Review

Management and mitigation of health risks associated with the occurrence of mycotoxins along the maize value chain in two counties in Kenya


*Department of Public Health, Pharmacology and Toxicology, University of Nairobi, Nairobi, Kenya, **Natural Resources Institute Finland, LUKE, Jokioinen, FI-31600 Jokioinen, Finland, ***Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya, ****School of Biological Sciences, University of Nairobi, 00100 Nairobi Kenya, *****Kenya Agriculture, Livestock Research Organization, Nairobi, Kenya, and ******Department of Dairy Science, Egerton University, Njoro, Egerton, Kenya

Correspondence to: E. K. Kang’ethe, Department of Public Health, Pharmacology and Toxicology, University of Nairobi, Box 29053-00625, Nairobi, Kenya. E-mail: mburiajudith@gmail.com

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Abstract

Aflatoxins and fumonisins are two mycotoxins that are prevalent in cereals. Both toxins have associated and causal health effects in humans and livestock. Once formed in the substrates, the toxins are not easily destroyed. The preferred mitigation is to prevent contamination of the cereals and animal source foods. In this paper we set out to examine the practices of the farmers in two counties (Nandi and Makueni) in Kenya which exacerbates aflatoxin contamination and the government steps to address the issue in the agriculture and livestock sectors. The practices identified in Nandi and Makueni, respectively, included seed varieties where 19.3% and 56% are using local varieties; use of soil amendments where 5.8% and 181% are not using any amendments; crop rotation where 54.6% and 60.5% are not practicing crop rotation; 22.7% and 37.5% are using wrong drying methods; and 53% and 77.1% are using poor threshing methods. The Kenya government is subsidizing fertilizers, seeds, increasing areas under irrigation, and providing extension services to build capacity of farmers to mitigate aflatoxin contamination. The paper examines also the cultural practices in land preparation, tillage, crop rotation, drying, sorting at farm, and proper storage as better alternative practices for easy adoption that would, if adopted, lead to a decrease in aflatoxin and fumonisin contamination and therefore reduce household exposure. Good agricultural practices should be a prerequisite for the adoption of other aflatoxin control technologies.

Key words: Aflatoxins; Fumonisins; Contamination; Maize value chains; Mitigations; Kenya.

Introduction

Kenya has had a problem with mycotoxicosis as evidenced by the 2004/2005 aflatoxin outbreak, which resulted in the high case fatality of 39.4% (Lewis et al., 2005). Subsequent outbreaks have also resulted in loss of life. Aflatoxins and fumonisins are the major fungal toxins that contaminate and have been detected in cereals in
Kenya (Mutiga et al., 2015). In addition to acute toxicity that leads to loss of life in case of aflatoxins, chronic exposure to the toxins has been associated with public health concerns and food security.

Chronic exposure of humans to aflatoxins has been associated with immunosuppression (Williams et al., 2004) and carcinogens causing liver cancer (Wu et al., 2011). International Agency for Research on Cancer (IARC) estimates that liver cancer incidences in Kenya associated with aflatoxin are 8.5 and 4.9/100 000 cases for males and females, respectively (Wu et al., 2011). There is no direct causal relationship between aflatoxin exposure and stunting in children but a high correlation between the two has been established (Gong et al., 2004; Leroy, 2013). It has been estimated that 25% of the world's grains are contaminated with aflatoxins (CAST, 2003), which would cause a serious world food security threat if the contaminated grains are removed from the food supply chain. Fumonisins have been suspected risk factors for human disease such as esophageal cancer (Marasas, 2001; Wakhisi et al., 2005) and neural tube defects (Meismer et al., 2006). While a causal relationship in human disease is unproven, fumonisins are recognized causes of equine leukoencephalomalacia (Kellerman, 1990), toxic feed syndrome in poultry, and porcine pulmonary edema syndrome in swine (Ross et al., 1993; Norred and Voss, 1994).

Mitigation of aflatoxin and fumonisin contamination can be targeted to preharvest and post-harvest periods to prevent plant infection and grain contamination. During preharvest, good agricultural practices reduce the vulnerability of crops to fungal infection (Munkvold, 2003). Post-harvest practices help to prevent mycotoxin development in the grains. Other mitigation technologies include biological control (Cotty, 1994) and use of enterosorbents and chemoreception to prevent absorption of the toxins in exposed individuals (Kensler et al., 2013; Miller et al., 2014). This paper investigates the extent to which farmers are adopting good agricultural (cultural) management practices which are known to mitigate aflatoxin and fumonisin contamination of cereals at pre-harvest and post-harvest period in the two counties of Makueni and Nandi, Kenya.

