		Disagree		Do not know		Agree		Strongly agree		Median	X ²	P value
	F	%	F	%	F	%	F	%	F	%			
Most farmers use canvas to dry their maize when drying.	15	6	113	47	11	5	78	33	22	9	2	172.8	0.000
Most farmers shell maize by beating the combs when in gunny bags	2	1	16	7	3	1	156	65	62	26	4	356.2	0.000
Most maize stores are not well ventilated	10	4	23	10	7	3	160	67	39	16	4	342.6	0.000
Most farmers do not use sisal bags to package maize after shelling	4	2	19	8	7	3	150	63	59	25	4	313.4	0.000



Inadequate inspection of maize stores	16	7	74	31	12	5	114	48	23	10	4	166.9	0.000
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Traders’ responses of different practices

Traders’ opinions of different practices on maize were sought and their responses are presented in Table 6. The results indicated that 84.1% of respondents agreed that maize traders have no moisture meters while 11.5% strongly agreed on the same (Table 4.4). The findings also showed 80.5% of respondents agreed that traders store maize in small and poorly ventilated stores. In general, majority of the respondents were in agreement that the different practices carried out by maize traders could influence aflatoxin contamination. Chi square results showed significant difference between the traders’ response and the different activities with $p= 0.000$

Table 4: Traders’ perceptions of different post-harvest practices

	strongly disagree		disagree		do not know		Agree		strongly agree		Me dia n	X ²	P
	F	%	F	%	F	%	F	%	F	%			
Most traders have no moisture meters to measure MC of maize.	0	0.00	3	2.70	2	1.80	95	84.10	13	11.5	4	212.912	.000
The Maize from farmers is not dry enough	0	0.00	42	32.80	0	0.00	77	60.20	9	7.00	4	54.203	.000
Most traders do not use sisal sacks to package the maize but jute bags	0	0.00	7	5.50	0	0.00	109	85.20	12	9.40	4	154.984	.000
The maize in sacks in heaped together no ventilation.	0	0.00	16	12.50	0	0.00	103	80.50	9	7.00	4	128.547	.000

Moisture content analysis

The collected maize samples and their moisture contents from the seven towns/markets in SE Kenya are tabulated in Table 8 below. They show an almost acceptable levels of moisture content of below 15%. The average are calculated from 32 samples.

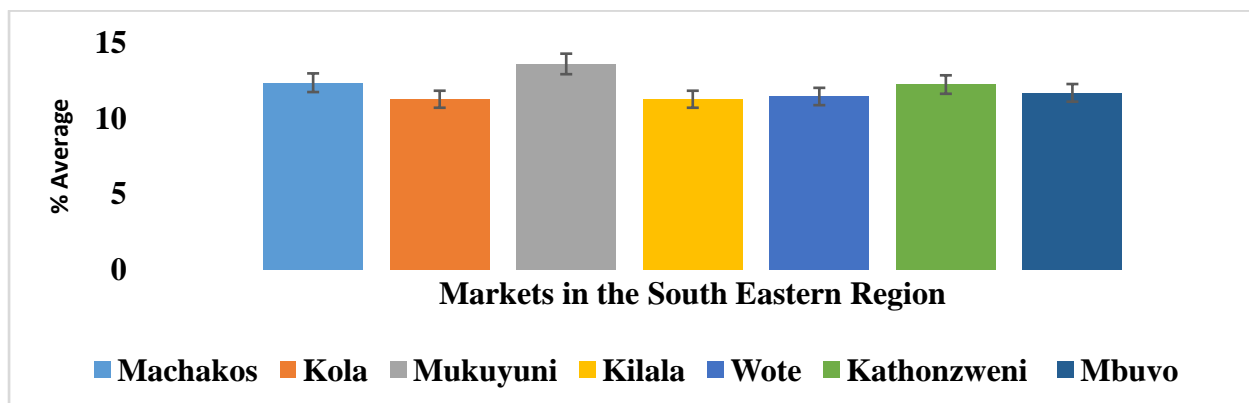




Figure 1. Comparative percentage of Maize Sample Moisture contents from the Machakos, Kola, Mukuyuni, Kilala, Wote, Kathozweni and Mbuvo markets as analyzed using random sampling of at least 30 samples in each market.

