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Isolation of Fungi from Maize Samples Collected from Selected Counties in Kenya

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ABSTRACT

Background: Maize is the stable food in Kenya. However, its production has been jeopardized by the high prevalence of fungi in most developing countries and the whole world at large. Some fungi produce mycotoxins which threaten human lives.

Methods: This study aimed at isolating fungi from selected Counties in Kenya. Maize samples were ground using a kitchen blender and cultured on Potato Dextrose agar at 28°C for 7 d. The fungal isolates were identified using morphological and cultural characteristics. Data was analyzed using Statistical Package for Social Sciences (SPSS) version 25.0 software.

Result: The mean fungal isolates varied from 10.8±0.2 CFU/g in *Wallenia spp.* to 47.4±0.2CFU/g in *Aspergillus spp.* The most common fungal isolates were *Aspergillus spp., Fusarium spp.* and *Penicilium spp.* The Mean fungal isolates from the selected Counties varied from Kitui (9.6±0.2 CFU/g), Machakos (9.7±0.3CFU/g), Bungoma (25±0.1CFU/g), Migori (25.3±0.3CFU/g), Kericho (25.3±0.2CFU/g), Kisumu (27.1±0.1CFU/g), Meru (27.1±0.2CFU/g), Kisii (28.5±0.1CFU/g) and Trans-Nzoia (30.1±0.3CFU/g). The number of spores in maize samples from baskets varied from 13.6±0.2-19.6±0.2, polypropylene (24.0±0.2-24.0±0.2), Jute (13.6±0.2-21.6±0.2) and polythene bag (48.0±0.2-72.0±0.2) CFU/g.

Conclusion: This study established that maize in the selected Counties is highly contaminated by pathogenic fungi. The most prevalent fungal spp. were *Aspergillus, Penicillium* and *Fusarium*. The best maize storage material for maize were baskets. There is need of identifying the most prevalent fungi up to the molecular level.

Key words: County, Fungi, Isolation, Maize, Samples.

INTRODUCTION

Maize is an important staple food in most parts of the world (Zhao *et al*., 2017). Its growth is expansive due to its adoptability to different farming systems (Samson *et al*., 2014). Besides, the crop is adjustable to different regions of the world (Paterson *et al*., 2017). Maize contributes to high food security especially in developing countries. With the rising human population all over the world, maize production needs to be supported by all means (Jančič *et al*., 2016).

In Kenya, farming is the key driver of the country's economy (Okioma *et al*., 2020). To small scale farmers, maize provides 60% of dietary calories and over 50% of proteins (Tobin-West *et al*., 2018). Small scale farmers grow about 2 million hectares annually with an average yield of 1.2-1.6 tons per annum (Odhiambo *et al*., 2013). The biggest drawback to maize production is infestation by fungi (Chaubey *et al*., 2015). Some fungi produce mycotoxins which impact negatively to human and animal health (Surendra *et al*., 2011). Mycotoxins are carcinogenic, mutagenic and teratogenic (Salau *et al*., 2017). In addition, they cause impaired growth in children and sometimes immunosuppression (Sangares *et al*., 2016). Mycotoxins cause leuco-encephalomalacia in horses, pulmonary oedema in pigs, liver and kidney cancer in mice and rats.

Fungal growth is increased by high temperature, humidity, monsoons, low rains and flooded conditions (Affeldt *et al*., 2014). Poor harvesting and postharvest practices predisposes maize to fungal attack (Zajc and Gunde-Cimerman, 2018). The highest producer of mycotoxins are in the genera *Aspergillus, Fusarium* and *Penicillium*. The fungi are ubiquitous and cosmopolitan (Medina, 2017). Additionally, the fungi are filamentous proliferating in a vast range of environmental conditions (Krulj, 2019). Damage by fungi in maize is manifested by colour change, decrease in nutritional value and reduction in overall quality and quantity of maize (Negash, 2018). This study aimed at isolating fungi in stored maize in selected counties in Kenya.