Materials and methods

Site and household selection

The counties Nandi and Makueni in Kenya were purposively selected based on history of human acute aflatoxicosis in Makueni (Lewis et al., 2005) and high incidences of esophageal cancer in Nandi (Wakhisi et al., 2005). At the county level, a team consisting of the researchers, veterinary, agriculture extension, and health officers selected three subcounties that best fitted the criteria of high dairy production and maize growing activities. At the subcounty and ward level, the extension officers selected the ward and the sublocation, respectively, that best fitted the same criteria. With the assistance of village elders (managers), the households that had dairy animals (cattle or goats); grew maize, sorghum, and/or millet; had a child below 5 years or the spouse was pregnant at the time were listed.

Based on the population and number of households in the sublocation and the households that fitted the criteria, a proportion of the households was randomly selected for sampling (Martin et al., 1987), and the household sample size was corrected for finite population according to Daniel (1999).

Nandi falls within the agroecological zones of lower humid highlands to upper midland and upper highland zones ((LH2, LH3, UM3, and UM4) (Jaeztold et al., 2006). It lies between 1300 to 2500 m above sea level and receives about 1200–2000 mm of rain per year. Nandi is best suited for tea, dairy activities, maize, wheat, and barley growing. Makueni falls within the lower midland agroecological zones LM3, LM4, and LM5. It receives between 200 and 1200 mm of rainfall per year, which is unreliable at times with frequent droughts resulting in crop failures.

Data collection tools

A questionnaire was administrated to heads or their spouses of selected households in Nandi and Makueni. The questionnaire sought to capture data on agricultural practices (use of soil amendments, seed varieties, crop rotation, harvesting, threshing, drying, sorting, and storage) during the maize cropping season.

Data relating to use, disposal of moldy grains, and health risk perceptions associated with consumption of moldy maize were obtained by asking the respondents what they used to determine that the maize was spoilt or moldy. In this regard, the researchers gave respondent women (women are responsible for family food preparation. Determining what is safe for family meals is their responsibility and were best suited to give information) during the questionnaire administration a handful of maize that had good and moldy grains. They were asked to sort out the good and the bad ones. After the exercise, they were asked to explain what criteria they used to sort out the maize. They too were asked what was the minimum level or type of spoilage that would allow consumption of moldy or spoilt grains; the methods they used to dispose of spoilt or moldy grains; the perception of health risks associated with feeding animals with moldy grains; and whether they considered milk from animals fed moldy grains to be safe.

The data collected through questionnaire were triangulated by group discussions that employed a discussion guide with county extension officers. Three workshops were held with county extension officers, which captured the role of the central and county governments in the management of the aflatoxin and fumonisin contamination through group discussions on whether they considered the problem worth mitigating and the measures they would adopt to control the problem in the counties.

Results and discussion

Good agricultural practices

Five hundred and forty-one questionnaires were administered; for which 280 respondents were from Makueni and 261 from Nandi. The study evaluated a number of agricultural practices as shown in Table 1.

Land preparation

During the preharvest stage in a maize cropping season, farmers in Nandi were better than their counterparts in Makueni in adopting good agricultural practices. Adoption of good practices along the food value chain has been proposed as the best way to reduce levels of fungal toxins in the food supply (Clarke and Fattori, 2013). This study did not evaluate land tillage practices. However, fungal population densities have been shown to be affected by land preparation methods. Nesi et al. (2006) and Zabloutowisc et al. (2007) compared the Aspergillus flavus density in land with no tillage and land with reduced tillage and found that land with no tillage and medium tillage with grazing had high A. flavus density compared with land with deep tillage. This was attributed to high organic matter content in land with no tillage. Communities in Makueni use oxen ploughs and may not practice deep tillage compared to the communities in Nandi who use tractors for ploughing after each crop season. Okoth et al. (2012) found that A. flavus was the most prevalent contaminant of
maize in both counties with an incidence of 82.33% and 73.26%, in Nandi and Makueni, respectively.