Analysis of variance (ANOVA) on moisture content in maize

A single factor ANOVA model was performed to establish whether there was a significant difference in average moisture content in maize among the seven towns. The overall average moisture content was found to significantly vary among the seven towns at 0.05 level of significance $F_{(6, 214)} = 44.44, p = 0.000$.

Table 5: Analysis of variance (ANOVA) on moisture content in maize from the Machakos, Kola, Mukuyuni, Kilala, Wote, Kathozweni and Mbuvo markets.

Source	Sum of Squares	Df (n-1)	Mean Square	F	Sig.
Markets	119.597	6	19.933	44.447	.000
Error	92.831	207	.448		
Total	31861.990	214			

The analysis shows significantly higher moisture content in maize at Mukuyuni town compared to all other towns. A few towns such as Mbuvo and Kilala towns and Kathonzweni and Machakos did not register significant difference in average moisture content in maize.

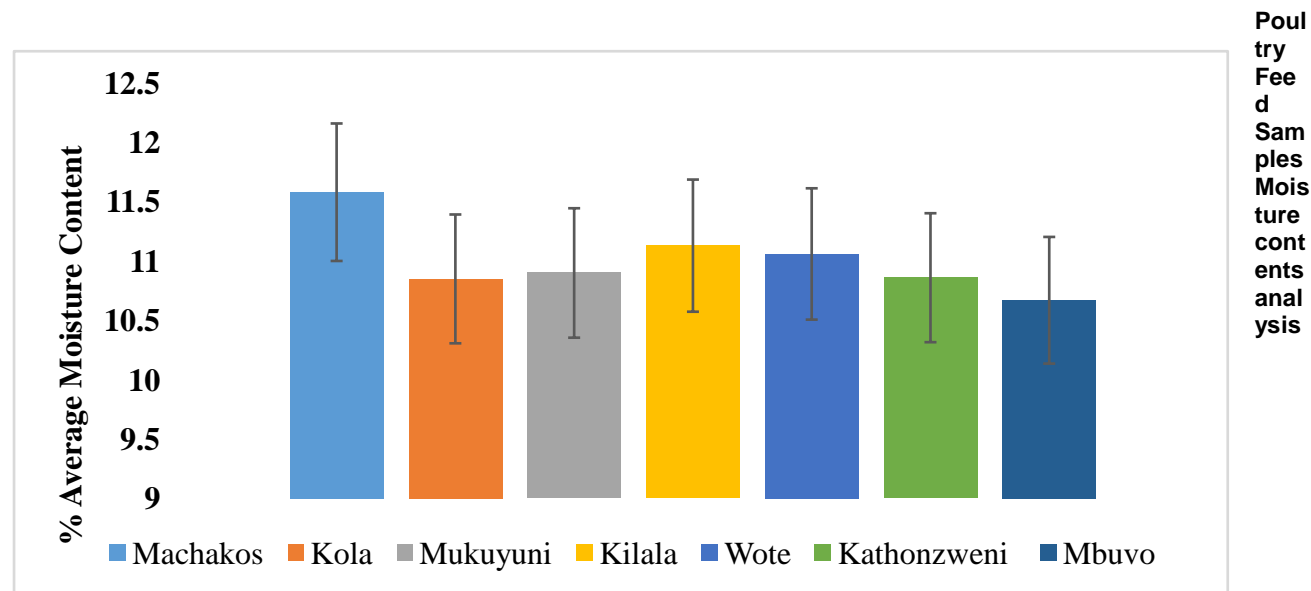


Figure 2 Poultry Feed Samples Moisture contents in the seven markets/towns of SE Kenya

Poultry feed moisture content Analysis of variance

Single factor ANOVA model was performed to establish the presence of significant differences in average moisture content in poultry feeds among the seven towns. The overall average moisture content was found to significantly vary among the seven towns at 0.05 level of significance $F_{(6, 189)} = 9.325, p = 0.000$.