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MATERIALS AND METHODS

The study areas

The current is study was carried out in Egerton University,

Department of Biological Sciences laboratories in the year 2020. Maize samples were collected from Trans Nzoia, Kisii, Kisumu, Bungoma, Migori, Kericho, Machakos, Kitui and Meru Counties. Recently, the counties had reported mycotoxin infections (Okioma *et al*., 2020). Trans-Nzoia county is located in Western part of Kenya. The county lies at 2,100 m above sea level. It experiences a temperatures range of 9.05°C-26.85°C (Mutegi *et al*., 2018). Kisii County lies 0°41′ 0 N 34°46′ 0 E. The temperatures varies from 16°C-27°C. The County has a population of 1,152,282 (Okioma *et al*., 2020). Kisumu County covers an area of 2085.9 km^2. The County is located at longitudes 33° 20′E and 35°20′E and latitudes 0°20′South and 0°50′South (Josephat *et al*., 2015). Bungoma County has an area of 2,069 km^2 and is located at 00°34′00″N, 34°34′00″E (Odhiambo *et al*., 2013). Migori County is located in Western Kenya and its temperature varies from 24°C to 31°C (Birgen *et al*., 2020). Kericho County lies at 35° 02′ and 35° 40′ E and 0 23′ S with an altitude of about 2002 m above the sea level (Odhiambo *et al*., 2013). Machakos County is found at latitudes 0°45′ S to 1°31′ S and longitudes 36° 45′ E to 37° 45′ E. The county lies at an altitude of 1000 to 2100 m above sea level (Josephat *et al*., 2015). Kitui County is found in Eastern Kenya at co-ordinates 1°22′ 0″ South and 38° 1′ 0″ East and a temperature range of 26°C to 34°C (Birgen *et al*., 2020). On the other hand, Meru County is located in Eastern Kenya at 0.047035° N and 37.649803° E. The County has a temperature range of 8°C-32°C (Mutegi *et al.,* 2018).

Collection of maize samples

Maize samples were collected from baskets, polypropyne, jute and polythene bags from the selected Counties. The sample size was calculate at 95% confidence level at a precision of 5% as proposed by Nleya *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).
e= Desired level of precision at 5% with a standard value of 0.05.

Substituting the values in the formula above, the sample size was determines as follows:

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

Samples were placed in sterile *khaki* bags and stored at 4°C in the Department of Biological Science Laboratories of Egerton University.

Isolation of fungi from maize samples

The maize samples were surface sterilized using 70% ethanol for 2 minutes. The samples were rinsed with distilled water to remove ethanol on the surface (Chukwudi *et al*., 2021). The Maize samples were blot dried (Pemingo *et al*., 2016). A dry mill kitchen blender (BL335, Kenwood, UK) was used in grinding one kilogram of each maize sample. One gram of each ground maize sample was separately placed in 9mL of sterile distilled water, shaken using an orbital shaker and serially diluted up to 10^{-2}. Aliquots of 0.1 mL were each plated on potato dextrose agar (PDA) and incubation at 28°C for 7 d (Menza and Muturi, 2018). The fungal isolates were sub-cultured on PDA. The fungal isolates were enumerated using a formula provided by Mezzomo *et al*. (2018);

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

Identification of the mycotoxin producing mycoflora

Macroscopic and microscopic characteristics were used in identifying the fungal isolates (Kumar and Kalita, 2017). Length and type of spores were used to morphologically characterize the isolates while cultural characteristics considered colour and margins of the colonies (Lee *et al*., 2013). In addition, the fungal isolates were characterized using fungal identification keys (Abdel-Sater *et al*., 2017).

Spores count of the fungal isolates

Fifty grams of each maize sample from baskets, polypropyne, jute and polythene bags was weighed and placed in a glass beaker containing 200 mL of double distilled water and stirred for two minutes (Okayo *et al*., 2020). Using a teat pipette, the spore suspension was transferred into a heamocytometer. The number of spores from each sample was determined with the help of a microscope (Abe *et al*., 2015).

Data analysis

Data on the number (CFU/g) of fungal isolates from the selected Counties, mean fungal isolates and spore count per gram of maize sample were subjected to analysis of variance (ANOVA) using PROC ANOVA procedure of Genstat Discovery 2 statistical software version 25.0. The means were compared using Fisher's protected LSD test at 5%.