Certified seeds

All the respondents in Nandi planted recommended and certified seeds for the agroecological zones compared to 56% of the farmers in Makueni who were using local varieties. National and international seed producing companies in Kenya had released over 164 varieties by 2009 (Kang’ethe, 2011). These varieties, though not fungally resistant, are tested for pest and disease resistance, drought, and low nitrogen tolerance in addition to being high yielding. They are ecologically adapted. In Nandi and Makueni, 19.3% and 56% of the farmers were using uncertified local variety seeds, which could be susceptible to fungal infection though they are adapted to local conditions as a result of many years of selection. These varieties have very low yields and are not consistent with the government policy of revitalizing agriculture as a business enterprise (SRA, 2004).

Crop rotation

The farmers in both counties, 83.6% and 74.7% in Makueni and Nandi, respectively, were not practicing crop rotation but planted maize every season on the same plot. Crop rotation ensures increased soil nutrient by nitrogen fixation by legumes and mitigates nitrogen stress. Aflatoxigenic Aspergillus isolates from soils have been shown to be highest in soils that have maize as the following crop (Abbas et al., 2004). Crop rotation in addition to reducing nutrient and nitrogen stress helps to break down the selection of toxigenic fungi that would infect the follower crop, therefore reducing the risk of preharvest infection, toxin production, and contamination. Only 21.7% of the farmers in both counties practiced crop rotation of maize with legumes. Failure to practice crop rotation leads to depletion of soil nutrients, selects fungal populations that specifically infect maize, therefore increasing the risk of colonization by toxigenic fungi and subsequent aflatoxin contamination (Hell et al., 2010).

Use of soil amendments

In both counties, majority of the farmers were using fertilizers, fertilizer and animal manure, and animal manure as soil amendments. Only 17.9% and 6.1% of the farmers in Makueni and Nandi, respectively, were not using any soil amendments. The nature and fertility of the soil help to reduce fungal infection of crops. The ability of the soil to hold moisture is important. Codex Alimentarius Commission (2004) reported that crops planted on sandy soils were more contaminated with aflatoxins than those planted on loamy soils. Loamy soils have the ability to retain moisture, which reduces moisture stress to the growing crops and therefore prevents fungal infection. In Kenya, farmers use fertilizer and manure to increase the soil nutrient content to ensure a healthy crop that would resist fungal infection. Manure (animal or compost) has the dual role of increasing the organic content of the soil and also nutrients, both of which mitigate fungal infection by ensuring healthy crops. Lime application, use of farm yard manure and cereal crop residues as soil amendments are effective in reducing A. flavus contamination as well as aflatoxin levels by 50%–90% (Hell and Mutegi, 2011). In Makueni and Nandi, 81.9% and 79.7% of the farmers, respectively, applied fertilizer only as soil amendments while 22% of the farmers in both Nandi and Makueni applied a mixture of fertilizer and manure during planting. Failure to use soil amendments results in soils that are low in organic nutrients with low ability to hold moisture, and this increases the vulnerability of the crops to fungal infection because of water and nutrient stress (Munkvold, 2003).

Harvesting and drying

During the harvesting period, the methods of harvesting were mainly stoking and removing the cobs and leaving the stovers standing in the field. Fifty percent of farmers, both in Nandi and Makueni, cut maize stovers with the cobs and stoked them in heaps in the field to dry. There was no method that was more preferred by farmers. Such practices expose the crop to proliferation of fungi and bacteria and contamination with soil, reducing the crop’s quality (Mejia and Farruci). The recommended maize-drying method was either on cob or as shelled grains on canvas. Of the farmers, 39.1% and 37.6% in Makueni and Nandi, respectively, were not drying maize on canvas but on cob on ground and leaving maize to dry in the field on stovers while standing. This practice increases the risk of picking up toxigenic fungal spores from the soil, thus adding to the risk of aflatoxin production and accumulation. The moisture level of the grains is an important factor in toxin production. Grains with moisture level above 13% are more prone to aflatoxin contamination than those with lower moisture content. Harvested grains should be dried within 24–48 h to moisture content of 13% to reduce risk of aflatoxin formation (Kaaya and Warren, 2005).

