Analysis of Aflatoxin and Maize Spoilage Prevention Technologies and Practices Among Smallholder Farmers of the Lake Victoria Region, Kenya

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Acknowledgements and Personal Reflection

I would like to express my gratitude to the World Food Prize Foundation and the International Center of Insect Physiology and Ecology for providing me with this remarkable opportunity. My experience as a Borlaug-Ruan Intern further opened my eyes to the realities of Kenyan agriculture, a topic I first became fascinated with three years ago when I applied to the Global Youth Institute. It was interesting to observe how similar, yet different, life is in distinct parts of the world. It was also inspiring to realize the difference various technologies such as push-pull have made in farmers' lives. Through the challenges of working remotely, unreliable internet, language barriers, and finicky excel spreadsheets, I have grown in my understanding of the rewarding and challenging complexities of research.

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Abstract

Pre- and post-harvest losses caused by factors such as aflatoxin, are a significant barrier to achieving global food security. Regions with temperate or tropical climates, with many smallholder farmers, and with economies heavily influenced by agriculture are especially impacted by these harvest losses. This study aimed to provide further information on how smallholder farmers in the Lake Victoria region of Kenya perceive and attempt to prevent agricultural losses caused by maize spoilage and aflatoxin contamination. To do this, thirty smallholder farmers from Migori and Kisumu counties were interviewed about their perceptions, practices, and experiences, surrounding maize spoilage and aflatoxin contamination. The results suggest that smallholder farmers in this region perceive maize spoilage as a significant issue in their communities but vary in both their methods of preventing this spoilage and their perceived knowledge of maize spoilage and aflatoxin contamination. More specifically, the results suggest that further research and programming could be useful to provide more easily adoptable and precise methods of determining the safety of spoiled maize and that it could also be helpful to develop livestock feeding recommendations that take into account maize spoilage and potential contamination.

Introduction

International Center of Insect Physiology and Ecology

The International Center of Insect Physiology and Ecology (ICIPE) was founded in Nairobi, Kenya in 1970, as a way of addressing the paradoxical nature of insects in agriculture and health. The center's purpose is to "*use insect science for sustainable development, to ensure food security and improve the overall health of communities in Africa by addressing the interlinked problems of poverty, poor health, low agricultural productivity and environmental degradation*" (*www.icipe.org*). ICIPE's diverse programs across its themes of human, animal, environmental, and plant health, range from malaria and bioprospecting to integrated pest management and tick-borne diseases (*www.icipe.org*).

Push-Pull Technology

Push-Pull technology is a novel technology developed by ICIPE and Rothamsted Research as a method of combatting stemborers and striga weed, as well as improving soil fertility. The push pull strategy is based on intercropping. It utilizes repellent plants such as desmodium which repel insects away from crops, as well as "attractant trap plants" which are planted along the border with "the purpose of attracting and trapping the pests" (*Push-Pull Technology - Demonstration of Research Impacts on Communities*). ICIPE has formed numerous partnerships to further disseminate this effective technology and this technology has increased maize production by at least threefold for 75% of farmers who adopt it (*Push-Pull Technology*).

Aflatoxin and Maize Spoilage

Globally, it is estimated that approximately one third of food produced is wasted and that post-harvest food loss is a leading cause of food insecurity for millions of families around the

world (*Post-Harvest Loss Reduction*). Besides effecting farmers' food security, agricultural losses often lead to reduced incomes, poorer health, diminished quality of diet, and decreased economic opportunity for farmers (*Post-Harvest Loss Reduction*). Furthermore, high post-harvest losses lead many farmers to sell their crops immediately, which often leads to even lower profits (*Post-Harvest Loss Reduction*).

Aflatoxins, a class of poisonous carcinogenic chemicals produced by certain varieties of fungi, are one major contributor to these global food losses. Aflatoxins often contaminate common staple crops such as maize and groundnut, and according to the World Health Organization, cause as much as 25% of the world's food crops to be destroyed annually (*Aflatoxins* 2018).

