MYCOTOXINS AND POSTHARVEST LOSSES IN SUB-SAHARAN AFRICA

June 18, 2021; Online workshop

Organized by: The African Postharvest Losses Information System (APHLIS),

Mytox-South, Mycokey and African Society of Mycotoxicology networks

Full Report

Contents

WELCOME AND MEETING OBJECTIVES

The workshop was organized by the European Commission Knowledge Centre for Global Food and Nutrition Security (KCFNS)[1] in collaboration with the main African and European scientific networks working on methods to quantify and reduce mycotoxin contamination of food and feed and grain postharvest losses (The African Postharvest Losses Information System (APHLIS), Mytox-South, Mycokey and African Society of Mycotoxicology (ASM)).

The main objective was to bring together the postharvest losses and mycotoxins research networks in Africa and to reflect on links and research priorities which are relevant to both communities. The workshop focused on existing network activities, common priority research questions and possibilities for stronger integration and collaboration between the networks.

The event was attended by members of the postharvest losses and African mycotoxins research networks as well as by invited experts of the international research community. Participants came from three continents, Africa (13), North America (6) and Europe (12).

INTRODUCTION

Mycotoxins in staple crops and nuts are an important food safety concern. These result from fungal damage of the crop in the field, in storage or both. There are five agriculturally important mycotoxins including aflatoxin, fumonisin, deoxynivalenol, zearalenone and ochratoxin A. Of these, the largest burdens on public health result from exposure to aflatoxin and fumonisin. These are pervasive contaminants in staple crops throughout sub-Saharan Africa. Aside from the considerable chemical hazard, fungal damage of the crop destroys nutrients and affects the taste of the damaged commodity. The African Postharvest Losses Information System (APHLIS) estimates losses for cereals and legumes in Africa but considers qualitative losses only when grains are then physically lost and/or excluded from human consumption. The APHLIS core team and network members view it as important for the postharvest community to understand the status of current research and existing information regarding the impact of mycotoxins on grain losses in Africa and their consequences for human nutrition.

The workshop brought together researchers from the main scientific networks that study issues related to food production and postharvest management in Africa and do so from different angles. The participants come from three different continents, Africa, North America as well as Europe. Some of the participants study agricultural production, others consider crop postharvest losses and others are concerned with food safety and mycotoxin-related issues, while all these aspects are linked by the overall objective of reducing food losses and ultimately contribute to improved food and nutrition security in Africa. This is particularly relevant in the current context of impending climate change and sustainability challenges of food systems and in response to the societal and political demand for food system transformation towards less environmentally damaging and

[1] The KCFNS is hosted by the JRC and supports the EU global commitment to end hunger, achieve food security and improve nutrition through a dedicated, reinforced science-policy interface and a fostered inter-policy dialogue. https://knowledge4policy.ec.europa.eu/global-food-nutrition-security_en

healthier food and food systems. The workshop was an opportunity to discuss priorities for all three groups of researchers and to explore possibilities of integration and collaboration.

PART I: KEYNOTE PRESENTATIONS

1. The African Postharvest Losses Information System (APHLIS)

Felix Rembold

In Africa, postharvest loss estimates from different sources show great variation and can reportedly reach as high as 50% or more of the total production for some perishable crops and up to 30% for grains. Although agricultural production is the leading employment sector and an important contributor to the GDP of many African countries, limited financial resources are devoted to preventing and reducing postharvest losses. In contrast to Africa, where food losses are generally viewed as being concentrated in the first part of the food production chain immediately after harvest, in Europe, parts of Asia as well as North America, greater proportions of food losses occur at the retail and consumer stages. This explains why postharvest loss reduction is particularly relevant in Africa, while in other countries food waste reduction at retail and consumer stages is the larger challenge.

