

Market-driven strategies for combating aflatoxins in Rwanda

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Market-Driven Strategies for Combating Aflatoxins in Rwanda

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1. Introduction

Aflatoxins¹ are naturally occurring fungal by-products that contaminate crops – especially cereals and oilseeds – and the contamination may occur in the field and storage. At low levels of dietary exposure, aflatoxins are associated with immune suppression (Mohsenzadeh et al., 2016), low birth weight (Passarelli et al. 2020), stunted growth in children (Rasheed et al. 2021), and liver cancer--the best known of aflatoxin health effects. The International Agency for Research on Cancer (IARC) of the World Health Organization (WHO) has classified aflatoxins as carcinogenic to humans and one of the most toxic and known carcinogenic substances. Humans are exposed to aflatoxins directly by consuming contaminated commodities or indirectly through contaminated milk, if dairy cows are fed contaminated feed (IARC 2012). More than 4 billion people – especially in Africa and Asia – are frequently exposed to aflatoxins worldwide (Williams et al., 2004). It was estimated that 4 – 25 % of liver cancers per year are attributed to aflatoxin exposure, with most cases occurring in sub-Saharan Africa and Southeast Asia (Li and Wu, 2010). Countries in tropical and sub-tropical regions – especially those, such as Rwanda, with climates characterized by high temperatures, drought risk, and high levels of humidity post-harvest - offer favorable climatic conditions for the growth of aflatoxin-producing fungi and the formation of aflatoxin in commodities in the field and storage (Kew 2013). Moreover, climate change may exacerbate aflatoxin contamination of agricultural commodities in tropical regions due to increasing temperatures and more erratic rainfall patterns (Thomas et al., 2019; Warnatzsch et al. 2020).

Aflatoxins pose significant public health, social and economic problems for Africa in general (Bankole and Debanjo, 2003; Wagacha and Muthomi, 2008), particularly for countries with high cereal production. The most deadly known outbreak of aflatoxicosis – poisoning due to ingestion of high levels of aflatoxin – occurred in 2005 in Kenya, and led to 317 cases of acute hepatic failure and 125 deaths (Lewis et al. 2005). Aflatoxin contamination can also restrict trade exchanges between countries due border rejection of contaminated products and even import bans. For instance, in March 2021, Kenya suspended maize imports from Uganda and Tanzania over the aflatoxin contamination in grains (Newtimes, 2021).

The Government of Rwanda launched the Crop Intensification Policy (CIP) with preliminary priority crops, including maize, cassava, beans, and potatoes in 2007 (Kathiresan, 2011). The CIP's success has resulted in increased agricultural production, especially cereals. According to World Bank data, cereal production increased three-fold during the 2007 to 2013 period, from 350,000 to 930,000 metric tons, respectively (World Bank, 2021). The increase in cereal production has been accompanied by postharvest losses, and aflatoxin contamination of cereals (Musabyimana and Tran, 2020). Consequently, some agro-processing companies have resorted to importing grains – mainly maize – from abroad to cope with the insufficient local supply of quality grains due to high

¹ There are four different types of aflatoxins: aflatoxin B1, aflatoxin B2, aflatoxin G1, and aflatoxin G2. Aflatoxin B1 is considered the most toxic.

aflatoxin contamination (Newtimes, 2018). The present policy brief is a follow-up to the webinar organized by the International Growth Center and the Rwandan Ministry of Agriculture titled: “Market-Driven Strategies for Mitigating Aflatoxin in Rwanda”. The policy brief highlights advances in science made to tackle aflatoxin contamination, describes the prevalence situation and regulation of aflatoxins in Rwanda, and finally proposes recommendations for supply-side and demand-side policies to mitigate aflatoxin contamination in the country.

2. International evidence on aflatoxin control

From discovering aflatoxins, significant progress has been made in defining causal factors and finding solutions to combat aflatoxin contamination in commodities at different stages within agricultural value chains. Intervention and strategies that can be applied to crops both pre- and post-harvest are discussed below.

