

Post-harvest Practices of Maize Farmers in Selected Counties in Kenya and Isolation of Mycotoxin Producing Fungi from Maize Samples

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ABSTRACT

Mycotoxins produced by fungi are among the leading causes of human mortality and morbidity all over the world. This study aimed at establishing the post-harvest practices that lead to contamination of maize with fungi in Trans Nzoia, Kisii, Kisumu, Bungoma, Migori, Kericho, Machakos, Kitui and Meru Counties in Kenya. The study was also aimed at isolating the most common mycotoxin producing fungi from maize samples collected from the study areas. The post-harvest practices were determined using a questionnaire. From each county, a total of 130 maize samples were collected. The samples from each county were mixed to make a composite sample. The moisture content of the maize samples were determined and percentage moisture content calculated. Each sample was ground using a dry mill kitchen blender (BL335, Kenwood, UK). A sample of 1g was suspended in 9mL of sterile distilled water and serial dilution up to 10⁻² carried out. A sample of 0.01mL was plated on potato dextrose agar. Mycotoxin producing fungi were identified using morphological characteristics and fungal identification keys. The post-harvest practices within the counties varied significantly. The mean moisture content of stored maize varied from 16.78% in Kitui to 19.33% in Trans Nzoia. The number of mycotoxin producing fungi ranged from 10.33 CFU/g in Machakos to 61.00CFU/g in Trans Nzoia. This study established that the post-harvest practices observed in the study areas led to contamination of maize with microflora. In addition, the moisture content levels of stored maize in the counties favoured growth of mycotoxin producing fungi. There is need to identify the mycotoxins produced by the mycotoxin producing fungi isolated in this study.

Keywords: Mycotoxin, Nzoia, Kisii, Kisumu, Bungoma, Migori, Kericho

INTRODUCTION

The term mycotoxin was coined in 1960 to refer to toxins basically found in contaminated pea nuts in animal feed and the loss of turkeys

in England (Cruz et al., 2013). The mycotoxin was there after identified as aflatoxin B1 produced by *Aspergillus flavus* (Pascual et al., 2016).

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Mycotoxins are natural products produced by fungi that evoke a toxic response when introduced in low concentrations to higher vertebrates and other animals by a natural route (Hussien et al., 2017). In addition, mycotoxins are secondary metabolites that act as metabolic intermediates. They occur as differentiation products in restricted taxonomic groups. Mycotoxins are biosynthesized from one or more general metabolites by a wider variety of pathways than is available in general metabolism (Mathana et al., 2017). The term mycotoxin was later applied to other toxic fungal natural products (Makuvaro et al., 2014).

Early taxonomist categorized mycotoxins into two groups. Those that invade seed crops were categorized as field fungi and they included *Cladosporium sp.*, *Fusarium sp.* and *Alternaria sp.* These fungi gain access to seeds during plant development stage (Maina et al., 2015). The second category were the storage fungi such as *Aspergillus sp.* and *Penicillium sp.*, which infect the stored produce during storage (Baquião et al., 2013). However, this categorization is not strictly being followed (Turner et al., 2015). Hussien et al. (2017), categorized fungi into four major groups. The first group formed the plant pathogens such as *Fusarium graminearum* and *Alternaria alternate* while the second group was composed of fungi that grow and produce mycotoxins on aged or stressed plants viz *F. moniliforme* and *Aspergillus flavus*. Fungi that initially colonize the plant and increase the feedstock's susceptibility to contamination after harvesting such as *A. flavus* were placed in the third category while those fungi that are found on the soil, decaying plant material, developing kernels in the field constituted the fourth group. These fungi proliferate later in the store if conditions allow and they include *P. verrucosum* and *A. ochraceus*.

Basically, most of the mycotoxin producing fungi are ubiquitous in soil and other substrates (Omara et al., 2020). The mycotoxins cause many diseases to crops, insects and animals including humans. Fungi infect agricultural crops including cereals and

a variety of oilseeds (Wacoo et al., 2019). Seetha et al. (2017) maintained that production of mycotoxins is species specific. This demands for proper identification and characterization of fungi in order to develop any prevention strategy. A wide variety of mycotoxins have been documented as contaminants of poultry feed, most important of which are aflatoxins (B1, B2, G1, G2) and Ochratoxin A (OTA) (Marin et al., 2012). Aflatoxins are the most studied group of mycotoxins (Czembor et al., 2015). Apart from producing clinical toxicosis, aflatoxins also reduce resistance to diseases and interfere with vaccine induced immunity in poultry (Amra et al., 2017).

Pascual et al. (2016) advocates for regular monitoring of toxigenic mycoflora of the agricultural based feeds and foods as an essential pre-requisite for the control of mycotoxicosis among animals and humans. The highest occurring mycotoxins in nature are aflatoxins which are produced mainly by *A. flavus* and *A. parasiticus* (Gong et al., 2016). At least 16 structurally close aflatoxin has been detected to date. However, the most common are aflatoxins B1, B2, G1 and G2. (Antonio et al., 2018). The most toxic causing hepatocarcinogenic among other ailments (Algabr et al., 2018).