Maize spoilage and associated aflatoxins are especially devastating to smallholder farmers living in temperate and tropical climates similar to those found in Kenya's Lake Victoria region (Kumar & Kalita, 2017). The significance of these issues is amplified by the fact that the agricultural sector makes up the backbone of its economy. In Kenya, agriculture accounts for nearly a third of GDP and almost 40% of the population is employed in agriculture (*Agriculture and Food Security: Kenya* 2021). Furthermore, farming plays a crucial role in meeting the country's Big 4 development agenda of providing 100% food and nutritional security for all Kenyans by 2022 (*Kenya Economic Update: Transforming Agricultural Productivity to achieve food security for all* 2019).

Given the significance of maize spoilage and aflatoxin contamination and its potentially devastating effects on farmers' health and livelihoods, this study intended to gather further information to aid in understanding farmers' perceptions and practices surrounding maize

spoilage and aflatoxin contamination and to help inform potential future research, policy, and programming.

More specifically, the study focused on the following objectives:

- Learning about Kenyan farmers' perceptions and experiences of maize spoilage and aflatoxin contamination
- Learning about farmers' knowledge levels of aflatoxin contamination
- Learning about maize spoilage and aflatoxin prevention measures and practices
- Learning about the most appropriate communication channels for dispersing information about aflatoxin

Methods

Procedure

In order to assess farmers' perceptions of aflatoxin and maize spoilage, farmers were virtually interviewed through the teleconferencing platform, Zoom. Participants were interviewed individually in groups of four to five. Each farmer was asked the same question and each of their answers were recorded before continuing to the next question. To aid in the mutual understanding of the participants and the interviewer, questions and responses were frequently interpreted by Dr. Ouma. The survey instrument (Appendix 1) included questions about demographics, farming practices, perceptions of maize spoilage and aflatoxin contamination, aflatoxin trainings, and beneficial communication channels for disseminating information about aflatoxin.

To help triangulate results from the individual interviews, a focus group discussion (FGD) was conducted in Kisumu and Migori Counties via Zoom. The group of participants were

asked key questions which had been modified from the original survey (Appendix 2). They were encouraged to share their responses spontaneously as well as to discuss answers with their fellow farmers. Dr. Ouma continued to provide interpretation throughout the discussion process.

Participants

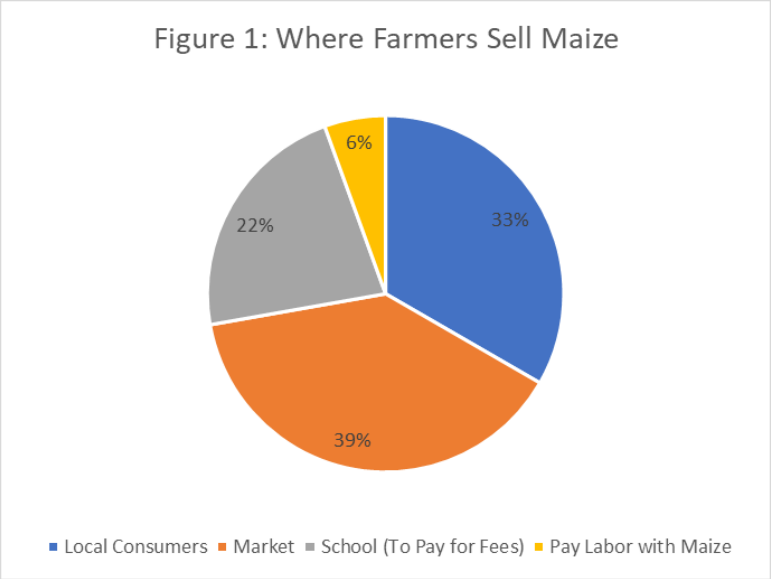
Individual interview participants were residents of either Migori or Kisumu County, and, with the exception of one farmer, all practiced push-pull farming. They ranged from 27-70 years of age and had a nearly equal gender balance. Sixty percent (60%) of interviewees had completed their education through at least grade 12, while 40% had not. The size of a farmer's family ranged from 4-12 with an average family size of 7. Participants' farm size ranged from 0.5-5.0 acres with an average farm size of 1.75 acres. Seventy percent (70%) of interviewed farmers sold their maize. Among those who did, 83% sold less than 60% of their maize harvest. Each interviewee grew maize, and a variety of other crops such as beans, vegetables, fruits, or cassava.