The APHLIS project has been studying postharvest cereal losses estimation in Africa for more than 10 years and has in that time become the main scientific reference for cereals weight loss. Specifically, the project aims at estimating what percentage of the loss occurs at different stages of cereal postharvest management up to marketing. The principle causes of loss are contamination by insects, rodents and fungi, the latter including toxigenic fungi. Factors influencing contamination by these organisms, include conditions and practices during harvesting, drying, transport, threshing; pest population density; and the quality, hygiene, management and monitoring of the storage facilities alongside the storage duration and conditions. It has been known for millennia that crops have to be stored dry to resist insect and fungal damage. The water content (measured as water activity, Aw) of the commodity must be lowered to below a level which will support the growth of insects and fungi. If there is growth of the fungi that are found in stored crops, mycotoxin contamination level can increase beyond those found preharvest, often to a considerable extent. APHLIS only estimates weight losses, whereas quality losses in grains are expected to be even larger and more difficult to measure, since their impact is locally variable and highly subjective. APHLIS considers 9 different cereals (maize, sorghum, millet, wheat, barley, rice, teff, fonio (*Digitaria* species) and oats in 38 sub-Saharan countries. This involves the integration of seasonal production, storage and climate data, with the postharvest loss profiles for each crop and climate situation, which are based on scientifically measured data. The work of the APHLIS network has made it possible to develop estimates of mass losses of grains, financial losses as well as the impact on the nutrition of the population.

Mycotoxins-related news from the global media are collated in a dedicated section of the EMM (European Media Monitor) and the link to these mycotoxins new articles is part of the APHLIS website. In addition, a simple predictive model of mycotoxin risk has been launched. At present, the model is based mainly on data on climatic anomalies (rainfall and temperature) in pre- and postharvest stages, when crops are most sensitive to fungal attack and gives an automatic warning when weather conditions typically enable the growth of toxigenic fungi in crop. The model has not yet been validated with field data in Africa and is not a measure of actual mycotoxin contamination but an early warning tool aimed at increasing awareness about weather-related risks. The calibration and validation of this model, like all mathematical models would require field measured occurrence data which can only happen thanks to the will of the scientific operators accompanied by the political support of the countries interested in the further development of such predictive models (Keller et al., 2021).

Good postharvest handling practices and the technologies put in place to reduce grain losses at and after harvest can also prevent increases in mycotoxin contamination from occurring during the postharvest stages. This is overlapping research interest area of the APHLIS Network and the Networks studying mycotoxins in feed and food or mycotoxin biomarkers in the serum and urine of different communities.

The APHLIS initiative was initially funded by the European Commission and in 2016, the Bill & Melinda Gates Foundation continued and extended the program through a grant that will finish at the end of 2022. Initial funding by the European Commission was mainly driven by food security concerns and the low accuracy of postharvest losses in national food balance sheets. Over time however, and especially with the new Farm to Fork policy, of increasing importance to the Commission are the factors - such as, postharvest losses and mycotoxins - that affect human and animal health.

In the preparation of the forthcoming UN Food Systems Summit and in the programs that will be financed by the new development instrument of the European Union, there is an effort package dedicated to ensuring food production and management is more sustainable for the environment and healthier for producers and consumers. This includes for example improved phytosanitary measures and reduction of toxins and chemical residues in food.

2. The African Society of Mycotoxicology

Lindy J. Rose

Mycotoxins are pervasive contaminants of staple foods consumed in every region of Africa and include crops such as maize, sorghum, millet and peanuts that are contaminated mainly with aflatoxins and/or, fumonisins.

Following the discovery of aflatoxin B1, it was identified and measured in several African countries where the consumption of highly contaminated food caused acute aflatoxicosis resulting in the loss of human life. Fumonisins were discovered and first reported as a natural contaminant in South Africa (Marasas, 2001). Information regarding the levels of mycotoxin exposure in African countries is sparse and only readily accessible in approximately 6 of 20 east African, 6 of 14 southern African development community (SADC), 4 of 7 northern African, 5 of 17 western African and 2 of 7 central African countries. Some African countries have more information about the presence of aflatoxins and fumonisins due to regulatory control measures and a heightened awareness of scientists who predominantly produce the data. Of greater concern is the clear paucity in data indicating mycotoxin exposure in vulnerable communities. Where such data is available, the studies may have only been conducted once, whereas chronic exposure can only be determined by monitoring over time. Generally, mycotoxin research in Africa is conducted in a predominantly uncoordinated manner while evidence of chronic contamination has not led to action to mitigate mycotoxin contamination.