The world has witnessed high levels of crop and livestock losses resulting from contamination of toxigenic fungi and mycotoxins (Williams et al., 2014). Economic loss have increased enactment of regulations that control conducting regulatory programs to prevent such contamination. Feeding livestock with aflatoxin contaminated feeds may lead to death, immune suppression, growth reduction and reduced yields in both animals and crops (Mboya et al., 2011). Besides, intake of aflatoxins contaminated animal and crop produce jeopardizes human existence (Czembor et al., 2015). The major aims of this study were to identify the maize post-harvest practices in Trans Nzoia, Kisii, Kisumu, Bungoma, Migori, Kericho, Machakos, Kitui and Meru counties and to isolate mycotoxin

producing fungi from maize samples collected from the study areas.

MATERIALS AND METHODS

The study areas

The study was carried out in different geographical locations of Trans Nzoia, Kisii, Kisumu, Bungoma, Migori, Kericho, Machakos, Kitui and Meru Counties. The counties had recently reported cases of mycotoxicosis (Omara et al., 2020). Trans-Nzoia County is an agricultural county situated in Western Kenya at an altitude of 2,100 m above sea level. Temperatures in this region range from a low of 9.05 °C to a high of 26.85 °C. The average rainfall ranges from 950 mm to 1500 mm annually (Gachara et al., 2018).

Kisii county is located on Latitude: 0° 41' 0 N and Longitude: 34° 46' 0 E. The county has a short rainfall season, between September and November and long one between February and June. The annual rainfall is over 1,500 mm per annum of rainfall with temperatures ranging from 16°C to 27 °C. The County has a population of 1,152,282 (Sichangi et al., 2020).

Kisumu County has a population of 1,155,574. The county covers an area of 2085.9 km² and an annual relief rainfall that ranges between 1200 mm and 1300 mm. Kisumu County lies within longitudes 33° 20'E and 35° 20'E and latitudes 0°20'South and 0°50'South (Juma et al., 2018). Bungoma County has a population of 1,670,570 and an area of 2,069 km². The economic activities of Bungoma County are mainly agricultural, centering on the sugarcane and maize industries. The area experiences high rainfall throughout the year, and is home to several large rivers, which are used for small-scale irrigation. The county is located at 00°34'00"N 34°34'00"E (Odhiambo et al., 2013).

Migori County is located in Western Kenya and has a population of 1,116,436 persons. The County has two main rainy seasons. The first rainy seasons starts in March and ends in May and is called long rains. The second season called "opon" starts in

September and ends in November. The minimum average temperature is 24°C and the maximum 31°C (Islam et al., 2018). Kericho County is located between longitude 35° 02' and 35° 40' East and between the equator and latitude 0 23' South with an altitude of about 2002m above the sea level. It has a population of 901,777 (2019 census) and an area of 2,111 km². The County has a temperature range and a population density 370 people per Km² (Rotich et al., 2017).

Machakos County has a population of 1,421,932. The county is located at latitudes 0° 45' S to 1° 31' S and longitudes 36° 45' E to 37° 45' E. It has a semi-arid climate with hilly terrain and stands at an altitude of 1000 to 2100 m above sea level. Residents of this County practice subsistence agriculture farming maize and drought-resistant crops such as sorghum and millet. The county covers an area of 6,208Km². The County lies at altitude of 1000-1600 meters above sea level (Islam et al., 2018). Kitui County is situated in Eastern Kenya. It is located at co-ordinates of 1° 22' 0" South and 38° 1' 0" East. The County has a population of 1,012,709 people and an area of 20,402 Km². The average rainfall in this area ranges from 500 mm to 1050 mm per annum. Long rains occur between March and May while short rains are experienced during October and December. Temperatures are normally high with the mean ranging from 26 °C to 34 °C. Residents of Kitui County practice subsistence farming as their main source of livelihood (Gachara et al., 2018).

Meru County is located in Eastern Kenya with a population of 987,653 and a population density of 6 people per Km². The County is located at 0.047035° N and 37.649803° E. The County experience an average temperature range of 8° C-32°C. The rainfall ranges between 300 mm and 2600mm per annum. The long rains come in April and May and short rains in November and December. The hot months are in the Months of June, September, January and February. The main sources of livelihood of the residents of Meru County are agriculture and trade (Wachira et al., 2015).

Administration of questionnaires

Questionnaires were used to collect data on post-harvest practices practiced in the study areas (Appendix I). The respondents were asked questions regarding source of maize, stage of maize harvesting, use of poor grade maize, maize vendor types and storage methods of maize. The collected responses was used to make conclusions based on the experimental results (Czembor et al., 2015).