RESULTS AND DISCUSSION

Fungal isolates from the selected counties

The fungal isolates from Trans-Nzoia varied from 12±0.3 CFU/g to 63±0.3 CFU/g, Kisii (11±0.2-62±0.3), Kisumu (11±0.2-59±0.2), Bungoma (12±0.1-55±0.1), Migori (13±0.2-54±0.3), Kericho (11±0.2-59±0.2), Machakos (4±0.1-15±0.2), Kitui (5±0.3-14±0.1) and Meru (6±0.2-57±0.3) CFU/g (Table 1). The mean fungal isolates varied from 10.8±0.2 CFU/g in *Wallenia spp.* to 47.4±0.2CFU/g in *Aspergillus spp.* The most common fungal isolates were *Aspergillus spp., Fusarium spp.* and *Penicilium spp.* (Fig 1). The number of fungal isolates from the selected counties varied significantly (F=1.987 P=0.0484). These results differed with a previous study carried out by Tola and Kebede, (2016). The difference could be attributed to variation in fungal control methods used by farmers in the study sites. Marroquin-Cardona *et al*. (2014) asserted that some farmers use long term fungal control methods which influence the fungal species that

infect maize. In addition the most common fungi are known to produce a variety of mycotoxins (Al-Defiery and Merjan, 2015). This may explain the high cases of mycotoxins poisoning outbreaks reported in the study areas (Njoroge *et al*., 2016).

Morphological and cultural characteristics of the fungal isolates

Identification of the fungal isolate was carried out using colony morphology (cell size, shape, pigmentation and arrangements) and cultural characteristics (Table 2). Use of morphological and cultural characteristics in identification of fungi is the oldest and most widely used tool for fungal identification (Tai *et al*., 2020). The morphological and cultural characteristics concurred with a previous study carried out by Mousa *et al*. (2016). This may be attributed to isolation of the same fungal species (Ncube *et al*., 2021). Okayo *et al*. (2020) successfully isolated and characterized maize fungi using morphological and cultural means.

Mean fungal isolates from the selected counties

The mean fungal isolates from the selected Counties varied from Kitui (9.6±0.2 CFU/g), Machakos (9.7±0.3 CFU/g), Bungoma (25±0.1 CFU/g), Migori (25.3±0.3 CFU/g), Kericho (25.3±0.2 CFU/g), Kisumu (27.1±0.1 CFU/g), Meru (27.1±0.2 CFU/g), Kisii (28.5±0.1CFU/g) and Trans-Nzoia (30.1±0.3 CFU/g) (Fig 2). The mean fungal isolates between the selected counties varied significantly (F=1.877

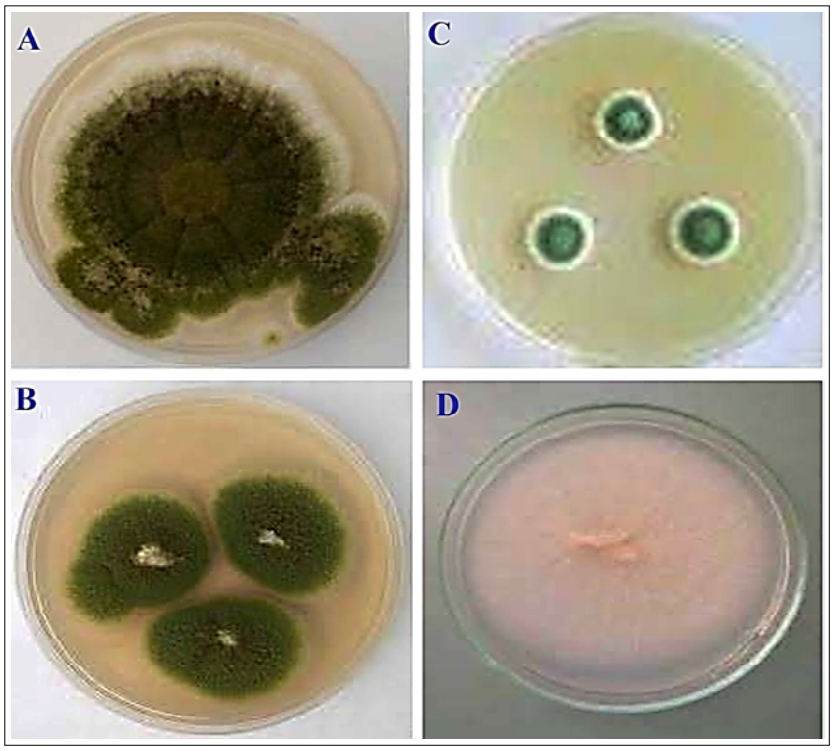


Fig 1: Most common fungal isolates from maize samples from the selected Counties; A and B; *Aspergillus spp*., C; *Penicillium spp*. and D; *Fusarium spp*.