There were eleven participants in the focus group discussion, all of whom were push-pull farmers. Each farmer was a resident of Kisumu County and there was a six to five ratio of men to women.

Results

Selling Maize

Among participants who reported selling some part of their maize harvest, roughly 40% of them sold their maize at some sort of market. However, as seen in Figure 1, the other 60% reported selling their maize to local consumers, workers on their farm, or schools – to help pay for their children's tuition and fees.

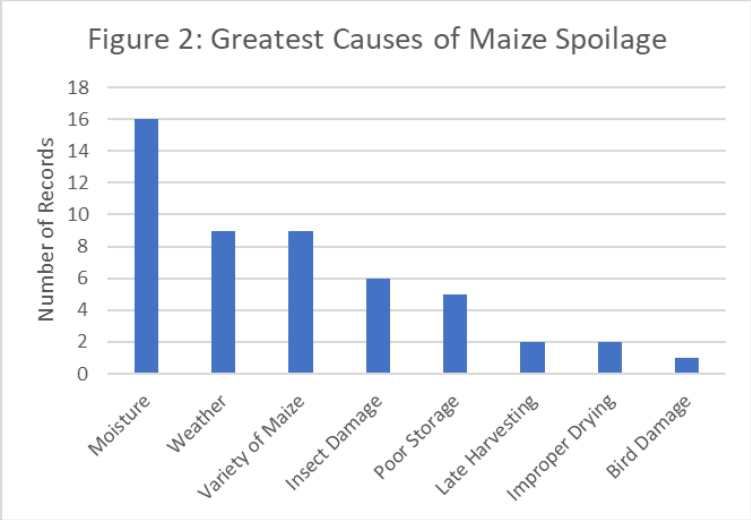


100% of farmers who sold their maize reported that buyers performed a visual inspection of the maize to ensure its cleanliness and lack of spoilage. Five farmers specifically mentioned that buyers would check the moisture content of the maize. Two farmers also mentioned buyers inquiring about growing and post-harvest handling practices such as the variety of maize or the chemicals applied to it.

Maize Spoilage

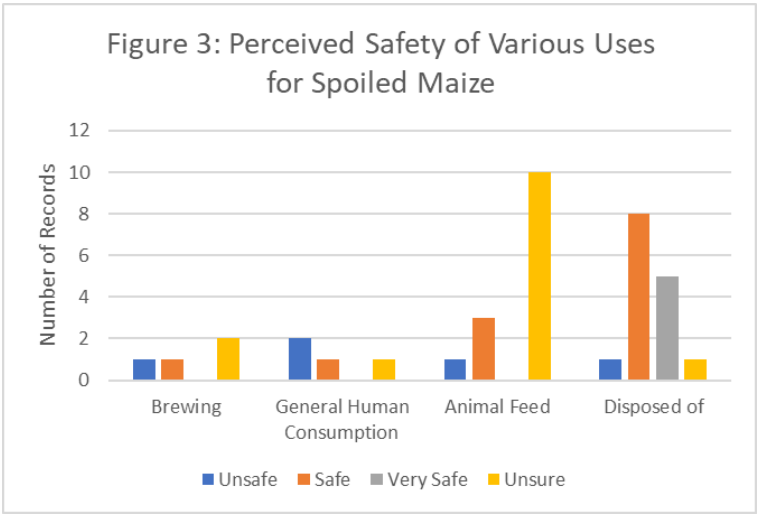
There was a general consensus among farmers in both individual interviews and the focus group discussion that maize spoilage is a significant issue in their communities. Approximately 78% of individual interviewees responded that maize spoilage was a significant issue in their communities, 15% that it was a somewhat significant issue, and 7% that it was a significant issue depending on the variety.

Some of the most commonly cited causes of maize spoilage included moisture (16 responses), weather (9 responses), variety of maize (9 responses), insect damage (6 responses), and poor storage (5 responses) – Figure 2. Approximately 65% of interviewed farmers responded that maize spoilage occurs more frequently before harvest, whereas approximately 30% of farmers believed that it occurs more frequently after harvest.