2.1. Pre-harvest measures

Pre-harvest measures to control a pathogen that results in yield loss or harmful toxin is the front line of defense. However, this strategy presents many challenges in mitigating aflatoxins risk since the contamination starts in the field and continues during storage.

a) Resistant grain varieties

Identifying grain-inbred lines capable of resisting aflatoxin contamination is the first step and key in minimizing aflatoxin grain contamination. With the help of two techniques, the genome-wide association study (GWAS) and mapping of quantitative trait loci (QTL), genes involved in the resistance to *A. flavus* contamination are known. Their discovery is crucial in developing breeding programs for maize – and other cereals – resisting to *A. flavus*, therefore, controlling aflatoxin accumulation in grains (Han et al. 2020; Hruska et al. 2020). However, it is worth noting that there are no such commercially grown resistant hybrids in the East African region to reduce the aflatoxin accumulation in grains (Massomo 2020). In the United States (US), researchers have developed maize germplasm line resistant to aflatoxin contamination. For instance, Williams and Windham (2006) released a maize germplasm line Mp717, as a source of resistance to *A. flavus* and capable of reducing aflatoxin contamination by 13 – 20 times compared to susceptible germplasm lines. In Rwanda, such efforts can be led by agriculture research institutions, such as Rwanda Agriculture, Animal Resources Board (RAB), to identify good maize varieties that would be not only resistant to aflatoxin contamination, but also to Rwanda’s ecology and farm needs.

b) Biocontrol

A biocontrol strategy introduces native strains of *A. flavus* that do not produce aflatoxin to out-compete existing *A. flavus* strains that produce aflatoxins. The U.S. introduced biocontrol over the past three decades to combat the predominant *A. flavus* strains in soil and crops. Following this example, the International Institute of Tropical Agriculture (IITA) has developed a biological control product and registered this as Aflasafe™ in several African countries including Nigeria,

Kenya, Senegal and Tanzania (Johnson et al. 2018; IITA 2018). Aflasafe applied to the soil before flowering and can achieve aflatoxin reduction in the field (Atehnkeng et al. 2008).

c) Good Agriculture Practices (GAPs)

The Food and Agriculture Organization of the United Nations (FAO) defines a good agricultural practice (GAP) as a "*collection of principles to apply for on-farm production and postproduction processes, resulting in safe and healthy food and non-food agriculture products, while taking into account economic, social and environmental sustainability*". Regarding reducing aflatoxin contamination, GAPs during the pre-harvest period include different strategies that reduce crop stress and boost crop vigor, thereby reducing the subsequent susceptibility of maize to aflatoxin-producing fungi. Strategies that can be adopted during pre-harvest include the following:

- **Crop rotation:** crop rotation sequences can significantly affect the level of aflatoxin produced by the fungus *A. flavus* (Jaime-Garcia, 2006).
- **Prevention of insect damage:** Insect damage is positively correlated with aflatoxin levels in maize (Ni et al., 2011). Therefore, reducing the insect pest populations in a field may reduce aflatoxin contamination in grains in some production environments; however, the pesticides employed must be chosen carefully because they can lead to pesticide residue accumulations in grains and can be very harmful to beneficial insects such as honeybees. Bio-pesticides offer a better choice for reducing insect pest populations including the use of genetically modified hybrids.
- **Crop management:** Environmental influences such as drought during cultivation (Chauhan et al., 2008), and humidity during the post-harvest period (Hell & Mutegi, 2011), increase aflatoxin risk. Farmers can modify their practices to address these risk factors through improved soil moisture management and timely planting and harvest. Tools to help farmers determine the best planting and harvest periods within a specific region are essential to reduce aflatoxin contamination significantly.

Pre-harvest measures for reducing aflatoxin contamination in grains are necessary, but they are not enough and need to be combined with postharvest measures to minimize contamination during storage. The following discussion focuses on postharvest mitigation strategies.

2.2. Postharvest measures to control aflatoxin contamination

a) Aflatoxin risk characterization and segregation at harvest

Measuring and managing aflatoxin risk at harvest represents a good first step commonly employed at the first collection points. This is done using approved sample collection, sample preparation, and testing protocol. For example, in the United States (U.S.) where maize is prone

to high levels of aflatoxin contamination such as Texas, commercial grain handlers and farmers utilize a protocol developed by the U.S. Department of Agriculture. The protocol includes prescribed volumes of grain sampled, fineness of grind during sample preparation, subsample test portion, and use of USDA validated field kit. Maize exceeding the maximum level of aflatoxin for human consumption is segregated and channeled to less susceptible animal species that pose less risk to the human food supply. To facilitate this process, reference material with known amounts of naturally occurring aflatoxin is used by firms to assist verification of testing accuracy.