Sample collection

Maize grains samples were collected from the various storage structures of farmers from Trans Nzoia, Kisii, Kisumu, Bungoma, Migori, Kericho, Machakos, Kitui and Meru Counties. The formula below was used to calculate the sample size at 95% confidence level and a desired level of precision at 5% (Algabr et al., 2018).

$$n = \frac{Z^2 pq}{e^2}$$

Where n=sample size, Z= confidence level at 95% (1.96), p= estimated proportion of the sample population, q= (1-p) and e= desired level of precision at 5% with a standard value of 0.05. Based on this formula at 5% precision and a Z value of 1.96, the sample size was determined as;

$$n = \frac{1.96^2(200)(1 - 200)}{0.05^2} = 130$$

The samples from each County were then mixed to form a composite sample. The samples were packed in new khaki bags and transported to Egerton University, Department of Biological Sciences laboratories. The

samples were stored at 4° C awaiting mycological analysis.

Determination of moisture content (MC)

Moisture content of each sample was determined by drying 5 g of the sample for 2 hours at 105°C in a hot air oven (ADP21/31 Yamato Scientific, America). The samples were allowed to cool at room temperature (20±2°C). The dry weight was recorded and used to calculate the moisture content expressed as a percentage using the formula below (Domenico et al., 2016);

$$\%MC = \frac{M_0 - M_1}{M_0}$$

Where: M₀ was the initial weight of the maize sample and M₁ was the final weigh of the maize sample.

Isolation of mycotoxins producing mycoflora

Surface sterilization of maize kernels was carried out using 70% ethanol for 2 minutes and rinsed twice in sterile distilled water to remove external contaminants (Nyongesa et al., 2015). The maize kernels were dried using sterile Whatman filter papers. One kilogram of each maize sample was ground using a dry mill kitchen blender (BL335, Kenwood, UK). One gram of each ground maize sample was suspended in 9 mL of sterile distilled water. The mixture was thoroughly shaken and serially diluted up to 10⁻². A sample of 0.01mL was plated on sterile Potato Dextrose Agar (PDA) media and incubated at 28°C for 7d (Wacoo et al., 2014). The isolates were sub-cultured on PDA to obtain pure cultures. The fungal isolates were enumerated as colony forming units per gram of maize (CFU/g) as follows (Varga et al., 2015);

$$\frac{CFU}{g} = \frac{\text{Number of colonies of a fungal species}}{\text{Amount plated} \times \text{Dilution factor}}$$

Identification of the mycotoxin producing mycoflora

The isolated fungal species were identified morphologically using their macroscopic and microscopic characteristics (Nyongesa et al.,

2015). Macroscopic features that were observed included colour of the colony, size of the spores, their texture and pattern. Microscopic features used in identifying the isolates were elevation of the philiades, the

size of the conidiohores and protrusion of the hyphae (Lee et al., 2013). Fungal identification keys were also used to further characterize the isolates (Mathana et al., 2017).

Data analysis

Analysis of variance was carried out using PROC ANOVA procedure of Genstat Discovery 2 statistical software (Lawes Agricultural Trust, Rothamsted Experimental Station 2006, version 9). The mean differences were compared using the Fisher's protected least significant difference test at 5% significance level.

Results

Post-harvest practices of maize farmers

The source of maize was evaluated since it affected the mycoflora recovered from maize. A proportion of 77.3% obtained their maize from the family farm (Table 1). This was the most common source of maize within the study areas. However, the least common source of maize were the millers (0.95). The sources of maize varied significantly ($F=0.55$ $P=0.0081$).

People within the study area harvested maize at different stages. Most people (93.9%) stacked maize and give it time to dry (Table

1). A minority of the farmers (1.1%) harvested and sold their maize when green. Stage of harvesting maize varied significantly within the study areas ($F=8.78$ $P=0.001$).

Farmers in the study areas used poor grade maize in different ways. Some farmers (94.4%) preferred feeding livestock with the poor grade maize. However, 1.1% of the farmers threw the maize away while others used it at home. The utilization of poor grade maize differed significantly from each other ($F=5.2$ $P=0.001$).

The type of maize vendor determines the level of contamination of maize. Farmers in the study areas obtained maize from different sources. Most of the farmers (92.5%) obtained maize from grain stockist while 1.1% sourced maize from migrant vendors. The sources of maize were significantly different within the study areas ($F= 0.19$ $P=0.0098$).

Different farmers stored maize differently after harvesting (Figure 1). Storing maize in sisal bags was the most common method (44.6%). However, a minority (1.3%) stored their maize in polythene bags. Maize storage methods differed significantly within the study areas ($F=0.13$ $P=0.009$).