Table 6 Analysis of variance (ANOVA) on moisture content of poultry feeds from the Machakos, Kola, Mukuyuni, Kilala, Wote, Kathozweni and Mbuvo markets.

Source	Type III Sum of Squares	Df (n-1)	Mean Square	F	Sig.
Maize Markets	14.304	6	2.384	9.325	0.00
Error	46.529	182	.256		
Total	23077.470	189			

In the presence of significant average moisture differences in the towns, pairwise mean comparison were performed using mean standard errors and the results as shown in above. There was significantly high moisture content in poultry feeds in Machakos town (by 0.04530-0.9108) compared to all the other towns. However, no significant difference in moisture content in Kola, Mukuyuni, Kathonzweni, and Mbuvo towns.

Dairy feed samples Moisture content analysis

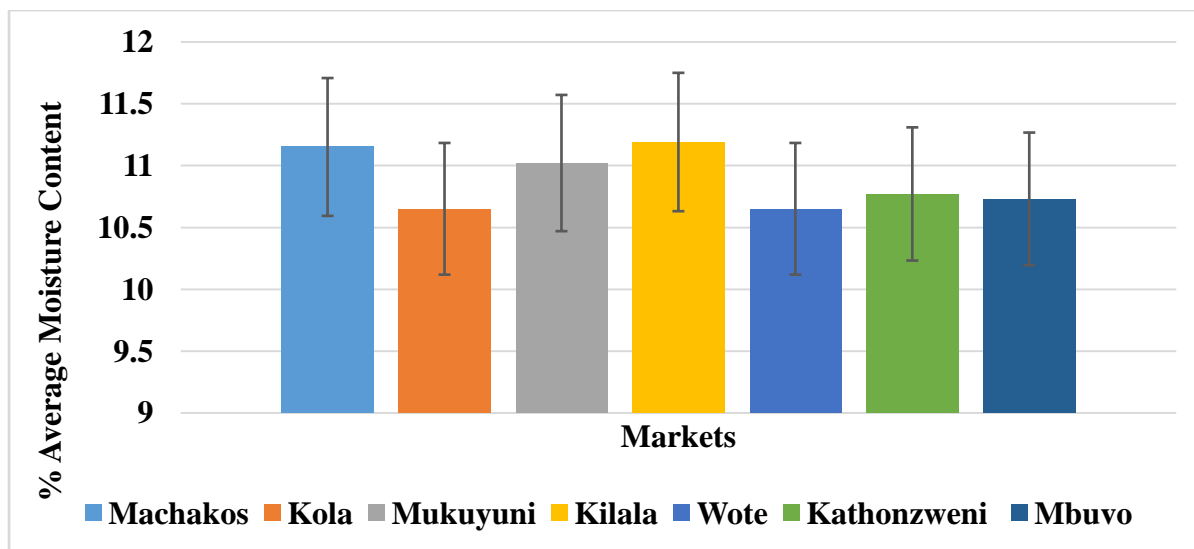


Figure 3 . Dairy feed samples Moisture contents from the Machakos, Kola, Mukuyuni, Kilala, Wote, Kathozweni and Mbuvo markets.

Analysis of variance (ANOVA) on moisture content in dairy feeds

A single factor ANOVA model was performed to establish presence of significant differences in average moisture content in dairy feeds among the seven towns. The overall average moisture content was found to significantly vary among the seven towns at 0.05 level of significance $F_{(6, 121)} = 2.865, p = 0.012$.