Additionally, the competent authority (Office of the Texas State Chemist) collects retained samples from the firm and verifies testing accuracy. Due to the economies of scale, these practices are less available for smallholder farmer enterprises in Africa. However, implementation of a continuous supply chain from production to consumption in these markets can facilitate testing and segregation at the first collection point. Such a model has been pioneered in Rwanda by Kumwe, a division of Africa Improved Foods Rwanda Ltd (AIF).²

b) Rapid and adequate drying after crop harvesting

After harvesting, grain quality must be maintained to avoid contamination with fungi, including those which produce aflatoxin. The grain moisture content (MC) is around 20-25% during the maturation of grain. Grains are susceptible to *Aspergillus* growth and aflatoxin contamination at this MC level. The reduction of MC in maize to around 13 ~ 13.5% in the field or through postharvest drying results in grain suitable for long-term storage. Storage of kernels with moisture above 15% results in an equilibrium relative humidity conducive to spore germination, fungal growth, and toxin production. Equilibrium relative humidity is easily measured by a water activity (a_w) meter, a tool with broad applicability to cereals, oilseeds, co-products, and finished food and feed.

Several methods can be used by small-scale farmers to dry their harvested grain. The natural solar drying method, in which farmers dry their crops directly on the ground or on used woven material recycled from storage bags, is the most commonly used method in Rwanda. Providing farmers with impermeable plastic drying sheets can make solar drying more efficient and significantly reduce aflatoxin contamination at a modest cost (Magnan et al., 2021).

However, the required MC level cannot reliably be achieved using this method because of solar variability, day and night sequences, and inconsistent solar availability. Industrial methods offer an efficient alternative for achieving required MC levels, but they require an initial investment that many farmers cannot afford. Various efforts have been undertaken to help small farmers cope with the drying challenges and affordable access to dryers. For instance, the Post-Harvest Loss Innovation Lab, a USAID-funded initiative at Kansas State University, USA, has developed tools and technologies to improve postharvest practices at the small-scale farm level. A hybrid dryer utilizing biomass (like agro-residues, timber scraps) along with solar drying has been developed

² <https://www.kumwe.com/>

and already scaled up in Ghana. Two types of dryers have been developed: portable and stationary. Stationary dryers can dry 3-5 metric tons (MT) of maize in 8 hours, while the mobile dryer can dry 1MT per batch^{3,4}. The same lab has also developed a low-cost, easy-to-use, and accurate moisture-meter, the "GrainMate moisture meter", which is commercially available via a distributor based in Ghana. Once dried, grains should be stored in gas-tight containers limit environmental exchange and storage loss from insects and fungal growth (Tubbs et al., 2016).

c) Proper storage

The last decades have seen a growing number of methods to store grains safely. Storage bins are commonly used in large-scale operations. On a smaller scale, metal silos and hermetic bags such as PICS (Purdue Improved Crop Storage) bags provide an alternative for farmers who cannot afford bins. PICS bags have been shown to reduce aflatoxin and insect control problems by up to 95% (Baoua et al., 2014; Hell et al., 2014). If the MC is controlled during storage, *A. flavus* cannot grow, preventing aflatoxin production. Electronic sensors and moisture meters are commercially available for large storage bins to monitor the internal MC in real-time. For small-scale farmers, a product called *Dry Card*®, developed by the University of California, Davis, can be used to monitor relative humidity and to infer MC levels during grain storage (Thompson et al., 2017). The *Dry Card*® is locally available in Rwanda.

d) Physical Separation: cleaning and sorting

Aflatoxins are heat stable, and thermal treatment commonly used for cooking cannot remove them. Sorting offers a way to minimize aflatoxin contamination in grains. There is a positive correlation between aflatoxin contamination and both physical kernel damage (Hoffmann et al., 2021) and visible mold (Galvez et al., 2003). Kernels with visible mold damage can contain up to 50 times that of healthy grains (Shi et al., 2014). Sorting based on physical properties such as color, size, shape, and density and the visible identification of fungal growth in affected crops, and rejection of kernels with characteristics correlated with aflatoxin can reduce the presence of aflatoxin and other contaminants in food and feed (Fandohan et al., 2005). Although sorting can be done manually, it is time-consuming. Various automated sorting technologies have been proposed in the literature (Stasiewicz et al., 2017). One of these, dubbed AflaSight, is currently being piloted in Rwanda.⁵

e) Direct interventions at the farm level

Training is crucial in preventing aflatoxin contamination. A study conducted in Kenya using training sessions on aflatoxin and practices to avoid contamination and to facilitate farmers' access

³ <https://agrilinks.org/post/path-safer-food-post-harvest-loss-innovation-lab-works-identify-and-mitigate-mycotoxins-major>

⁴ https://www.k-state.edu/phl/resources/SBHD%20Fact%20Sheet%20Sept2018_2.pdf

⁵ <https://innovation.wfp.org/project/aflasight>, <https://africabusinesscommunities.com/agribusiness/news/kigali-based-agriculture-startup-aflasight-partners-launch-innovative-projects-to-improve-maize-quality-in-rwanda/>

to plastic sheets, mobile maize dryers, and hermetic storage showed a significant reduction of aflatoxin contamination by 55 percent three months after harvest (Pretari, Hoffmann, and Tian 2019). The authors attributed most of this reduction to training and drying sheets, which had the highest level of take-up among the technologies offered.