Table 1: Post-harvest practices (%) of maize farmers in the study counties

Post-harvest practice		County									Mean
		T. Nzoia	Kisii	Kisumu	Bungo	Migori	Kericho	Macha	Kitui	Meru	
Source of maize	F. farm	96.0	93.8	76.9	88.5	78.5	96.2	53.4	50.8	61.5	77.3 ^a
	N. market	1.5	2.3	16.2	9.2	15.4	1.5	42.7	46.2	35.2	18.9 ^b
	NCPB	0.8	0.8	1.5	0.8	1.5	0.8	0.8	1.5	1.0	1.1 ^c
	Merchants	0.9	2.3	3.1	0.0	3.8	1.5	2.3	1.5	0.8	1.8 ^c
	Millers	0.8	0.8	2.3	1.5	0.8	0.0	0.8	0.0	1.5	0.9 ^c
Stage of harvesting	S.T.D	96.1	92.3	88.5	96.9	95.4	96.9	91.5	94.6	93.0	93.9 ^a
	D.C	2.3	4.6	7.7	1.5	2.3	0.8	4.6	1.5	5.4	3.4 ^b
	W.S.D	0.8	1.6	2.3	0.8	1.5	0.8	3.1	2.3	0.8	1.6 ^c
	H.S.G	0.8	1.5	1.5	0.8	0.8	1.5	0.8	1.6	0.8	1.1 ^c
Use of poor grade maize	Fed. livestock	95.3	94.6	93.1	91.5	94.6	95.2	94.9	94.6	96.2	94.4 ^a
	S. away	3.1	3.1	3.8	6.2	3.1	2.7	3.1	3.8	1.5	3.4 ^b
	T. away	0.8	1.5	1.5	0.8	0.8	1.3	0.8	0.8	1.5	1.1 ^c
	U. home	0.8	0.8	1.6	1.5	1.5	0.8	1.2	0.8	0.8	1.1 ^c
Maize vendor type	G. stockist	92.3	93.8	91.5	90.8	95.4	93.1	93.1	90.0	92.2	92.5 ^a
	P. millers	5.4	3.9	5.4	4.6	3.1	3.8	3.1	6.9	6.2	4.7 ^b
	M. vender	0.8	0.8	1.6	1.5	0.7	1.6	1.5	0.8	0.8	1.1 ^c
	C. millers	1.5	1.5	1.5	3.1	0.8	1.5	2.3	2.3	0.8	1.7 ^c
Storage method	S. bag	16.8	23.1	34.5	38.5	35.4	23.1	69.2	71.5	89.2	44.6 ^a
	Granary	56.2	62.3	46.2	42.2	41.5	62.3	23.1	19.2	0	39.2 ^b
	Po. bag	20.8	5.4	10.0	13.1	11.5	9.2	1.5	1.6	5.4	8.7 ^c
	Basket	1.5	4.6	5.4	3.8	5.4	1.5	1.5	0.8	0.8	2.8 ^d
	F.M.H	0.8	1.5	0.8	0.8	2.4	0.9	3.1	4.6	2.3	1.9 ^d
	Clay pot	3.1	0.8	2.3	0.8	2.3	1.5	0.8	1.5	0.8	1.5 ^d
	P. bag	0.8	2.3	0.8	0.8	1.5	1.5	0.8	0.8	1.5	1.3 ^d

T. Nzoia; Trans Nzoia, Bungo; Bungoma, Macha; Machakos, F. farm; Family farm, N. Market; Nearby market, NCPB; National Cereals and Produce Board, W.S.D; when starting to dry, D.C; Dry completely, S. T.D; Staked and left to dry, H. S. G; Harvested and sold green, T. away; thrown away, U. home; Used at home, S. away; Sold away, F. livestock; Fed to livestock, G. stockist; Grain stockist, M. vender; Migrant vender, P. millers; Posho millers, C. millers; Commercial millers, F.M.H; floor of the family house, S. bag; Sisal bag, P. bag; Polythene bag and Po. Bag; Polypropylene bag. Means within a column followed by the same superscripts are not significantly different at $P \leq 0.05$. The P-values were calculated using SPSS P-significant tests.



Fig. 1: Storage of maize in granary (A), sisal bags (B), polythene bags (C) and polypropylene bags. (D).

Moisture content of the stored maize

The moisture content (MC) in maize determine the mycoflora isolated from maize. In Trans Nzoia, the MC ranged from 12 to 24%, Kisii (8-26%), Kisumu (9-27%), Bungoma (10-30%), Migori (11-28%), Kericho (10-34%),

Machakos (7-22%), Kitui (6-24%) and Meru (11-34%) (Table2). The mean MC varied from 22.51% in Meru to 16.78%. There was no significant difference among the moisture contents of maize samples within the study areas ($F=140.01$ $P=0.32$).

Table 2: Moisture content of the maize samples

Sample site	n	MC range (%)	Samples >13.5%	Samples <13.5%	Mean MC (%)
Trans Nzoia	130	12-24	125	5	19.33 ^a
Kisii	130	8-26	122	8	17.12 ^a
Kisumu	130	9-27	120	10	19.21 ^a
Bungoma	130	10-30	118	12	20.72 ^a
Migori	130	11-28	121	9	18.51 ^a
Kericho	130	10-34	122	8	21.42 ^a
Machakos	130	7-22	115	15	18.50 ^a
Kitui	130	6-24	117	13	16.78 ^a
Meru	130	11-34	121	9	22.51 ^a

Means within a column followed by the same superscripts are not significantly different at $P \leq 0.05$. The P-values were calculated using SPSS P-significant tests.