Spoiled maize was most commonly used as either animal feed (14 responses) or was disposed of by throwing it away, burning it, or burying it into the soil (14 responses). Interviewees also responded that they use it for human consumption when mixed with other grains (5 responses) or that they either use it for brewing or for selling to brewers in the area (4 responses).

As Figure 3 shows, interviewed farmers varied on their opinions about the safety of how they utilized their spoiled maize. The majority of farmers felt that the way they disposed of spoiled maize was either safe or very safe (17 responses). However, there were also many who were unsure of the degree of safety in how they dispose of maize (12 responses) and some who believed their methods were unsafe (3 responses). Farmers were the most confident in the safety



of disposing of, and not using, spoiled maize but tended to be unsure of the safety of feeding spoiled maize to animals. In addition, two participants mentioned that they often do not have a choice as to whether they eat or do not eat spoiled maize – sometimes the only option is to eat it and not waste food.

Aflatoxin Knowledge

In general, participants believed they possessed limited knowledge of aflatoxin. Approximately 45% of participants described themselves as having no knowledge about aflatoxin, 27.5% as being somewhat knowledgeable, and 27.5% as being knowledgeable or very knowledgeable.

There was much variation in individual answers given to the question about signs of aflatoxin contamination, risk factors for aflatoxin contamination, and symptoms of aflatoxin exposure. Participants were generally able to correctly identify discoloration as a key sign of aflatoxin contamination, but many did not identify the typical colors of green, grey, white, or yellow. The most commonly cited colors were brownish (10 responses) blackish (9 responses), greenish (4 responses), and whitish (3 responses). Farmers also mentioned that affected maize might appear rotten or moldy, might have a bad or bitter taste, or that the individual grains of maize might lose their shape. The most commonly referenced risk factors for aflatoxin contamination included moisture (8 responses) and insect damage (9 responses). The majority of farmers also cited potential symptoms of exposure, including stomach problems (18 responses), diarrhea (13 responses), vomiting (5 responses), and restlessness (4 responses).

The number of farmers who had received training on aflatoxin (14 responses) and the number who had not, were roughly equal (16 responses). Farmers who had received training

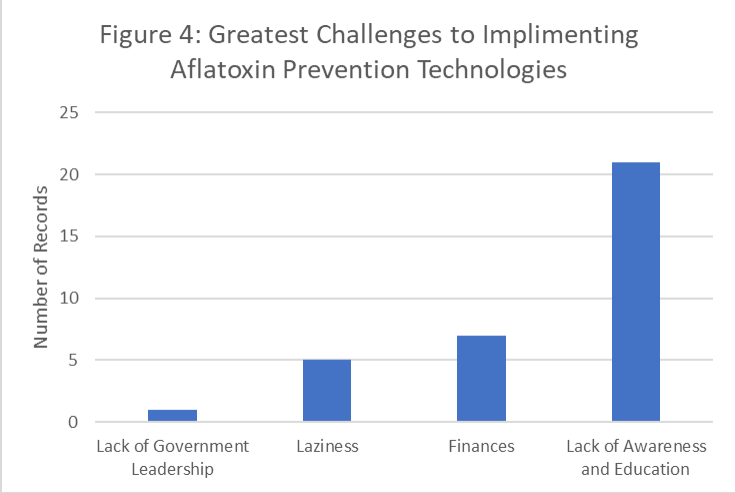
stated that they received it from ICIPE field staff (7 responses), agriculture extension (6 responses), or radio (2 responses).

Aflatoxin Prevention

29 out of 30 interviewed farmers did not report currently using any chemical control methods for aflatoxin, although 5 farmers stated that they had used chemical controls in the past.

24 participants reported using hermetic bags for maize storage and 7 of those participants reported using polypropylene or jute bags when hermetic bags were not affordable. Four (4) participants reported regularly using polypropylene bags for maize storage and 4 reported using plastic or metallic drums. 100% of interviewed farmers reported sun drying their maize before storage. Several farmers also mentioned using other storage practices such as adding wood ash to storage bags (6 responses), storing maize with dried cow dung (3 responses), storing maize with pesticide (1 response) and using smoke to help keep insects away from maize (1 response).