3. Situational analysis of aflatoxins in Rwanda

3.1. Review of the literature concerning peer-reviewed publications of aflatoxins in Rwanda

Data – especially peer-reviewed publications – on the prevalence of mycotoxins in general and aflatoxins in particular in Rwanda, is scarce. By using Scopus⁶, the largest abstract and citation database for peer-reviewed literature, only eleven documents can be retrieved using "Aflatoxin" and "Rwanda" as keywords. These range from studies estimating contamination in food and feed to the presence of mycotoxin biomarkers in human blood samples. All studies confirm a high level of Aflatoxin exposure in food, feed, and human diets.

The most recent publication documents high levels of mycotoxin exposure among 189 women of childbearing age (Collins et al. 2021). Nishimwe et al. (2016) and Niyibituronsa et al. (2020) assessed aflatoxin contamination in maize samples and found levels 90.4 % and 28-87% above EAC standards, respectively. Nishimwe et al. (2019) found high levels of aflatoxins and fumonisins in more than 3,000 feed and feed ingredient samples collected at six time-points in all 30 districts of Rwanda, suggesting that aflatoxin contamination is also a problem in animal source food (i.e., milk).

It is known that complementary foods play a key role in early child nutrition and that the safety and quality of these foods is thus critical. Ten popular complementary foods (with maize, soya, sorghum, rice and wheat as main ingredients) available in the Rwandan market were analyzed for aflatoxin contamination. The mean for both total Aflatoxin and Aflatoxin B1 exceeded 50 µg/kg, greatly surpassing the tolerable limits of 10 µg/kg of total aflatoxins and 5 µg/kg of aflatoxin B1 set by RSB, respectively. (Grosshagauer et al. 2020).

3.2. Existing efforts to mitigate aflatoxin contamination in Rwanda

Several ongoing or completed projects aim to mitigate aflatoxin contamination in food and feed in Rwanda. Most of these target farmers, while a few focus on downstream value chain actors including consumers and traders. Farm-based interventions include (i) a RAB intervention to avail drying shelters and mobile dryers to farmers, (ii) an Alliance for a Green Revolution in Africa (AGRA) project supporting the development and commercialization of Aflasafe biocontrol, and another project also funded by AGRA to reduce aflatoxin levels in maize in Eastern province, and (iii) two projects focusing on mitigating aflatoxin contamination in feeds funded by Livestock Systems Innovation Lab (LSIL). More recently, Africa Improved Food/Kumwe Harvest in collaboration with the World Food Program and support from the International Finance

⁶ <https://www.scopus.com/search/form.uri?display=basic#basic>

Corporation, have implemented a new mechanical sorting technology under the AflaSight initiative to remove aflatoxin-infected kernels prior to grain processing⁷.

A timely and welcome initiative establishing a Technical Working Group (TWG) on aflatoxin management has been essential to bring together various stakeholders and discuss all challenges linked to aflatoxin contamination in Rwanda.

4. Proposed policy and public investments to enable aflatoxin control in Rwanda

In this section, we discuss proposed changes to improve the enabling environment for control of aflatoxin through policy and public investment.

4.1. Policy Framework and regulations of aflatoxins in Rwanda

Existing policies related to food and agriculture

In Rwanda, food safety is formed within the National Agriculture Policy, the Rwanda National Food and Nutrition Policy (NFNP), Vision 2050, and National Strategy for Transformation, which set out goals and frameworks for the transformation of the country's economy in general and agriculture sector in particular. In 2014, NFNP, a joint multi-sectoral policy developed by the Ministry of Local Government, Ministry of Health, and Ministry of Agriculture and Animal Resources, was revised and updated to substantially reduce the prevalence of stunted children under two years of age and improve household food security--particularly among Rwanda's most vulnerable families. Food safety is not emphasized in this policy.

Three public institutions are involved in the regulation of aflatoxins: the Rwanda Standard Board (RSB), the Rwanda Inspectorate, the Competition and Consumer Protection Authority (RICA), and the Rwanda Food and Drug Authority (Rwanda FDA):

- RSB establishes, publishes, and disseminates national standards information. Aflatoxin standards align with regional (i.e., East African) and international (i.e., *Codex Alimentarius*) standards. Regulatory institutions use RSB standards to develop specific technical regulations and guidelines.
- RICA and Rwanda FDA are in charge of inspecting unprocessed food products and feeds, and processed food and feeds, respectively. They are both responsible for enforcing aflatoxin inspection standards and regulations along with diverse food and feed value chains.