Shelling (threshing)

Shelling or threshing was mainly done by hand, machine, or manual pounding using sticks. Manual pounding (maize put in the sack and beaten with sticks) was the most preferred method; being adopted by 76.8% and 75.1% of the respondents in Makueni and Nandi, respectively, though it is not the recommended method of shelling maize as it results in many damaged kernels. Damaged kernels increase the ease by which fungal hyphae penetrate the kernels. Use of seed varieties that have incomplete husk cover also exposes the cobs to damage by birds, which results in similar effects of increasing rate of kernel colonization by toxigenic fungi.
Use of preservatives during storage
About 25% of the farmers in both counties were not adding any pesticides during storage. Weevils are notorious pests that attack maize in storage and in the field. They cause mechanical damage that disrupts the seed coat and facilitates penetration by fungal inoculum. In addition, they transmit spores from other plants to inoculate already defective kernels (Hussaini et al., 2012). It has been shown that insects and other pests create microclimates within the storage bags that increase humidity and favor fungal production of aflatoxins and contamination of the crop (Makun, 2012). The method of storage could increase fungal growth and aflatoxin contamination. A majority of the farmers used the recommended storage methods apart from 39.1% in Nandi who were storing maize in bags in the house and on the floor. In the two counties, shelled maize was stored in the house (48.6% of respondents) and in the granary (44.3% of respondents). The type of bags used for storage of maize could favor mycotoxin accumulation. Polypropylene bags were used by all farmers, and these have been reported to increase moisture content, which encourages fungal growth with concomitant production of aflatoxin (Bulaong, 2002; Mutege et al., 2013). Fungi are aerobic micro-organisms, and technologies have been developed that reduce the oxygen content and increase carbon dioxide content to reduce the growth of *A. flavus* during storage and therefore limit aflatoxin production. In use, currently in Kenya, are metal silos for the storage of small quantities of grains and hermetic improved bags (these bags have a second lining which is impermeable to oxygen and thus create anaerobic conditions that inhibit growth of fungal spores and weevils) based on triple bagging developed for storing cow peas (Ben et al., 2009).

Sorting of moldy grains
A majority of the spouse respondents used the colors they saw on moldy grains to determine whether grains were moldy or not. Using expert opinion, the colors they gave were matched with colors produced by *Aspergillus* and *Fusarium* species when they grew on maize substrate (Table 2). These results show that co-occurrence of *Aspergillus* and *Fusarium* species are the major contaminants of maize in Makueni and Nandi (Kangethe et al. (unpublished data) showed that 60% and 85%; and 55% and 75% of homegrown and market maize samples in Nandi and Makueni, respectively, were contaminated with both aflatoxin and fumonisin. *Aspergillus* separately was five and four times more frequent as a contaminant of maize in Makueni and Nandi, respectively, than *Fusarium* species. Sorting out physically damaged and infected grains (known from colorations, odd shapes, and size) from the intact commodity can result in 40%–80% reduction in aflatoxin levels (Park, 2002; Fandohan et al., 2005). The advantage of this method is that it reduces toxin concentrations to safe levels without production of toxin degradation products or any reduction in the nutritional value of the food. This could be done manually or by using electronic sorters. Table 2 shows that women in both Nandi and Makueni could easily identify fungal-infected grains that could pose a risk of aflatoxin contamination, while insect and pest damaged kernels increase the rate of fungal penetration and colonization.

Perceptions of health risks associated with use of spoilt grains
When asked about health risks associated with feeding animals with moldy feeds, the respondents gave responses which were associated with known effects of aflatoxins in livestock (reduced milk production, reduced milk quality, reduced weight gain, increased susceptibility to diseases, death, loss of appetite, and liver problems) (Table 3). Respondents in Nandi identified more with effects of chronic aflatoxicosis leading to loss of productivity (low milk production, poor quality milk, and reduced weight gain) while Makueni respondents identified more with effects of acute aflatoxicosis (death, liver problems, loss of appetite, and susceptibility to diseases).

When they were asked as to how they would dispose of moldy or rotten maize, 59% indicated they would use this as animal feed while 15% would use the rotten/moldy maize for making traditional brews (*changaa* and *busaa*). Feeding moldy or rotten maize to livestock, if that maize was contaminated with aflatoxins, would lead to aflatoxin M1 (AFM1) in milk and eventually expose humans to AFM1. We reported a high proportion of milk contaminated with AFM1 (96% and 52% of milk samples from Makueni and Nandi, respectively, and 93% of goat milk samples from Makueni (Kangethe et al., unpublished data). When the respondents were asked if milk from animals fed on moldy/rotten maize was safe for consumption, 54.1% considered the milk safe. Of this, 75.1% and 24.9% were from Nandi and Makueni, respectively. This clearly reveals lack of awareness of the transition of aflatoxins in animal feeds to milk and the risk posed by consuming such contaminated animal products.