Chronic exposure to mycotoxins through the ingestion of contaminated food, particularly aflatoxins and fumonisins, has been shown to have a significant impact on the African population particularly relating to the stunting of children and various cancers. Further studies would be needed to describe these effects of contamination on populations across more African countries.

Research in Africa has shown that increased awareness of the dangers of mycotoxins has led to more studies, testing and monitoring of mycotoxins other than the predominant aflatoxins and fumonisins. The use of contaminated feed has also been shown to affect animal health potentially affecting meat production. It has been pointed out that there is a need for appropriate management systems for these contaminated feedstuffs. We need data on the degree of contamination and on the management of contaminated food and feed. There is a need for more extensive and coordinated studies that allow for integration of monitoring systems. There is a lack of linkage between the knowledge developed and its practical application that threatens appropriate technology uptake.

During the Mycored Conference in Africa 2011, then International Society for Mycotoxicology president, Antonio Logrieco, expressed a vision for a network to address the threat of mycotoxins to the African continent. Prof. Altus Viljoen (Stellenbosch University, South Africa) established the African Mycotoxin Network and together with Prof. Sheila Okoth (University of Nairobi, Kenya) convened the 1st African Symposium on Mycotoxicology (ASM) in 2015. The 2nd ASM was held in 2018 with Prof. Okoth elected as the new President of the society. Optimistically, ASM looks forward to presenting the next ASM jointly with MYTOX-SOUTH during 2022.

The main objectives of ASM are the promotion of research at national and international level, coordination, integration of applied systems and dissemination of information throughout the African continent. For these purposes, ASM has set up a website (https://africansocietyofmycotoxicology.org/) through which it seeks to engage new members and identify collaborators both in Africa and elsewhere. Strategic relationships that help enhance ASM priorities have been formed especially with networks such as MYTOX-SOUTH and Partnership for Aflatoxin control in Africa (PACA) steering committee for the development of food safety strategies and aflatoxin control and with the Africa Centre of Excellence for Mycotoxin and Food Safety. ASM is always present at international congresses and conferences in the field of food safety and mycotoxins as well as those organized by other networks such as APHLIS.

Unfortunately, regardless of the efforts made so far, there is still insufficient collaboration and coordination of efforts at African level. ASM will continue to support collaborations, courses and workshops to promote its activities in the field of food safety.

3. Mytox-South

Sarah De Saeger

Five years after the project's launch, the Mytox-South International Thematic Network is still growing, as the problem of mycotoxin contamination is a global problem and requires a global approach and internationally shared management strategies.

The project coordination team is located at Ghent University. The project has partners from all over the world, from Italy to Shanghai, from the United States to South America (Argentina, Uruguay and Brazil) and Africa. Some partners are historic, i.e. they have been present since the beginning of the project, such as ISPA-CNR, while others have joined recently, such as the EU Joint Research Centre (JRC) and the Soybean Innovation lab (SIL, USA). Special mention must be made of the close link with LadyAgri, an organization that aims at the inclusion of women in the agri-food sector in Africa.

Mytox-South is an academic project with the main goal of educating and training young scientists from low and middle income countries. Development of new knowledge and awareness on food safety, co-creation and networking are main objectives.

In practical terms, the research activities that are supported involve the application of innovative technologies and mitigation strategies.

The list of partners with whom Mytox-South has signed a memorandum of understanding has been extended in the COVID period during which we were able to organize on-line courses and seminars.

The new collaboration with the JRC proved to be very active as already 3 webinars were co-organized. The first one was dedicated to "Mycotoxin predictive modelling", while the second one was entitled "How to improve knowledge on mycotoxins and food security". They were organized on 26 October and 27 November 2020, respectively.

The third one is ongoing, on “Mycotoxins and post-harvested losses in Sub-Saharan African countries”.