⁷ <https://www.kumwe.com/>

All aflatoxin standards are aligned to East African Community (EAC) standards. Levels of aflatoxin B1 and total aflatoxins allowable in food products are set at 5 and 10 µg/kg, respectively. In contrast, aflatoxin limits vary for animal feeds, depending on the animal's physiological state (i.e., lactating, growing, and finishing). Details on aflatoxin standards are provided in the Appendix.

Adoption of risk-based food safety policies and priorities

There is a need to develop a specific food safety policy to provide a legal and guidance framework to reduce and prevent foodborne diseases, especially to prevent aflatoxin contamination, in Rwanda, clearly using holistic and risk-based approaches to address food safety challenges.

Globally, the traditional regulatory approach of controlling potentially harmful agents in food has given way to a risk-based approach that takes into account not only the presence of a hazard but also the level of exposure and vulnerabilities of the exposed population (Barlow et al., 2015). Determining the stringency of aflatoxin regulations, as well as the resources devoted to their enforcement, should be based on a formal risk assessment. Such an assessment would include an estimation of exposure to aflatoxin among different age groups based on diets, and prevalence of synergistic risk factors for developing aflatoxin-induced liver (i.e., rates of infection with hepatitis B and C).

Rationalization of existing standards

Several aspects of the EAC standards for aflatoxin make testing unnecessarily difficult for both private firms and regulators. First, the EAC has published official procedures for measurement of aflatoxin using high-performance liquid chromatography (HPLC) and enzyme-linked immunoassay (ELISA methods) (EAC 901-2017). This limits the use of many other validated testing options. While HPLC instrumentation is relatively easy to use, the capital cost of initial purchase, maintenance, and support systems within a lab (including temperature control, ultra-pure water, uninterrupted electrical support, and high-grade reagents) limits the application of this technology to relatively few labs within Africa and can drive up the cost of analysis to USD 170. Even if ELISA is considered as a cheap analytical method, it presents some advantages, such as the presence of interferents and cross reaction from samples leading to false results. Consequently, the quality control is crucial for ELISA methods.

The cost of lateral flow rapid tests, on the other hand, range from USD 5 to USD 25. Prices for these tests in the U.S. are as much as 50% lower, suggesting that increased volume of demand as well as pressure on suppliers could lead to lower prices in Rwanda as well. As there are many rapid aflatoxin tests on the market, the United States Department of Agriculture's Federal Grain Inspection Service (FGIS) has developed a protocol for their validation relative to the HPLC “gold standard”. This is the only official standard published by a regulatory body (USDA 2018) and has been used to validate aflatoxin field kit platforms that effectively manage aflatoxin risk in the

global grain trade. By recognizing USDA-validated test kits, Rwanda could significantly reduce the cost of aflatoxin compliance and surveillance.

Second, the level of aflatoxin B1 detected in food and feed is generally approximately 80% of total aflatoxins, so the need for standards setting limits on each of these separately is not clear. Moreover, the relative values of the current standards for total aflatoxins and B1 do not align with the relative levels observed in reality. Related to this, paucity of validated field test kits for measuring aflatoxin B1 implies challenges for compliance with the B1 standard.

Finally, the EAC recently prescribed a 10 kg sample for aflatoxin measurement (EAC 2017), a ten-fold increase in sample amount from the EAC 2008 standard, and recommended mycotoxin testing in Codex Alimentarius standards. There is a need for adaptation of standards to make them more suitable for commerce within Rwanda and active involvement by the Rwandan delegation participating in EAC standard development meetings to promulgate standards that can simultaneously manage aflatoxin risk while facilitating commerce and broad-scale adoption.

Laboratory accreditation

Accreditation of laboratories that involves aflatoxin proficiency testing and use of reference material are two quality control techniques advocated in the ISO 17025:2017 standard for measurement accuracy. Increasingly, regulatory agencies worldwide, including in Africa, have become accredited under this standard. Regulators and merchants must be confident that reported analytical results are unbiased, accurate, traceable, and the measurement uncertainty is correctly defined. APTECA, which stands for Aflatoxin Proficiency Testing and Control in Africa, was launched in 2014 to offer aflatoxin proficiency testing and accreditation services to public and private laboratories on the continent. This program has subsequently expanded to Asia, the Americas, and Europe. The APTECA program has assisted labs in Eastern and Southern Africa to achieve accreditation to the ISO 17025:2005, 2017 standards by offering proficiency testing and reference material at no cost, and by hosting analyst qualification workshops. The APTECA program has conducted internal audits of food safety plans at commercial mills, provided verification services to assist private and public sector testing accuracy, and offered graduate-level education through an online course, “Laboratory Quality Systems”, in collaboration with the United Nations Food and Agriculture Organization (FAO). It has led policy discussions resulting in model bills that helped update agriculture and public health agencies' approach to managing aflatoxin risk⁸.