Traditional brewing methods do not detoxify the brews if made from contaminated foodstuffs. Fumonisins have been detected in local brews in Botswana (Nkwe et al., 2012) and South Africa (Shephard et al., 2005). Fumonisins and other mycotoxins have been detected in Kenyan beers (Mbugua and Gathumbi, 2004). Fifteen percent would use these rotten moldy maize to make traditional brews.

When the respondents were asked what was the minimum level or type of spoilage, when they would still consume moldy/rotten maize, 52.4% replied they would eat despite the level of spoilage. Perceptions of health risks associated with use of spoilt grains

Table 2. Ability of women to detect spoilt maize using colors seen on spoilt grains and linked to those produced by *Aspergillus* and *Fusarium* species growing on maize.

<table>
<thead>
<tr>
<th>County</th>
<th>Criteria for Spoilt</th>
<th>Aspergillus (%)</th>
<th>Fusarium (%)</th>
<th>Pests/insects damage (%)</th>
<th>Others (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makueni</td>
<td>433</td>
<td>44.6</td>
<td>22.4</td>
<td>19.4</td>
<td>9.2</td>
</tr>
<tr>
<td>Nandi</td>
<td>424</td>
<td>59.9</td>
<td>14.9</td>
<td>9.2</td>
<td>12.5</td>
</tr>
</tbody>
</table>

*Black with red or yellow or brown or maroon or orange, yellow with green or blue.*

*Red, yellow, maroon, red/yellow, and red/purple.*

*Others = Smelling, sprouting, and bitter taste; n = number of respondents in each county; (%) = proportion of respondents who mentioned colors produced by the fungal species.*
Nandi, respectively. The reasons given for eating such maize were: if not all the maize is spoilt, if not bitter, if not so mouldy, if there is a slight color change or smell, and if no alternative food was available. This clearly shows lack of awareness and poverty (population living below poverty line 47.4% and 64.1% Nandi and Makueni, respectively, CRA, 2011) as the main reasons for consuming overtly spoilt or moldy maize. The average estimates of maize lost in Makueni and Nandi by being moldy or rotten were 7.5% and 6.8%, respectively. This translated into KShs 1667 and KShs 2856 per household in Makueni and Nandi per season, respectively. It is imperative that such losses are controlled to increase food security and reduce exposure at households.

Kenya has relied heavily on creating awareness among the farming communities on ways to mitigate preharvest and postharvest problems that exacerbate aflatoxin and fumonisin production. This approach is hampered by the shortage of extension officers in the field. The ratio of extension officers to the farmers in the country is about 1:5000 (GFRAS, 2017). Bandyopadhyay et al., (2008) using a nominal group discussion technique identified and prioritized communication (knowledge) as an important barrier to farmers and consumers understanding the risks of mycotoxins in their food and especially low-grade exposure and their long-term effects.

A majority of the households in Nandi and Makueni do not understand that if maize is moldy, it could be a risk to health and could be contaminated with aflatoxins and fumonisins. Equally, if households in Makueni were to intensify the adoption of good agricultural practices, this could bring down the proportions and level of contamination and points to the need to create awareness at the household level on the causes of contamination of cereals and animal source foods with aflatoxins and fumonisins and mitigation measures to reduce exposure to mycotoxins.

Government contribution to good agricultural practices

The 200 officers from the county governments (from health, agriculture, and county administration) who attended the three workshops, one in Nandi and two in Makueni, said that the problem of mycotoxins is serious and required mitigation. The reasons indicated were that the two mycotoxins: (i) are carcinogens, mutagens and teratogens, (ii) result in deaths when they occur and cause psychosocial problems and put a greater burden on the households that are living below the poverty line; (iii) are associated with loss of production (reduced milk and egg production, poor quality of animal source products, and reduced weight gain); (iv) increase production costs (increased susceptibility to diseases, takes longer to reach market weight, treatment costs resulting in income loss); (v) loss of labor (chronic exposure leads to immunosuppression with subsequent frequent bouts of illness with many days on sick leave); (vi) aflatoxins and fumonisins are antinutritional and contribute to stunting and wasting in children; and (vii) contaminated foods and feeds are condemned and are threat to the country’s food security. They suggested various good agricultural practices as mitigation measures, as described in Figure 1. The government has adopted various strategies to mitigate the problem of mycotoxins and food security. These include (i) establishment by the government of 1 million acres under irrigation in Tana Delta under the water master plan 2030 (JICA, 2014) to stop dependence on rain for agriculture in growing mainly maize (Citing for the reference Uhuru Kenyatta appearing in the reference list); (ii) adoption of the East-African harmonized standards on marketed maize, which includes aflatoxin control (KS EAS2, 2005); (iii) provision of subsidized agroecologically recommended and certified seeds and fertilizer to farmers in order to grow more food for home and market; and (iv) as agriculture is a devolved function, county governments are employing extension officers to carry out extension messages in support of farming activities. While regulation helps to reduce exposure if enforced, grains marketed in Kenya should comply with KS EAS2 (2005), which limits the moisture content of less than 13%, broken, discolored, rotten, and diseased, pest-damaged grains should be less than 4% and aflatoxin concentrations less than 5 ppb for aflatoxin B1 (AFB1) and 10 ppb for total aflatoxins. Ninety percent of the rural households in Kenya grow maize, and the maize production is dominated by small-scale farmers who produce 75% of the overall maize yield (Kang‘ethe, 2011). Smallholder farmers depend more on homegrown maize for household consumption and less on market-purchased grains. They would be less affected by the demands of aflatoxin content regulation and would continue to be prone to aflatoxin exposure through consumption of homegrown maize if mitigation steps are not adopted.