When asked about the biggest barriers to implementing aflatoxin prevention technologies, farmers responded that the biggest barriers included lack of awareness and education (21 responses), finances (7 responses), laziness (5 responses), and lack of government leadership (1 response) – Figure 4.



Interviewed farmers were unanimously interested in receiving further trainings on aflatoxin and generally supported a variety of different types of proposed programs. 29 farmers responded in favor of aflatoxin awareness training, 29 farmers responded in support of aflatoxin

prevention training, and 19 farmers responded in favor of free or subsidized trials of aflatoxin prevention technologies.

Farmers recommended several channels for communicating information about aflatoxin: agricultural extension (13 responses), TV/radio (10 responses), field days (5 responses), social media (4 responses). In addition to these communication channels, several farmers recommended implementing programing using local dialects (4 responses) and incorporating a group approach (6 responses).

Discussion

Results from the individual interviews and focus group discussions provided substantial information informing the four key areas of interest in the study:

- Learning about Kenyan farmers' perceptions and experiences of maize spoilage and aflatoxin contamination
- Learning about farmers' knowledge levels of aflatoxin contamination
- Learning about maize spoilage and aflatoxin prevention measures and practices
- Learning about the most appropriate communication channels for dispersing information about aflatoxin

From a commercial perspective, almost 70% of farmers sold at least a portion of their maize crop, and many farmers who did, reported using a solely visual method of determining maize quality. Visual inspection of maize post-harvest is tremendously helpful for determining maize that is already spoiled, but it isn't necessarily a reliable means of testing for moisture and non-visible contaminants that might become more problematic later in storage.

There was near universal agreement from farmers across the study that maize spoilage is at least somewhat significant in their communities and a challenge that they want to address. Similar to observations made by other researchers, interviewed farmers referenced moisture, weather, variety of maize, insect damage, and poor storage, as key causes of maize spoilage (Suleiman et al., 2013). Surprisingly, only one farmer reported using chemical controls for maize spoilage and no farmers reported using the aflatoxin biological control agent known as Aflasafe™. However, every interviewed farmer reported sun drying their maize. If done properly, sun drying can be an important step in reducing the risk of maize spoilage. It would be interesting to further study the farmers' practices of sun drying their maize to determine how well they are implementing the process as well as how they are determining whether the maize has adequately dried. Such studies could be implemented by organizations such as ICIPE and could be used to improve ICIPE's training programs, as well as the training programs of other NGOs and extension programs. Many interviewed farmers also reported using hermetic storage bags, another highly effective prevention technology when used alongside other technologies (Baributsa et al., 2020). Unfortunately, financial barriers also influenced how many hermetic storage bags the farmers could afford to purchase. Many farmers could only afford to store a portion of their maize in these bags.

Participants consistently referenced lack of awareness and education about aflatoxin as a barrier to addressing aflatoxin contamination on their farms. This is surprising, considering that almost half of interviewees had received some sort of aflatoxin training. Perhaps programming providers should consider how curriculum could be further enriched or if programing intensity should be increased. Though the result of the interviews suggests that there are some potential gaps in current training programs and that there are still farmers who haven't had the opportunity

to participate in them, all interviewed farmers were still interested in learning more about aflatoxin.

Farmers reported a variety of uses for spoiled maize, the most common being animal feed and no usage - disposing of it. Concerning how safe participants feel about their uses for spoiled maize, it was interesting that the majority of farmers who fed spoiled maize to animals were not sure of the safety of doing that. Perhaps further educational programing and outreach in this area would be helpful to farmers. However, the programing might become complicated by the fact that many farmers do not know with certainty what contaminants are present in their maize and in what amounts (Stepman, 2018). Theoretically, spoiled maize could be used as animal feed, but it could have detrimental effects on animal and human health if too much of a contaminant like aflatoxin were present in the maize used as feed (Stepman, 2018).