Table 1: Number (CFU/g) of fungal isolates from the selected counties.

Isolate	County									Mean
	T. Nzoia	Kisii	Kisumu	Bungoma	Migori	Kericho	Machakos	Kitui	Meru	
Alternaria spp	21±0.3	20±0.1	17±0.3	16±0.2	14±0.2	15±0.3	4±0.1	6±0.3	21±0.2	14.9±0.2
Fusarium spp	59±0.2	56±0.2	49±0.1	52±0.3	47±0.1	53±0.3	9±0.3	10±0.2	57±0.3	43.6±0.1
Epicoccum spp	23±0.1	19±0.3	15±0.2	10±0.1	13±0.2	12±0.2	9±0.2	8±0.1	14±0.3	13.7±0.3
Wallenia spp	12±0.3	14±0.1	11±0.2	12±0.3	15±0.3	14±0.1	8±0.2	5±0.3	6±0.2	10.8±0.2
Penicillium spp	61±0.2	62±0.3	59±0.2	49±0.1	50±0.3	48±0.1	10±0.1	13±0.2	51±0.3	44.8±0.1
Xeromyces spp	14±0.3	11±0.2	15±0.1	12±0.2	14±0.1	11±0.2	11±0.3	14±0.1	18±0.3	13.3±0.2
Mucor spp	20±0.1	15±0.2	21±0.3	12±0.1	16±0.1	13±0.3	9±0.2	10±0.3	17±0.1	14.8±0.2
Aspergillus spp	63±0.3	60±0.1	57±0.2	55±0.1	54±0.3	59±0.2	12±0.2	11±0.1	56±0.2	47.4±0.2
Rhizopus spp	13±0.1	15±0.3	13±0.2	16±0.1	17±0.2	13±0.3	15±0.2	10±0.3	13±0.1	13.9±0.2
Nigrospora spp	15±0.2	13±0.3	14±0.1	16±0.2	13±0.3	15±0.1	10±0.2	9±0.3	18±0.2	13.7±0.1

T. Nzoia: Trans-Nzoia.

P=0.0474). Although these results indicated that fungi can grow in a wide range of ecological conditions, Kitui presented the lowest fungal isolates while Trans-Nzoia County presented the highest. This disagreed with other studies curried out elsewhere (Maryam, 2017; Okayo *et al*., 2020; Tai *et al*., 2020) which can attributed to differences in humidity conditions of various study sites (Medina, 2017). According to Ncube *et al*. (2021), fungal growth is favoured by warm, moist and humid conditions.

Spores count of the fungal isolates

The number of spores in maize samples from baskets varied from 13.6±0.2-19.6±0.2, polypropylene (24.0±0.2-24.0±0.2), Jute (13.6±0.2-21.6±0.2) and polythene bag (48.0±0.2-72.0±0.2) CFU/g (Table 3). The number of spores obtained from maize stored in baskets, polypropylene, jute and polythene bag varied significantly (F=3.815 P=0.03945). The results were in agreement with a previous study by Nyongesa *et al*. (2015). Dube and Mutewa (2015) observed that baskets allows further drying of maize in storage conditions. According to Peremingo *et al.* (2016) maize is in most cases harvested when moisture content is still high (Njoroge *et al*., 2016). Tai *et al.* (2020) recommended storage of maize in well aerated containers to further reduce the moisture content in the grains. Further, Negash *et al*. (2018)