Table 7: Analysis of variance (ANOVA) on moisture content in dairy feeds

Source	Type III Sum of Squares	Df n-1)	Mean Square	F	Sig.
Markets	6.854	6	1.142	2.865	.012
Error	48.241	121	.399		
Total	15302.040	128			

In the presence of significant average moisture differences in the towns, pair-wise mean comparison were performed using mean standard errors and the results as shown in figure 8. Kilala, Mukuyuni and Machakos registered significantly higher moisture contents in dairy feeds compared to the other towns though they didn't differ significantly within the towns. Mbuvo, Kathonzweni, Wote and kola recorded relatively same moisture contents in dairy feeds

Combined analysis of the maize, poultry and dairy feed moisture contents

Using the R software version 3.3.1 (2016-06-21) -- "Bug in Your Hair". Copyright (C) 2016 The R Foundation for Statistical Computing Platform: i386-w64-mingw32/i386 (32-bit). We compared the p values of the maize, poultry and dairy feeds and found that the moisture contents of the three sources were significantly different (Table) below. However there was a closer relationship between the maize and the poultry. Suggesting a higher consumption of poultry feed than maize feed in the area. Previous studies showed that poultry feed on aflatoxin contaminated feed could be transmitted to the eggs and meat of poultry. This pointing that this could be a unknown source of aflatoxin poisoning in the south eastern region of Kenya.

**Table 8. P values of maize, poultry feed and dairy feed moisture content in the South Eastern region in Kenya.**

Moisture Content Combination			
	M + P	M + P	P + D
P value	0.02420	0.01398	0.3890

M = maize moisture content; **P** = Poultry feed moisture content; **D** = dairy feed moisture content

DISCUSSIONS AND CONCLUSIONS

According to the results obtained on farmers' perception on different pre-harvest agronomic practices, make it clear first that the key entry points of aflatoxin contamination are, close spacing of maize (less than 90 x 30 cm), poor plant nutrition (inadequate fertilizer and manure application), late planting, and late weeding which cause stress on the maize crop and encourages growth of fungi (mycotoxin) which causes contamination. A range of 84 % to 90 % of farmers responded positively on the pre-harvest activities. The chi-square analysis on the pre-harvest activities registered a significant difference with $p < 0.05$

The results agree with Burns et al, 2003 factors that increases the risk of aflatoxin contamination in the field (pre-harvest) contributes intensively in managing aflatoxin. Management practice that reduce the incidence of aflatoxin contamination in the field include timely planting maintaining plant densities, spacing, proper plant nutrition, Burn et al (2003). This is because the maize plant will be healthy and the maize grains (cob) which will resist attach by the mycotoxins. Also, according to Diener et al 1987, who found out that in Africa crops are cultivated mainly under rain fed conditions with inadequate fertilizers and pesticides application. This management also promotes aflatoxin. Contamination by *A. Flavus*.

On harvest agronomic practices the results obtained indicates that the farmers response agreed on the harvest agronomic practices ranging between 70-95 %. These are the key entry points of mycotoxin contamination. They include; delayed harvesting when M.C is high, harvesting and allowing contact of maize and soil, use of plastic (jute) bags to put harvested maize cobs, and heaping of maize with stoppers before harvesting. The high M.C encourages growth of mycotoxin, maize contact with the contaminated soil and heaping of maize with stoppers also encourages growth of mycotoxin and also the poor aeration of plastic bags due to increased temperature within the bags. The chi square results on the harvest agronomic practices indicated significant difference with $p < 0.05$. This in agreement with Borgemeister et al, 1998 who found out that extended field drying could result in serious grain losses during storage as such harvesting immediately after physiological maturity is recommended to combat aflatoxin problems. Kaaya et al 2006. observed that the aflatoxin level increased 4 times by the third week and more than 7 times when maize harvest was delayed for 4 weeks. Also in agreement with Muthomi et al (2009) that the fungal inoculums is present in the soil and should be avoided during harvest.