Number of the most common mycotoxin producing fungi isolated from maize samples

The *Aspergillus sp.* ranged from 11 CFU/g in Kitui to 63 CFU/g in Trans Nzoia, *Penicillium sp.* from 13 CFU/g in Kitui to 62 CFU/g in Kisii and *Fusarium sp.* from 9 CFU/g in

Machakos to 59 CFU/g in Trans Nzoia (Table 3). The mean mycoflora isolates varied from 10.33 CFU/g in Machakos to 61.00 CFU/g in Trans Nzoia. There was no significant difference in the mean MC among the study areas ($F=0.08$ $P=0.40$).

Table 3: Number of mycotoxin producing fungi (CFU/g) isolated from maize from the study areas

County	Number of fungi			Mean
	<i>Aspergillus sp.</i>	<i>Penicillium sp.</i>	<i>Fusarium sp.</i>	
Trans Nzoia	63	61	59	61.00 ^a
Kisii	60	62	56	59.33 ^a
Kisumu	57	59	49	55.00 ^a
Bungoma	55	49	52	52.00 ^a
Migori	54	50	47	50.33 ^a
Kericho	59	48	53	53.33 ^a
Machakos	12	10	9	10.33 ^a
Kitui	11	13	10	11.31 ^a
Meru	56	51	57	54.67 ^a

Means within a column followed by the same superscripts are not significantly different at $P \leq 0.05$. The P-values were calculated using SPSS P-significant tests.

DISCUSSION

Maize is the staple food in Kenya (Nyongesa et al., 2015). It offers most Kenyan communities with food security (Wagacha et al., 2013). As a result, it's produced in many places in the country. However, maize production is threatened by prevalence of a wide variety of fungi some of which produce mycotoxins that are toxic to humans.

According to Akowuah et al. (2015), maize source greatly influences the levels of maize contamination with fungal spores. In this study, most people obtained maize from family farms while the minority got them from millers. This agreed with a previous study by Williams et al. (2014). This may be attributed to similarity in the regions from which the samples were obtained.

Stage of harvesting maize influences growth of fungi on the produce (Mboya et al., 2011). Majority of the respondents in this study stalked maize in heaps and allowed them to dry while some of them harvested and sold the maize at green stage. These results differed with those of a previous study carried out by Voss et al. (2014). Variations in the respondent's economic status could have contributed to the differences (Queiroz et al., 2012). Makuvaro et al. (2014) maintained that farmers with a good economic status delayed harvesting of maize thus allowing it to dry properly before harvesting. This reduces the

chances of fungal growth on the harvested maize (Amra et al., 2017).

Farmers living in areas that receive high amounts of rainfall obtain many poor grade maize due to fungal infection before harvesting than those in dry areas (Antonio et al., 2018). The poor grade maize is used in a variety of ways (Lee et al., 2013). In the present study, most farmers fed livestock with the poor grade maize. However, 1.1% farmers threw the poor grade maize away. In addition, 1.1% of the farmers used the maize at home. These results disagreed with those of a previous study by Bii et al. (2012). This may be attributed to differences in the levels of knowledge about dangers of using poor grade maize (Varga et al., 2015). Feeding animals with poor grade maize is unsafe since mycotoxins produced by fungi present in the maize may end up in the animal products such as milk (Wacoo et al., 2019). The animal products are unsafe for human consumption (Soares et al., 2012).

The study areas had different maize vendors such as grain stockist, migrant vendors, posho millers and commercial millers. Majority of the respondents in the study areas obtained maize from maize grain stockist while the minority sourced maize from migrant vendors. These results contradicted those of a study carried out on occurrences and frequency of fungi and detection of

mycotoxins on poultry rations in Yemen by Algabr et al. (2018). This could be attributed to differences in the ability of the vendors to reach the respondents (Viebrants et al., 2016). According to Czembor et al. (2015), the ability of maize vendors to transport maize affects the accessibility of the produce to potential buyers. In addition, the type of maize vendors affects the contamination level of maize by mycoflora. This result from differences in maize handling practices among vendors (Perrone et al., 2014).

Storage method affects moisture content in maize (Baranyi et al., 2013). High moisture content favours growth of mycoflora leading to increased production of mycotoxins (Warth et al., 2012). In the present study, 44.6% of farmers stored maize in sisal bags while 1.3% stored maize in polythene bags. These results differed with those of a previous study by Seetha et al. (2017). This could be attributed to differences in knowledge about the right containers for maize storage among respondents. In addition variations in the ability to buy the right maize storage container may be a contributing factor (Gong et al., 2016).

Fungi require a certain water activity for optimal growth (Omara et al., 2020). High moisture content levels were found in the majority of the samples in this study. Similar results were obtained by Brandyopadhyay et al. (2016) when carrying out a study on biological control of aflatoxins in Africa. This could be attributed to similarity in agro ecological zones from which the samples were collected. The recommended moisture content in maize and other cereals is 13% (Wacoo et al., 2014). Trans Nzoia recorded the highest mean moisture content (19.33%) while Kitui recorded the least (16.78%). The high moisture contents observed in the current study may be attributed to the rising cases of mycotoxin contamination in the study areas. Previous studies show that fungi grow optimally at moisture contents above 15% and low or no growth at moisture contents of or below 12% (Palmer et al., 2013). This indicated that most of the maize samples in the present study were

at risk of mycoflora attack (Ehrlich & Mack, 2014).