Co-regulation

Presently, most of the regulatory bodies globally rely upon their own sampling, chain-of-custody, sample preparation, and testing to regulated contaminants. An alternative to the traditional command and control regulation of aflatoxin was adopted by the Office of the Texas State Chemist

⁸ (<https://apteca.tamu.edu/>).

in 2011 and introduced in Kenya in 2014. The Texas program, referred to as the One Sample Strategy (OSS) utilizes the concept that a single sample of maize collected, prepared, and analyzed using official methods developed and validated by FGIS will yield results that are suitable for marketing, crop insurance, and regulatory purposes (Texas State Chemist Office, 2021). This co-regulation approach shifts the regulatory paradigm from regulatory sampling and testing products into conformance to monitoring firms' quality systems to measure and manage risk, including through the analysis of randomly selected duplicate samples by the regulator or its designate.

This alternative strategy aligns with current thinking involving preventive regulatory controls contained within the U.S. Food Safety Modernization Act and the ISO 17025:2017 standard that focuses on managing risk within the analytical process from sampling through analysis. This approach provides the additional benefit of constant and consistent monitoring of food safety, unlike that provided by a regulatory agency with limited resources where regulators cannot be presented at every grain storage and processing establishment all the time. One measure of success occurred in a recent study by Hoffmann *et al.*, which reported that the formal maize milling sectors delivered aflatoxin-safe products at the time of the study (2021). The study was significant in that it revealed the success of the formal maize milling sector to manage aflatoxin risk through the adoption of APTECA. Samples for the study were analyzed at the University of Nairobi, where APTECA facilitated the adoption of the ISO 17025:2017 standard.

Use of contaminated food and feed

What is supposed to be done if aflatoxin levels in food and feed products exceed legal limits? The East African Community has developed a policy brief (#8) containing instructions for the disposal and alternative use of aflatoxin-contaminated food and feed (EAC, 2021). One option is to add mycotoxin binders to contaminated material, and use it as animal feed.⁹ Clay binders have been most tested, and studies show they are effective and do not affect animal performance at inclusion rates varying from 0.25 to 5% (Neeff *et al.*, 2013). Many parameters, including the type of binder, amount used, species, and other factors influencing production affect the rate of pass-through of aflatoxin into animal products (Giovati *et al.* 2015). The use of binders is on rise in East Africa; in Kenya, the quantity imported increased threefold between 2017 and 2018 (Mutua *et al.*, 2019). However, similar to other countries in the region, Rwanda does not have standards that regulate the use of mycotoxin binders. Rwanda should adopt standards for the use of mycotoxin binders. The use of binders proven to be effective should be reflected in allowable mycotoxin levels in feed.

Texas is an example of how the use of binders, among other tools, can help ensure a well-functioning market that delivers an abundant supply of aflatoxin safe feed and food. To manage high levels of aflatoxin risk comparable to Rwanda's, Texas allows the use of binders, ammoniation, and blending of contaminated crops at different levels of contamination, all

⁹ Binders are defined as "substances that bind aflatoxins and prevent them from being absorbed through the gut into the blood, from which they are excreted into animal products like milk".

performed under the supervision of the Office of the Texas State Chemist (TAC 2019). Further, the agency has developed guidance to industry on the use of these procedures (see Feed Industry Memorandums 5-12, 5-17, and 23). The presence of these policies highlights the limited success of pre-harvest aflatoxin control strategies. It also highlights the importance of the regulatory risk manager's active involvement in providing creative science-based solutions to manage aflatoxin risk.

4.2. Supply-side policies

While not new, the problem of aflatoxin contamination in commodities is surprisingly persistent, despite the availability of effective technologies to reduce aflatoxin contamination in the field and during storage. So, faced with this paradox, the question is "what should Rwandan agriculture sector stakeholders do?".

Although effective technologies (such as Dry Card® and hermetic bags) are locally available, adoption of these technologies by farmers remains low. Studies in Kenya and Ghana have shown that raising awareness can motivate small-scale farmers to adopt aflatoxin control practices, and that subsidies can greatly increase the use of appropriate postharvest technologies and significantly reduce aflatoxin contamination (Hoffmann and Jones, 2021 & Magnan et al., 2021). These approaches could be tested on a pilot basis to adapt them to the Rwandan context and also understand how to target aflatoxin control technologies to those who can benefit the most from their use.