Another important event in which Mytox-South will participate thanks to the collaboration with the JRC will be the Fourth AU EU Agriculture Ministerial Conference Session 3: Use of digital solutions in agriculture to combat diseases and to strengthen rural communities on 22 June 2021. During this session, we will make a presentation entitled "Current status of food safety big data in Europe & Africa".

In all the venues in which we found ourselves discussing food safety in Africa, the dominant factor is the accessibility of existing data and creating new information and knowledge when there are gaps. One of the shared objectives is the creation and sharing of new data and data avenues for food security in Africa.

Mytox-South plans to work together with the JRC to define what is missing in our knowledge in order to monitor and improve the state of food security in Africa. We find that there is a lack of data, and a lack of facilities to store and share data, a lack of legislative support, a lack of predictive modelling of the risk of contamination, and a lack of data flow to use.

With SIL, Mytox-South collaborates on advancing the technical competence of agro-processors in Sub-Saharan Africa through the development of an online training materials which will be open for all.

Another important activity carried out by students from Ghent University together with the Mytox-South partners was the assessment of the current legislative situation in Latin America and Africa.

Besides, research projects in the field of human biomonitoring of mycotoxin exposure associated to cancer development are ongoing (funded by the Flemish Government and the European Research Council). The next step will be to study the concept of the "exposome" where mycotoxins will be one of the studied environmental factors (Flexigut exposome project, 2021-2024). This comprises the multifactorial cumulative effect of different environmental factors to which we are exposed throughout our lives and the associations with the occurrence of cancers in the gastro-intestinal tract as well as metabolic disorders.

4. MycoKey project outcomes for postharvest mycotoxin management

Antonio F. Logrieco

The presentation describes four potential approaches for the management of contaminated products when mycotoxins are present above regulatory limits. Different strategies to reduce mycotoxin contamination in cereals were investigated including blending with uncontaminated batches (banned in the EU), destruction (resulting in an economic loss), sale as biofuel, redirection into feed production and decontamination/detoxification processes. It is extremely important to prevent postharvest contamination and develop practical and effective postharvest procedures for mycotoxin reduction in the food supply chains and to provide alternative and safe use options for contaminated batches in high-risk areas as in Africa.

In collaboration with a Chinese consortium, an industrial-scale application of **cleaning technologies** was tested to reduce the presence of aflatoxins and Fusarium toxins in maize. The overall reduction is very promising providing a 55 to 94% decrease depending on the conditions.

Feed detoxification is mainly performed by multi-mycotoxin adsorbent surfaces (Bio-organoclay surfaces), or by adding **innovative feed additives** such as acid-treated durian peel (ATDP), or yeast cell wall products whose successful performance is tested by in vitro and in vivo models. These products can be considered safe, as they are obtained using materials that are listed in the European Union Register of Feed Additives (EC Regulation, No.1831/2003). These findings make a contribution towards the development of a novel green and effective technology for the bioremediation of mycotoxin contaminated commodities.

Microbial enzymatic detoxification was performed using Devosia insula A16 which performed well in the degradation of trichothecenes in wheat (Wang et al., 2019, Food Chemistry 279, 436). Another approach tested was detoxification operated by *Pleurotus eryngii* which can grow in liquid and solid media removing a range of 67 up to 100% of mycotoxins depending on the growth conditions (at fixed value of growth days, temperature and pH range). Mycotoxin degradation can also be achieved by using the crude extract or the purified laccase enzyme from *Pleurotus pulmonarius*. The results are already published in five different publications from 2017 to 2020 (Branà et al., 2017, Loi et al., 2017, Loi et al., 2018, Haidukowski et al., 2019, Branà et al., 2020). Furthermore, the identification of the Ery4 laccase from *P. eryngii* PS419 capable of transforming Aflatoxin B1 into a less toxic metabolite was studied in collaboration with Agricultural and Agri-Food Canada.

Pre-formed sustainable **fermentation processes** using microorganisms (yeast) or enzymes such as *Saccharomyces cerevisiae* VTT-C-3436 strain and laccase gene cloned in yeast, respectively, is under study

Additionally, there are the **Ozone system** STREAMOZONE (pilot ozone system) and **Mustard-based postharvest strategy** which is considered a very cheap strategy.