Aspergillus sp., *Penicillium sp.* and *Fusarium sp.* were the main mycotoxin producing fungi isolated in this study. This agreed with a previous study by Marin et al. (2012). This could be attributed to similarity in the study areas in terms of environmental conditions (Domenico et al., 2016). Ismaiel and Papenbrock, (2015) explained that the fungal isolates differ depending on the agro ecological zones. The highest fungal isolates were obtained from Trans Nzoia while the least were obtained from Machakos. Trans Nzoia is a humid region while Machakos is a semi-arid area with low humidity levels a factor that may have led to the observed results. In addition, variations in the number of fungal isolates within the study areas could be attributed to differences in maize management practices after harvesting (Cruz et al., 2013).

CONCLUSION

The maize post-harvest practices observed in the study areas led to contamination of maize with mycoflora. The moisture content levels of stored maize favoured growth of mycotoxin producing fungi.

Recommendations

There is need to identify the species of the mycotoxin producing fungi obtained in this study. The mycotoxins produced by the fungal species needs to be established.

REFERENCES

- Akowuah, J. O., Mensah, L. D., Chan, C., & Roskilly, A. (2015). Effects of practices of maize farmers and traders in Ghana on contamination of maize by aflatoxins: Case study of Ejura-Sekyeredomase Municipality. *African Journal of Microbiology Research*; 9(25), 1658-1666.
- Algabr, H. M., Alwaseai, A., Alzumir, M. A., Hassen, A. A., & Taresh, S. A. (2018). Occurrences and frequency of fungi and detection of mycotoxins on poultry rations in Yemen. *Bulletin of*

- the National Research Centre; 42(32), 1-12.
- Amra, H., Hussien, T., Sultan, Y., Magan, N., Carlobos-Lopez, A., Cumagun, C. J., & Yli-Mattila, T. (2017). New genotypes of aflatoxin-producing fungi from Egypt and Philippines. *Clinical Microbiology*; 6, 67-78.
- Antonio, M., Esther, G. C., Amedeo, P., Peter, J. C., & Paola, B. (2018). Biological control products for aflatoxin prevention in Italy: Commercial field evaluation of atoxigenic *Aspergillus flavus* active ingredients. *Toxins*; 10(30), 2-14.
- Bandyopadhyay, R., Ortega-Beltra, A., Akande, A., Mutegi, C., Atehnkeng, J., & Kaptoge, L. (2016). Biological control of aflatoxins in Africa: current status and potential challenges in the face of climate change. *World Mycotoxin Journal*; 9(5), 771-789.
- Baquião, A. C., de Oliveira, M. M. M., Reis, T. A., Zorzete, P., Diniz Atayde, D., & Correa, B. (2013). Polyphasic approach to the identification of *Aspergillus* section *Flavi* isolated from Brazil nuts. *Food Chemistry*; 139(1-4), 1127-1132.
- Baranyi, N., Kocsube, S., Vagvolgyi, C., & Varga, J. (2013). Current trends in aflatoxin research. *Acta Biologica Szegediensis*; 57, 95-107.
- Bii, F., Wanyoike, W., Nyende, A. B., Gituru, R. W., & Bii, C. (2012). Fumonisin contamination of maize (*Zea Mays*) in aflatoxin 'Hot' zones in Eastern Province of Kenya," *African Journal of Health Sciences*; 20, 28-36.
- Cruz, A., Marín, P., González-Jaén, M. T., Aguilar, K. G. I., & Cumagun, C. J. R. (2013). Phylogenetic analysis, fumonisin production and pathogenicity of *Fusarium fujikuroi* strains isolated from rice in the Philippines. *Journal of the Science Food and Agriculture* 93, 3032-3039.
- Czembor, E., Stepień, Ł., & Waśkiewicz, A. (2015). Effect of environmental factors on *Fusarium* sp. and associated mycotoxins in maize grain grown in Poland. *PloS One*; 10(7), e0133644-e0133644.
- Domenico, A. S. D., Busso, C., Hashimoto, E. H., Frata, M. T., Christ, D., & Coelho, S. R. M. (2016). Occurrence of *Aspergillus* spp., *Fusarium* spp. and aflatoxins in corn hybrids with different systems of storage. *Agronomy*; 38(1), 111-121.
- Ehrlich, K. C., & Mack, B. M. (2014). Comparison of expression of secondary metabolite biosynthesis cluster genes in *Aspergillus flavus*, *A. parasiticus* and *A. oryzae*. *Toxins*; 6(6), 16-28.
- Gachara, G. W., Nyamache, A. K., Harvey, J., Gnonlonfn, G. J. B., & Wainaina, J. (2018). Genetic diversity of *Aspergillus flavus* and occurrence of aflatoxin contamination in stored maize across three agro-ecological zones in Kenya. *Agriculture and food security*; 7(52), 1-8.
- Gong, Y. Y., Watson, S., & Routledge, M. N. (2016). Aflatoxin exposure and associated human health effects, a review of epidemiological studies. *Food Safety*; 4(1), 14-27.
- Hussien, T., Carlobos-Lopez, A. L., Cumagun, C. J. R., & Tapani, Y. M. (2017). Identification and quantification of fumonisin-producing *Fusarium* sp. in grain and soil samples from Egypt and the Philippines. *Phytopathologia Mediterranea*; 56, 146-153.
- Islam, A., Callicott, K. A., Mutegi, C., Bandyopadhyay, R., & Cotty, P. J. (2018). *Aspergillus flavus* resident in Kenya: High genetic diversity in an ancient population primarily shaped by clonal reproduction and mutation-driven evolution. *Fungal Ecology*; 35, 20-33.
- Ismaiel, A. A., & Papenbrock, J. (2015). Mycotoxins: Producing fungi and mechanisms of phytotoxicity. *Agriculture*; 5, 492-537.