Although it may appear as if the majority of the farmers are adopting good agricultural practices (Table 1) that would additively help to control the negative effects of mycotoxin exposure, the reality is that this proportion is very large but the effects are minimal because what is done is not done properly and consistently. When the proportion of those that were not practicing crop rotation and had samples that were positive for aflatoxin were compared to the proportion of homegrown maize that was positive for aflatoxins, this differed significantly ($\chi^2 = 6.82, df = 1, P = 0.009$) between Makueni and Nandi. Significant differences were also observed in the proportions of households who did not use soil amendments ($\chi^2 = 10.27, df = 1, P = 0.001$), shelled their maize manually by pounding ($\chi^2 = 4.44, df = 1, P = 0.04$), and did not use chemicals as preservatives ($\chi^2 = 6.82, df = 1, P = 0.009$). This indicates that an increase in the use of good agricultural practices of crop rotation, application of soil amendments, a reduction on pounding while shelling, and the adoption of chemical use as preservatives in Makueni will significantly bring down the proportions of the positive samples for aflatoxins and fumonisins closer to those witnessed in Nandi. However, a comparison of the proportions of the maize dried on the ground and no canvas to the proportions of positive samples for aflatoxins did not differ significantly ($\chi^2 = 2.68, df = 1, P = 0.10$) between Makueni and Nandi. This may not be singly the result of better adoption of agricultural practices, but other factors like nature of aflatoxigenic A. flavus found in Makueni and Nandi may be contributing to the better effects of good agricultural practices in Nandi compared to Makueni (Okoth et al., 2012).

<table>
<thead>
<tr>
<th>Risks to livestock</th>
<th>$n$</th>
<th>Makueni</th>
<th>Nandi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce milk production</td>
<td>15</td>
<td>26.7</td>
<td>73.3</td>
</tr>
<tr>
<td>Reduce milk quality</td>
<td>110</td>
<td>21.9</td>
<td>78.1</td>
</tr>
<tr>
<td>Reduce weight gain</td>
<td>3</td>
<td>66.6</td>
<td>33.3</td>
</tr>
<tr>
<td>Susceptible to diseases</td>
<td>120</td>
<td>64.2</td>
<td>35.8</td>
</tr>
<tr>
<td>Death</td>
<td>44</td>
<td>97.7</td>
<td>2.3</td>
</tr>
<tr>
<td>Loss of appetite</td>
<td>8</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Liver problems</td>
<td>7</td>
<td>85.7</td>
<td>14.3</td>
</tr>
<tr>
<td>Others</td>
<td>4</td>
<td>75.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>
reported that good agricultural practices in groundnut production, for instance application of farmyard manure, reduces aflatoxins during the preharvest period by 42% while combination with lime application results in aflatoxin reduction of 84%. Post-harvest good agricultural practices were found to reduce aflatoxin contamination by 66%–88% depending on the location. The authors advocate that good agricultural practices are the bare basic minimum (prerequisites) on which other technologies can build to substantially reduce aflatoxin and fumonisin preharvest and post-harvest contamination.

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Conflict of interest statement. The authors confirm that there would be no conflict of interest with the publication of this manuscript.

References


Figure 1. Good agricultural and husbandry practices recommended by policy teams from National and County governments of Nandi and Makueni to mitigate aflatoxins and fumonisins at household level.