While public intervention may be needed to introduce new technologies to farmers and trigger demand, in the longer run, a self-sustaining market-based supply chain for the technology would ideally emerge. In order for the private sector to distribute a technology, that technology must generate value for the value chain actors who will pay for it, which could be farmers, traders, or processors (Sonka, 2020). As the ultimate beneficiaries of safer food, consumer's demand for aflatoxin control will be essential in driving this value.

4.3. Demand-side policies

As citizens are not generally able to discern the safety of food offered for sale, the state must take the lead in holding firms accountable to food safety standards. The threat of regulatory action can spur formal sector companies to investment in food safety due to the risk of reputational damage to their brands (Hoffmann and Moser, 2017). To generate broad results across the sector, it is important that regulatory surveillance and action is applied broadly, and not only to the largest firms.

Of course, such action will only improve the safety of the food supply if firms are able to comply with regulations. Newly available technologies such as AflaSight promise to expand the tools available to maize processors. Availability of affordable testing options and laboratory

capacity are also critical to firms' compliance capacity, as noted in Section 5.1. Mechanisms for firms to ensure the reliability of their own aflatoxin test results should be made available, for example through an independent proficiency testing program. Several maize processing firms in Kenya have used APTECA's proficiency testing services with strong results.

A major challenge to effective regulation in Rwanda is the fact that a large, arguably majority, share of the food supply is through small-scale, informal, and thus difficult to regulate firms. While the threat of a mandatory recall of contaminated food is an effective motivator for firms that survive based on the reputation of their brands, regulatory action against a micro scale maize processor or vendor who fails to comply with standards is unlikely to make the food supply any safer. A potentially effective approach is to shift consumer demand, by educating consumers about which foods within a category are particularly high-risk. Evidence from eastern Kenya (Kariuki and Hoffmann, 2021), as well as preliminary results from a 6-round, 10-city study, also in Kenya (Hoffmann, Okoth, Ndisio, and Murphy, *in progress*), show that unrefined maize flour produced by small-scale hammer mills has a far higher likelihood of contamination than sifted flour produced in larger-scale roller mills. This pattern is driven at least in part by the removal of the more contaminated germ and exterior fibrous layer (pericarp), and thus also expected to hold in Rwanda. An experimental study in which households were informed about the contamination status of the maize flour they currently consuming resulted in safer product choices 9 weeks later (Kariuki and Hoffmann, 2021). Informing consumers about the relative safety of unpackaged, micro-processed versus formally branded, packaged flour, which is also required to be fortified with essential vitamins and minerals, could help shift demand, and thus accelerate the transformation of this sector to one in which regulations can be more easily enforced.

Awareness campaigns must be accompanied by routinely detecting and quantifying aflatoxins along the value chain. This requires the availability and regulatory recognition of low-cost, validated aflatoxin testing options, as well as a system for accrediting the laboratories performing these tests to ensure they deliver accurate results, as discussed in Section 5.1.

Conclusions

Like other tropical and sub-tropical countries, Rwanda has a climate that favors the growth of aflatoxin-producing fungi and the contamination of agricultural commodities with aflatoxin. Aflatoxin contamination in susceptible crops is thus a challenge for the agricultural sector. Despite the existence of standards and regulations and several ongoing or completed projects to mitigate aflatoxin contamination in different commodities, there remain several gaps in the evidence, awareness, and capacity required for effective control of aflatoxin in Rwanda. These include:

- Scarcity of published data on mycotoxins, in general, and on aflatoxin specifically in the Rwandan context.
- Despite low-cost postharvest technologies (hermetic bags, Dry Cards) available locally and binders to reduce aflatoxin in contaminated feeds, adoption of these by farmers remains very low.
- Inadequate awareness of aflatoxins among different stakeholders
- Inadequate aflatoxin testing capacity for farmers and other stakeholders involved in grain value chains.

This brief proposes the following recommendations to improve the enabling environment for aflatoxin control in Rwanda:

- Regulatory:
 - Develop a context-appropriate food safety policy which would provide a legal framework and guidance for the control of foodborne hazards including aflatoxin.
 - Increase access to and affordability of aflatoxin testing through official recognition of validated, low-cost, field-ready testing platforms such as those based on lateral flow technology.
 - Adopt standards for the use of mycotoxin binders. The use of binders proven to be effective should be reflected in allowable mycotoxin levels in feed.
 - Improve and ensure the capacity of laboratories to deliver valid results via accreditation through an aflatoxin proficiency testing program.
 - Adopt a co-regulatory approach to shift some of the responsibility for monitoring food safety outcomes from the regulator to private firms, while maintaining accountability through the analysis of randomly selected duplicate samples by the regulator.
- Supply-side
 - Make available farm-level solutions for aflatoxin control that take into account the characteristics, motivations, and constraints (specifically resource constraints) of Rwandan farmers. Lessons on the importance of information and technology cost can be taken from other settings and approaches tailored to the Rwandan context via pilot programs prior to wide-scale implementation.