- Juma E. O. A., Musyimi D. M., & Opande, G. (2018). Antagonistic Potential Of Selected Fungal And Bacterial Isolates From Rhizosphere Of Sugarcane Variety Co 421 Against *Sporisorium Scitamineum* In Kibos, Kisumu County, Kenya. *Applied Science Reports*; 17(1), 7-15.
- Lee, S., Lee, S., & Sserumaga, J. P. (2013). Survey for contamination of aflatoxin in Uganda maize. *Journal of the Korean Society of International Agriculture*; 25(4), 335-340.
- Maina, P. K., Wachira, P. M., Okoth, S. A., Kimenju, J. W., Otupa, M., & Kiarie, J. W. (2015). Effects of land-use intensification on distribution and diversity of *Fusarium* species in Machakos County, Kenya. *Journal of Agricultural Science*; 7(4), 48-60.
- Makuvaro, V., Sue, W., Adelaide, M., Phillip, M. T., Cyril, M., & Ignatius, C. (2014). An overview of current agronomic practices of smallholder farmers in semi-arid Central and Western Zimbabwe. *African Journal of Agricultural Research*; 9(35), 2710-2720.
- Marin, S., Ramos, A. J., Germán, C. S., & Sanchis, V. (2012). Reduction of mycotoxins and toxigenic fungi in the Mediterranean basin maize chain. *Phytopathologia Mediterranea*; 51(1), 93-118.
- Mboya, R., Tongoona, P., Yobo, K. S., Derera, J., Mudhara, M., & Langyintuo, A. (2011). "The quality of maize stored using roof and sack storage methods in Katumba Ward, Rungwe District, Tanzania: Implications on household food security. *Journal of Stored Products and Postharvest Research*; 2(9), 189-99.
- Nyongesa, B. W., Okoth, S., & Ayugi, V. (2015). Identification key for *Aspergillus* species isolated from maize and soil of Nandi County, Kenya. *Advances in Microbiology*; 5, 205-229.
- Odhiambo, B. O., Murage, H., & Wagara, S. N. (2013). Isolation and characterisation of aflatoxigenic *Aspergillus* species from maize and soil samples from selected counties of Kenya. *African Journal of Microbiology Research*; 7(34), 4379-4388.
- Omara, T., Nassazi, W., Omute, T., Awath, A., Laker, F., Kalukusu, R., Musau, B., Nakabuye, B. V., Kagoya, S., Otim, G., & Adupa, E. (2020). Aflatoxins in Uganda: An encyclopedic review of the etiology, epidemiology, detection, quantification, exposure assessment, reduction, and control. *International Journal of Microbiology*; 12, 1-18.
- Palmer, J. M., Theisen, J. M., Duran, R. M., Grayburn, W. S., Calvo, A. M., & Keller, N. P. (2013). Secondary metabolism and development is mediated by LlmF control of VeA subcellular localization in *Aspergillus nidulans*. *PLoS Genet*; 9(1), e1003193.
- Pascual, C. B., Barcos, A. K. S., Mandap, J. A. L., & Ocampo, E. T. M. (2016). Fumonisin-producing *Fusarium* sp. causing ear rot of corn in the Philippines. *Philipp. Journal of Crop Science* 41, 12-21.
- Perrone, G., Gallo, A., & Logrieco, A. F. (2014). Biodiversity of *Aspergillus* section *Flavi* in Europe in relation to the management of aflatoxin risk. *Frontiers in Microbiology*; 5, 377, 2014.
- Queiroz, V. A., de Oliveira Alves, G. L., da Conceição, R. R., Guimarães, L. J., Mendes, S. M., de Aquino Ribeiro, P. E., & da Costa R. V. (2012). Occurrence of fumonisins and zearalenone in maize stored in family farm in Minas Gerais, Brazil. *Food Control*; 28(1), 83-86.
- Rotich, M. C., Magiri, E., Bii, C., & Maina, N. (2017). Bio-Prospecting for Broad Spectrum Antibiotic Producing Actinomycetes Isolated from Virgin