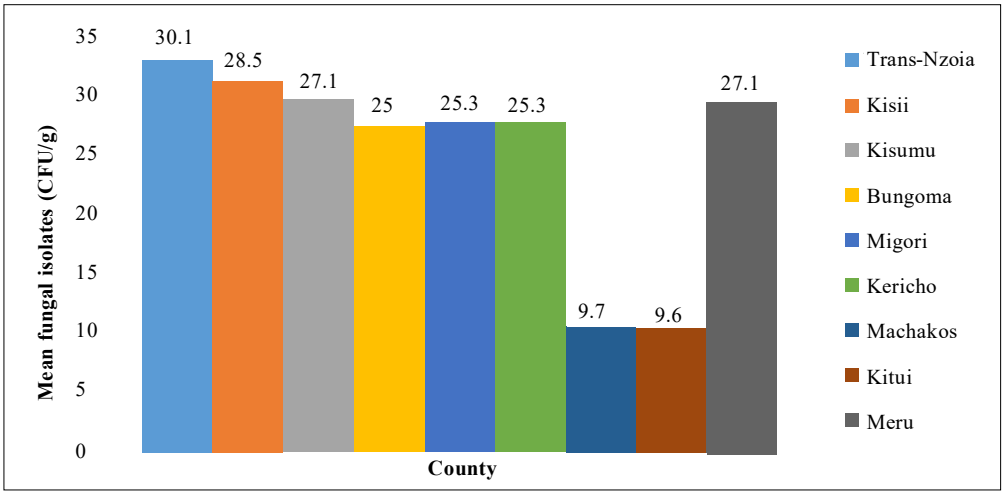


Fig 2: Mean fungal isolates from the selected Counties.

Table 2: Morphological and cultural characteristics of the fungal isolates.

Isolate	Morphological characteristics	Cultural characteristics
Alternaria spp.	Long chains of septate hyphae with dark brown conidiophores.	Black coloured colonies with irregular margins.
Fusarium spp.	Many celled distinct sickle shaped macro conidia.	Rapidly growing wooly to cottony, lemon and yellow coloured colonies.
Epicoccum spp.	Septate yellow to brown hyphae forming dark coloured, warted and spherical blastoconidia.	Felty colonies that appear in bright shades of yellow, orange and red, brown or black.
Wallenia spp.	Transparent hyphae, forming a compact mycelium with conidiphores.	Small brown colonies with a fine velvety texture, with long rows of spores that round up and become free at maturity.
Penicillium spp.	Coenocytic branched hyphal enlarge at the apex forming cornidophores that produce brownish black conidiain chains.	Large fluffy white colonies covering the whole agar surface.
Xeromyces spp.	Hyphae having closed fruiting bodies and D-shaped ascospores.	Low, transluscent, glistering, colourless faintly brown colonies.
Mucor spp.	Sporangium emanating from the hyphae without stolon or rhizoids.	Large fluffy white colonies almost covering the whole agar surface
Aspergillus spp.	Conidia designed in 360 arrangements covering the upper conidiophores.	Green colonies some with whitish margins colonies.
Rhizopus spp.	Coenocytic hyphae with up right sporagiophore bearing sporangiaconnected by stolon and rhizoids.	Large fluffy white milky colonies which later turned black with age
Nigrospora spp.	Septate hyphae bearing conidiophores that are straight or slightly curved producing brownish black, oblate spheroid and single celled conidia.	Rapidly growing colonies and appear hairy or woolly.

Table 3: Number of spores per gram of maize sample.

Replicate	Storage material			
	Basket	Polypropylene	Jute	Polythene bag
1	13.6±0.2	24.0±0.2	13.6±0.2	48.0±0.2
2	17.6±0.1	30.4±0.3	14.4±0.1	68.8±0.1
3	18.4±0.3	30.4±0.1	21.6±0.2	72.0±0.2
4	19.6±0.2	31.8±0.1	20.6±0.3	58.8±0.1
5	16.5±0.1	28.3±0.3	16.5±0.2	62.9±0.2
Mean	17.14±0.1	28.98±0.3	17.34±0.2	62.1±0.2

established that post-harvest practices of most farmers expose maize to infection by fungi prior to storage.

CONCLUSION

This study established that maize in the selected Counties is highly contaminated with fungi. The most prevalent fungal spp. were *Aspergillus, Penicillium* and *Fusarium*. The best maize storage material for maize were baskets. There is need of identifying the most prevalent fungi up to the molecular level. The mycotoxins produced by the most prevalent fungal spp. need to be established.

REFERENCES

Abdel- Sater, M.A., Abdel-Hafez, S.I.I., Nemmat, A.H. and A.L- Amery, E.A. (2017). Fungi associated with maize and sorghum grains and their potential for amylase and aflatoxins production. Egypt Journal of Botany. 57(1): 119-137.

Abe, C.A.L., Faria, C.B., Castro, F.F., Souza, S.R., Santos, F.C., Silva, C.N., Tessmann, D.J. and Barbosa, I. P. (2015). Fungi isolated from maize (*Zea mays* L.) grains and production of associated enzyme activities. International Journal of Molecular Sciences. 16(7): 15328-15346.