In summary, interviewed farmers perceived maize spoilage to be a significant issue in their communities but varied in their methods of preventing maize spoilage and aflatoxin contamination and varied in their confidence about their knowledge of maize spoilage and aflatoxin contamination. In the future, it would be interesting to repeat similar interviews with both push-pull and non-push-pull farmers in order to gain a fuller picture of maize spoilage and aflatoxin contamination in the region. Research by Njeru et al. (2020), showed that several compounds present in desmodium inhibit the growth of *A. flavus* and *F. verticillioides,* fungal species known for releasing mycotoxins (Njeru et al., 2020). Push-pull farmers could be less likely to experience aflatoxin contamination issues. Some potential areas for further research include developing more effective aflatoxin related training, learning more about how farmers determine maize moisture content, developing more easily adoptable and precise methods of determining the safety of spoiled maize, and developing livestock feeding recommendations that

take into account spoiled maize concentrations. In addition, national agricultural authorities and non-governmental organizations should consider increasing aflatoxin and maize spoilage education offerings.

References

Baributsa, D., Bakoye, O. N., Ibrahim, B., & Murdock, L. (2020, August 17). *Performance of five postharvest storage methods for maize preservation in northern Benin*. US National Library of Medicine National Institutes of Health. Retrieved October 24, 2021, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7469259/.

International Centre of Insect Physiology and Ecology. (n.d.). *Push-Pull Technology - Demonstration of Research Impacts on Communities*. icipe. Retrieved October 24, 2021, from http://www.icipe.org/impacts/demonstration-research-impacts-communities/push-pull-technology.

International Centre of Insect Physiology and Ecology. (n.d.). *What We Do*. icipe. Retrieved October 24, 2021, from http://www.icipe.org/about/who_we_are.

Kumar, D., & Kalita, P. (2017, January 15). *Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries*. US National Library of Medicine National Institutes of Health . Retrieved October 24, 2021, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5296677/.

Njeru, N., Midega, C., Muthomi, J., Khan, Z., & Wagacha, J. (2020). *In vitro antifungal activity of Desmodium intortum and D. uncinatum root extracts against growth of toxigenic Fusarium verticillioides and Aspergillus flavus*. Australian Journal of Crop Science. Retrieved November 26, 2021.

Stepman, F. (2018, March 23). *Scaling-up the impact of aflatoxin research in Africa. the role of Social Sciences*. US National Library of Medicine National Institutes of Health. Retrieved October 24, 2021, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5923302/.

Suleiman, R., Rosentrater, K., & Bern, C. (2013). *Effects of Deterioration Parameters on Storage of Maize: A Review*. Iowa State University Digital Repository. Retrieved October 24, 2021, from https://lib.dr.iastate.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1730&context=abe_eng_pubs#:~:text=Deterioration%20of%20maize%20is%20mainly,fungal%20growth%2C%20and%20insect%20pests.

U.S. Agency for International Development. (2021, March 19). *Agriculture and Food Security: Kenya*. USAID. Retrieved October 24, 2021, from https://www.usaid.gov/kenya/agriculture-and-food-security.

The World Bank. (2019, April 8). *Kenya economic update: Transforming Agricultural Productivity to achieve food security for all*. The World Bank. Retrieved October 24, 2021, from https://www.worldbank.org/en/country/kenya/publication/kenya-economic-update-transforming-agricultural-productivity-to-achieve-food-security-for-all.

World Food Program. (n.d.). *Post-Harvest Loss Reduction*. World Food Program Innovation Accelerator. Retrieved October 24, 2021, from https://innovation.wfp.org/project/post-harvest-loss-prevention.

World health Organization Department of Food Safety and Zoonoses. (2018, February). *Aflatoxins*. World Health Organization Food Safety Digest. Retrieved October 24, 2021, from https://www.who.int/foodsafety/FSDigest_Aflatoxins_EN.pdf.