- Soils in Kericho County, Kenya. *Advances in Microbiology*, 7, 56-70.
- Seetha, A., Munthali, W., & Msere, H. W. (2017). Occurrence of aflatoxins and its management in diverse cropping systems of central Tanzania. *Mycotoxin Research*; 33(4), 323–331.
- Sichangi, M. B., Nduko, J. M., & Matofari, J. W. (2020). Molecular investigation of potential lactic acid bacteria starter culture organisms/probiotics in the Kenyan spontaneously fermented milk, *amahere amaruranu*. *Parkistan Journal of Nutrition*; 19(3), 132-145.
- Soares, C., Rodrigues, P., Peterson, S. W., Lima, N., & Venâncio, A. (2012). A new species of *Aspergillus* section Flavi isolated from almonds and maize in Portugal. *Mycologia*; 104(3), 682-697.
- Thathana, M. G., Murage, H., Abia, A. L. K., & Pillay, M. (2017). Morphological characterization and determination of aflatoxin-production potentials of *Aspergillus flavus* isolated from maize and soil in Kenya. *Agriculture*; 7(80), 2-14.
- Turner, N. W., Bramhmbhatt, H., Szabo-Vezse, M., Poma, A., Coker, R., & Piletsky, S. A. (2015). Analytical methods for determination of mycotoxins: An update (2009-2014). *Analytica Chimica Acta*; 101, 12-33.
- Varga, J., Baranyi, N., Chandrasekaran, M., Vágvolgyi, C., & Kocsis, S. (2015). "Mycotoxin producers in the *Aspergillus* genus: an update. *Acta Biologica Szegediensis*; 59(2), 151–167.
- Varga, J., Baranyi, N., Chandrasekaran, M., Vágvolgyi, M., & Kocsis, S. (2015). Mycotoxin producers in the *Aspergillus*: an update. *Acta Biologica Szegediensis*; 59(2), 151–167.
- Viebrantz, P. C., Radunz, L. L., & Dionello, R. G. (2016). Mortality of insects and quality of maize grains in hermetic and non-hermetic storage. *Revista Brasileira de Engenharia Agrícola e Ambiental*; 20(5), 487-492.
- Voss, K. A., Riley, R. T., & Gelineau-van Waes, J. (2014). Fumonisin B1 induced neural tube defects were not increased in LM/Bc mice fed folate-deficient diet. *Molecular Nutrition and Food Research*; 58(6), 190-1198.
- Wachira P. M., Kimenju J. W., & Otupa, M. (2015). Change in diversity and abundance of nematode destroying fungi in land use under irrigation in selected small scale irrigation schemes in Kenya. *Agriculture, Forestry and Fisheries*. 4(1), 7-13.
- Wacoo, A. P., Wendi, D., Vuzi, P. C., & Hawumba, J. F. (2014). Methods for detection of aflatoxins in agricultural food crops. *Journal of Applied Chemistry*; 2, 1-15.
- Wacoo, A., Mukisa, I., & Meeme, R. (2019). Probiotic enrichment and reduction of aflatoxins in a traditional African maize based fermented food. *Nutrients*; 11(2), 265-275.
- Wagacha, J. M., Mutegi, C. K., Christie, M. E., Karanja, L.W., & Kimani, J. (2013). Changes in fungal population and aflatoxin levels and assessment of major aflatoxin types in stored peanuts (*Arachis hypogaea* Linnaeus). *Journal of Food Research*; 2(5), 10-23.
- Warth, B., Parich, A., & Atehnkeng, J. (2012). Quantitation of mycotoxins in food and feed from Burkina Faso and Mozambique using a modern LC-MS/MS multitoxin method. *Journal of Agricultural and Food Chemistry*; 60(36), 9352–9363.
- Williams, S. B., Baributsa, D., & Woloshuk, C. (2014). Assessing Purdue Improved Crop Storage (PICS) bags to mitigate fungal growth and aflatoxin contamination. *Journal of Stored Products Research*; 59, 190-196.

Appendix 1: Questionnaire

a) Location of sampling area

County _____ Ward _____ Location _____
Division _____ Name of Village/Market _____

b) Source of maize and maize products

Where do you get your maize from?

- i) Family farm
- ii) Nearby market
- iii) NCPB store
- iv) Merchants
- v) At the mill
- Any other source.....

c) Storage method/material

- i) Granary
- ii) Polypropylene bag
- iii) Sisal bag
- iv) Basket
- v) Polythene bag
- vi) Clay pot
- vii) On the floor of the family house
- Any other.....

d) At what stage do you harvest your maize

- i) When mature and staling to dry
- ii) Left standing until it dries completely
- iii) Staked and left to dry completely
- iv) Harvested and sold green

e) What do you do with the very poor grade of maize you sort out?

- i) Thrown away
- ii) Dried and used at home
- iii) Sold away to willing buyers
- iv) Fed to family livestock
- v) Other uses

b) Vendor Type

- i) Store Merchant (Grain Stockist)
- ii) Migrant Vendor (Jua Kali)
- iii) Posho miller
- iv) Commercial miller
- v) Maize wholesale
- vi) Farmers own maize

e) Other Maize Handlers

- i) Maize drier
- ii) Bulk grain handler
- iii) WFP store
- iv) NCPB
- v) Other grain handler.....