- Demand-side
 - Use regulatory action such as mandatory recalls to incentivize compliance with aflatoxin regulations in the formal processing sector, while also supporting firms' capacity for compliance through access to technologies such as mechanized sorting, affordable testing platforms, accredited laboratories, and proficiency testing for internal quality assurance.
 - Conduct regular surveillance of both formally packaged and informally milled flour and inform consumers about the relative safety of these two product classes to accelerate the transformation of the maize flour sector toward dominance of formally milled and packaged flour, which is both easier to monitor for contaminants and has nutritional benefits due to required fortification with essential vitamins and minerals.

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APPENDIX

Table 1. Aflatoxin standards for food and feed products listed in the RSB database

RSB Reference number	Standard Title	Maximum Limits (ug/kg)		
		Aflatoxin B1	Total Aflatoxins	Aflatoxin M1
Food Products				
RS 101: 2018	Cookies - specification	5	10	
RS 150: 2018	Cooked Packaged Maize - specification	5	10	
RS 25: 2015	Edible maize starch - specification	5	20	
RS 388: 2018	Roasted soya bean flour - specification	2	4	
RS 389: 2018	Popcorn	2	4	
R.S. 58: 2015	Flaked breakfast cereals - specification	5	20	
RS 78: 2018	Cakes - specification	5	10	
RS 416: 2020	Sesame flour	5	10	
RS 415: 2020	Sesame seeds	5	10	
RS 417: 2020	Peanut flour	5	10	
RS EAS 60: 2013	Peanut butter - specification	5	10	
RS 418: 2020	Pumpkin seed flour	5	10	
RS 419: 2020	Pumpkin pulp flour	5	10	
RS 429: 2020	Chocolate and chocolate products			0.5
RTS 436: 2020	Instant fortified whole maize flour	5	10	
RS EAS 1: 2019	Wheat flour - specification	5	10	
RS EAS 2: 2017	Maize grains - specification	5	10	
RS EAS 128: 2017	Milled rice - specification	5	10	
RS EAS 173: 2004	Pasta products - specification		10	
RS EAS 284: 2013	Pearl millet grains	5	10	

RS EAS 44: 2019	Milled maize products - specification	5	10	
RS EAS 768: 2019	Fortified milled maize - specification	5	10	
RS EAS 51: 2017	Wheat grains - specification	5	10	
RS EAS 757: 2019	Sorghum grains - specification	5	10	
RS EAS 762: 2017	Dry soybeans - specification	5	10	
RS EAS 764: 2013	Rough rice - specification	5	10	
RS EAS 765: 2013	Brown rice - specification	5	10	
RS EAS 782: 2019	Composite flour - specification	5	10	
RS EAS 800: 2014	Soya milk - specification	5	10	
RS EAS 89: 2017	Millet flour - specification	5	10	
RS EAS 888: 2018	Raw and roasted groundnuts - specification	5	10	
RS EAS 95: 2017	Sorghum flour - specification	5	10	
Dairy Products				
RS EAS 69: 2019	Pasteurized milk			0.5
RS EAS 67 2019	Raw cow milk			0.5
RS EAS 49: 2019	Milk powder			0.5
RS EAS 27: 2019	UHT milk			0.5
R.S. 50-4 2017	Processed cheese			0.5
Feed Ingredients and Complete Feed				
RS EAS 353: 2019	Wheat bran for animal feeds - specification		20	
RS EAS 75: 2019	Compounded cattle feed - specification	5 – 50*	100 – 300*	
RS EAS 55: 2019	Compounded pig feeds - specification	10 – 20*	50 – 200*	
RS EAS 90: 2019	Compounded poultry feeds - specification	10 – 20*	50 – 100*	
RS EAS 973: 2019	Compounded fish feeds - specification	10	100	

RS EAS 974: 2019	Compounded dairy goat feeds - specification	5 – 50*	100 – 300*	
Other standards				
RS 286: 2015	Prevention and reduction of aflatoxin contamination in peanuts			
RS ISO 16050: 2003	Determination of Aflatoxin in cereals, nuts, and derived products – HPLC method			

* Specific listed standards with an (*) vary, depending on the animal's physiological state (i.e., lactating, growing, and finishing).

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