On post-harvest agronomic practices, the results indicate that majority of farmers (more than 50 %) do not use canvas to dry maize but throw on the ground where the soil may be contaminated. Also 91% of farmers shell maize by beating which breaks the grain exposing them to fungal growth. While 84 % of farmers agreed that poor storage encourages growth of fungus. This is due to poor ventilation and keeping the maize on the floor without wooden flat forms. Also poor package of shelled maize is another entry point where 88 % of farmers do not use sisal bags but jute bags which are not well aerated and this encourages mycotoxin growth. Finally inadequate inspection of stores to monitor the status of maize in stores is another key entry factor. The contaminated maize should be removed and destroyed before it spreads. 58 % of farmers agreed that they don't inspect their stores.

The study agrees with Hell et al (2008) who found out that Aflatoxin contamination can increase 10 fold in a 3 day period when field harvested maize is stored with high moisture content. Also Constructing modern houses which are large and well ventilated are expensive they store in poly propylene bags which are not air tight, which also facilitates aflatoxin development, Hell et al 2000, Udo et al (2000). In the local market of SE is informal marketing system thus its difficult to regulate and establish proper system for handling grain post-harvest especially for small scale traders and also in the open air market system also support spoilage due to weather changes and abrupt rainfall that wet the grains as they are not covered appropriately (Mutegi et al 2009). The traders response indicate that inadequate use of moisture meter by most traders to measure the M.C of maize on reception especially when the M.C is more than 15% is a key cause of



aflatoxin contamination. NB ; $p=0.000$ means that there was significant difference on the farmers perception on the agronomic practices listed ($p<0.05$)

RECOMMENDATIONS AND CONCLUSIONS

Training farmers on the right agronomic practices like; right spacing of maize, application of adequate fertilizer and manure, timely harvesting, proper drying, and proper storage of the maize. The training of farmers is important so as to reduce or eradicate the aflatoxins contamination in the maize production chain. Also, training traders on proper storage of grains to reduce or eliminate contamination by the aflatoxin. strengthening surveillance of aflatoxin contamination in S. E. Kenya by the extension staff of ministry of agriculture and health, supported by devolved governments. The surveillance will be able to enable the ministries concerned to take necessary action in case of contamination. Also training and sensitizing all stakeholders (i.e), farmers, extension staff, researchers, traders, consumers, on dangers of aflatoxin contamination of food and animal feed in the maize production chain. Sensitizing of farmers, traders and public health staff on regular food inspection in farmers stores and traders stores and in the markets as sustainable solutions for aflatoxin mitigation for the South Eastern Kenya

Conclusions

In conclusion the study has found that the perception of farmers on the key entry points of aflatoxins contamination in maize and animal feed in S.E. Kenya are as follows; in pre-harvest agronomic stage of maize production, the factors that cause plant stress like, close spacing of maize (88% of farmers agreed), Poor plant nutrition (87% of farmers agreed), Late planting and late weeding (61% & 60% farmers agreed). For harvest agronomic stage the key entry points were; -delayed harvesting of maize (95% of farmers agreed), contact of maize with soil when maize cobs are thrown on the ground (90% of farmers agreed). On post-harvest agronomic practice; the key entry points are poor drying of maize, (53% of farmers agreed), poor shelling by breaking maize grains, poor storage (95% of farmers store maize in poor ventilated stores) and inadequate inspection of stores (58% of farmers agreed that they do not inspect their stores). In Traders and Agro-vet shops; the entry points are poor storage of food and feeds (88%) and inadequate inspection (66%) of store

The study also found out that the level of moisture content in maize was significantly high for Mukuyuni town (13.57%) compared to the other towns of, Kilala (12.65%), Machakos (12.33%), Kathonzi (12.22%), Mbuvi (11.66%), Wote (11.42%) and, Kola (11.24%) the lowest. The reason being that the source of maize was from the local farmers who had not properly dried the maize which been harvested that season for Mukuyuni, Kilala and Machakos. For the other markets the maize samples were for previous season or from other sources like Tanzania, Busia and Simba Hills. Farmers and traders need to be sensitized and trained on proper drying and proper storage to avoid the growth of the mycotoxin. Inspection and surveillance of maize by extension staff of the MOAL&F and public health staff needs to be done so that they can timely advise farmers and traders on contamination of maize and other food stuffs.

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