Appendices

Appendix 1: Individual Interview Questions

Background

What is your name? _____ Age _____ Gender _____

Level of Education _____ Household size _____ Farm size _____

- What crops do you grow? _____
- In a typical growing season, which of the following products are you likely to use for your maize crop?
  - Insecticide
  - Herbicide
  - Inorganic/chemical fertilizer
  - Organic fertilizer (manure, compost, etc.)
- Do you sell any of your maize crop? If yes, what quantity do you sell?
  100 %; 75%, 50 %, 25%,
  - Who do you sell maize to? _____
  - How soon after harvesting do you sell your maize crop? Why? _____
  - What quality standards do the purchasers have? Do they test for aflatoxin? _____

Maize Spoilage

- Do you believe maize spoilage is a significant issue in your community?
  - Significant issue
  - Somewhat significant issue
  - Insignificant issue
- Please speak to your experience with maize spoilage: when does it most frequently occur, and what most frequently causes it?
  - _____
- How do you use your spoiled maize?
  - Animal feed
  - Brewing
  - Food for family
  - Mixed with other cereals

- Sold (specify) _____
- Other (specify) _____

- Do you feel the way you deal with spoiled maize is safe?
  - Very safe
  - Safe
  - Somewhat safe
  - Unsafe
  - Not sure

Aflatoxin Knowledge

- How would you describe your knowledge of aflatoxin?
  - Very knowledgeable
  - Knowledgeable
  - Somewhat knowledgeable
  - Not knowledgeable

- What do you know about aflatoxin (signs of contamination, risk factors, symptoms of exposure, etc.) ?
  - _____

Preventing Aflatoxin

- Are you familiar with any of the following practices and technologies for preventing or reducing aflatoxin contamination?
  - Drying maize before storage
  - Testing maize for aflatoxin
  - Storing maize in chemically treated storage bags
  - Storing maize in hermetic storage bags
  - Using biological control agents such as Aflasafe
  - Chemically treating maize post-harvest
  - Other (specify) _____

- Do you dry your maize before storage? If yes, how?
  - Sun drying on plastic sheets
  - Mechanical method
  - Solar method
  - Dry maize in the field
  - Other (specify) _____

- What type of bags do you store maize in?
  - Non chemically treated sisal/jute/burlap bags
  - Chemically treated sisal/jute/burlap bags
  - Polypropylene bags

  - Hermetic bags
  - Other (specify) _____

- Have you ever heard of Aflasafe?
  - Yes, I've heard of it and used it
  - Yes, I've heard of it but never used it
  - No
  - Unsure

- Have you used chemical control agents for preventing aflatoxin?
  - Yes
  - No
  - Unsure

- If yes, what kind and how did you apply it? _____

- Have you received any training on the dangers of aflatoxin and/or reducing the risk of aflatoxin contamination?
  - Yes
  - No
  - Unsure

  If yes, from what source did you receive the training? _____

<u>Communication and Future Programming</u>

- Of the aflatoxin prevention technologies mentioned (biological control agents, chemical control agents, pre-harvest drying, storage bags), what do you think are the biggest challenges to implementing them?
  - Lack of awareness and education about aflatoxin and aflatoxin prevention strategies
  - Finances
  - Lack of local agri-input stores
  - Other (specify) _____

- Would you be interested in learning more about aflatoxin?
  - Yes
  - No

- Which aflatoxin related programs are you most interested in and which do you think would be the most helpful?
  - Aflatoxin awareness training
  - Aflatoxin prevention training
  - Free or subsidized trials of aflatoxin prevention technologies
  - All the above

- Other (specify) _____

- Which platforms/channels do you think would be most appropriate and helpful for accessing and sharing information about aflatoxin?
  - Social media
  - Print media
  - Television/radio
  - Agricultural extension
  - Other (specify) _____

- Do you have anything else you would like to share regarding aflatoxin, aflatoxin control, or food safety?
  - _____

Appendix 2: Focus Group Discussion Questions

1. How significant of an issue is maize spoilage in your community?
2. What are the biggest causes of maize spoilage on your farm and how do you try to prevent them?
3. What do you do with spoiled maize?
4. What do you know about aflatoxin and how confident are you in your knowledge of aflatoxin?
5. What do you think could be done to address aflatoxin contamination and maize spoilage? What programing might be helpful?
6. How do you go about selling maize? Who do you sell it to? When do you sell it? Why?