Affeldt, K.J., Carrig, J., Amare, M., Keller, N.P. (2014). Global survey of canonical *Aspergillus flavus* G protein-coupled receptors. Mbio. 5: e01501-e01514.

Al-Defiery, M.E. and Merjan, A.F. (2015). Mycoflora of mold contamination in wheat flour and storage wheat flour. Meso Environment Journal. 1: 18-25.

Birgen, J.K., Cheruiyot, R.C. and Akwa, T.E. (2020). Mycotoxin contamination of stored maize in Kenya and the associated fungi. Journal of Plant Pathology Research. 2(1): 7-13.

Chaubey, A.K., Singh, H.P. and Shahi, U.P. (2015). Mycorrhizal strains efficacy in soybean. Agricultural Science Digest. 35(3): 183-186.

Chukwudi, U.P., Kutu, F.R., Mavengahama, S. (2021). Mycotoxins in Maize and Implications on Food Security: A review. Agricultural Reviews. 42(1): 42-49

Dube, L. and Mutetwa, M. (2015). Assessment of aflatoxin awareness by players in groundnut value chain: The case of Dora in Mutare, Zimbabwe. International Journal of Innovative Research and Development. 4: 90-100.

Jančič, S., Zalar, P., Kocev, D., Schroers, H.-J., Džeroski, S. and Gunde-Cimerman, N. (2016). New insights into the extremophilic life-style of *Wallemia* with the description of *Wallemia hederae* sp. nov. Fungal Diversity. 76: 97-118.

Josephat, K.T., Kiiyukia, C. and Christine, C.B. (2015). Mycotoxigenic fungi, distribution and infestation of maize in selected sites- Kenya. Global Advanced Research Journal of Agricultural Science. 4(6): 248-258.

Krulj, J. (2019). The effect of storage temperature and water activity on aflatoxin B1 accumulation in hull-less and hulled spelt grains. Journal of the Science of Food and Agriculture. 99: 3703-3710.

Kumar, D. and Kalita, P. (2017). Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. Foods. 6(1): 8-20.

Lee, S., Medina, A., Rodríguez, A., Sulyok, M. and Magan, N. (2013). Mycotoxigenic fungi and mycotoxins associated with stored maize from different regions of Lesotho. Mycotoxin Research. 29: 209-219.

Marroquín-Cardona, A.G., Johnson, N.M., Phillips, T.D. and Hayes, A.W. (2014). Mycotoxins in a changing global environment-a review. Food and Chemical Toxicology. 69: 220-230.

Maryam, A.S. (2017). Isolation and identification of fungi from cereal grains in Libya. International Journal of Photochemistry and Photobiology. 1(1): 9-12.

Medina, A. (2017). Interactions between water activity and temperature on the *Aspergillus flavus* transcriptome and aflatoxin B1 production. International Journal of Food Microbiology. 256: 36-44.

Menza, N.C. and Muturi, M.W. (2018). Occurrence of aflatoxigenic *Aspergillus* spp in peanut varieties in Busia and Kisii central districts, Kenya. Open Journal of Medical Microbiology. 8: 98-108.

Mezzomo, R., Rolim, J.M., Poletto, T., de Oliveira, M.B., Lazarotto, M. and Muñiz, M.F. (2018). Mycelial growth and sporulation of *Fusarium* spp. pathogenic to Ilex paraguariensis in different culture media and under exposure to different light levels. Scientia Agraria. 19(1): 14-19.

Mousa, W., Ghazali, F.M., Jinap, S., Ghazali, H.M., Radu, S. and Salama, A.E.R. (2016). Temperature, water activity and gas composition effects on the growth and aflatoxin production by *Aspergillus flavus* on paddy. Journal of Stored Products Research. 67: 49-55.

Mutegi, C.K., Cotty, P.J. and Bandyopadhyay, R. (2018). Prevalence and mitigation of aflatoxins in Kenya (1960-to date). World Mycotoxin Journal. 11(3): 341-357.

Ncube, J., Ndlovu, E., Musarandega, L. and Maphosa, M. (2021). Occurrence of mycoflora, their association and production of aflatoxin B1 in groundnuts. Journal of Yeast and Fungal Research. 12(1): 1-7.

Negash, D. (2018). A review of aflatoxin: occurrence, prevention and gaps in both food and feed safety. Nutritional Health and Food Engineering. 8: 190-197.

Njoroge, S.M.C., Kanenga, K., Siambi, M., Waliyar, F. and Monyo, E.S. (2016). Identification and toxigenicity of *Aspergillus* spp. from soils planted to peanuts in Eastern Zambia. Peanut Sciences. 43: 148-156.

Nleya, N., Adetunji, M.C. and Mwanza, M. (2018). Current status of mycotoxin contamination of food commodities in Zimbabwe. Toxins. 10: 89-103.

Nyongesa, B.W., Okoth, S. and Ayugi, V. (2015). Identification key for *Aspergillus* species isolated from maize and soil of Nandi country, Kenya. Advances in Microbiology. 5: 10-25.

Odhiambo, B.O., Murage, H. and Wagara, I.N. (2013). Isolation and characterization of aflatoxigenic *Aspergillus* species from maize and soil samples from selected counties of Kenya. African Journal of Microbiology Research. 7: 4379-4388.

Okayo, R.O. andika, D.O., Dida, M.M., K'Otuto, G.O and Gichimu, B.O. (2020). Morphological and molecular characterization of Toxigenic *Aspergillus flavus* from groundnut Kernels in Kenya. International Journal of Microbiology. 1: 1-10.

Okioma, M.S.N., Gathuru, E.M., Wagara, I.N., Waithaka, P.N. and Githaiga, B.M. (2020). Post-harvest practices of maize farmers in selected Counties in Kenya and isolation of mycotoxin producing fungi from maize samples. Indian Journal of Pure Applied Biosciences. 8(5): 20-30.

Paterson, R.R.M. and Lima, N. (2017). Filamentous fungal human pathogens from Food emphasizing on *Aspergillus, Fusarium* and *Mucor* spp. Microorganisms. 5: 44-56.

Peromingo, B., Rodríguez, A., Bernáldez, V., Delgado, J. and Rodríguez, M. (2016). Effect of temperature and water activity on growth and aflatoxin production by *Aspergillus flavus* and *Aspergillus parasiticus* on cured meat model systems. Meat Science. 122: 76-83.

Salau, I.A., Shehu, K. and Kasarawa, A.B. (2017). Morphological characterization of mycotoxigenic fungi contaminating groundnut products in Sokoto State. Research in Pharmacy and Biosciences. 4: 1-7.

Samson, R.A., Visagae, C.M., Houbraken, J., Hon, S.B., Hubka, V., Klaassen, C.H.W., Perrone, G., Seiffet, K.N., Susca, A., Tanney, J.B., Varga, J., Koscube, S., Szigeti, G., Yaguchi, T. and Frisvad, J.C. (2014). Phylogeny identification, nomenclature of the genus *Aspergillus*. Mycology. 78: 141-173.

Sangareswari, N.M., Thangamuthu, P.K., Umesh, K., S., Karthiba, L., Saravanakumar, D. (2016). Fungal microbes associated with agarwood formation. American Journal of Plant Sciences. 7: 1445-1452.

Surendra, K.G., Sally K.M. and Girija, D. (2011). *Catharanthus roseus*- A highly infective host of arbuscular mycorrhizal fungi. Agricultural Science Digest. 31(4): 285-288.

Tai, B., Chang, J., Liu, Y. and Xing, F. (2020). Recent progress of the effect of environmental factors on Aspergillus flavus growth and aflatoxins production on foods. Food Quality and Safety. 4: 21-28.

Tobin-West, M.D., Dimkpa, S.O.N. and Osakwe, J.A. (2018). Isolation and identification of fungi associated with raw groundnut seeds sold at four major markets in Port Harcourt Metropolis, Rivers State. Biology, Agriculture and Healthcare. 8: 29-34.

Tola, M. and Kebede, B. (2016). Occurrence, importance and control of mycotoxins: A review. Cogent Food and Agriculture. 2: 1-12.

Zajc, J. and Gunde-Cimerman, N. (2018). The genus *Wallemia*-From contamination of food to health threat. Microorganisms. 6: 46-62.

Zhao, R. L., Li, G. J., Sánchez-Ramírez, S., Stata, M., Yang, Z.L., Wu, G., Dai, Y.C., He, S.H., Cui, B.K. and Zhou, J.L. (2017). A six-gene phylogenetic overview of Basidiomycota and allied phyla with estimated divergence times of higher taxa and a phyloproteomics perspective. Fungal Diversity. 84: 43-74.