However, these approaches have not yet been given regulatory approval.

As part of this project, a **Mycotoxin Charter** (charter.mycokey.eu) was launched to share the need for global harmonization of mycotoxin legislation and policies and to minimize human and animal exposure worldwide, with particular attention to less developed countries that lack effective legislation

Finally, **FoodSafety4EU** (https://foodsafety4eu) is a new H2020 financed EU project coordinated by Veronica Lattanzio, which is developing new approaches for risk communication and raising awareness of food safety issues in civil society. The developed models could be made available and adapted to Africa. The project will also deliver a platform to support a better link between research and food system actors/innovators (in line with and potentially supporting the FOOD2030 Pathway 9 – Food Systems Africa).

PART II: GROUP WORK

WORKING GROUP 1: Main links between postharvest losses and mycotoxins research

Participants: Altus Viljoen, Juan Andrade, Antonio Logrieco, Brighton Mvumi, Bwalya Katati, Celine Meerpoel, J. David Miller, Felix Rembold, Hussaini Makun, Kizito Nishimwe, Lindy Rose, Marthe De Boevre, Naresh Magan, Sheila Okoth.

The working group discussion was concentrated on the links and common interest between postharvest losses and mycotoxins research. The following questions from the Workshop Concept note were used as a starting point for the discussion:

- What are the main connections between postharvest losses and mycotoxins for different stages of the postharvest value chain of cereals, legumes, roots and tubers?
- What mycotoxin information is relevant for better understanding postharvest losses during different stages of the chain, such as drying or storage?
- Is there ongoing research of interest both for mycotoxins and for postharvest losses?

The group discussion however went beyond these initial questions to identify the main research questions, existing information gaps and related opportunities for collaboration.

The group identified eight *priority research questions*.

1. Are there currently appropriate **storage technologies** in place?

    Grain storage structures in rural Africa are evolving in different ways across countries. Inexpensive on-farm storage solutions exist including on-farm hermetic bags. If used as designed, these limit insect & fungal damage. A number of studies have shown these to be effective on small farms, but they typically last only a few years and are not widely used. A wide variety of other containers, including plastic water buckets are used. Large plastic bags have been promoted as useful storage containers for grains. These can be useful but their lifespan is not clear. Holes in the plastic that permit water and insects to enter need to be patched as and when they are seen (Baribusta et al., 2014, Martin et al., 2015, Makinya et al., 2021). There are concerns about plastic waste. Corrugated steel silos are available in most grain producing countries in Africa because they are effective and relatively cheap. However, the use of appropriate storage technologies remains limited and most grains are typically dried on the ground or on timber platforms and then stored in fabric sacks or simple structures made of locally available material (Nwaigwe, 2019).

    Identify opportunities for collaboration:

Provide information on grain storage and the losses due to fungi and insects in primary schools. Dissemination of information to farmers by the cheapest means possible (sending texts) appears to be effective (Channa et al., 2019).

The need to improve storage through the value chain in Africa has been recognized for more than 60 years but progress has been slow. One reason for this is that postharvest losses, including mycotoxin accumulation in storage, are not generally considered in the economic analysis of donor decisions. A World Bank analysis based in part on APHLIS estimates focuses on the part of the value chain from farm to urban consumers as an economic driver (Zorya et al., 2011), but does not address specifically small scale farmers needs for loss reduction

2. Maintain **storage at local** farm-level, pros and cons?

Many papers on this topic have appeared but most are lacking in economic, insect and mycotoxins data from storage improvements on farms.

Identify opportunities for collaboration:

Investigate using cooperatives to centralize local harvest plus storage. Some advocate mobile steel storage which may be useful to address this recommendation (Lanier et al., 2018).

3. Remediation **technologies**?

Various technologies have been proposed to reduce aflatoxin in grains but require regulatory approval and are not applicable to small farmers. These do not address the losses due to insect damage.

Identify opportunities for collaboration:

Difficult to implement, require capital investments better placed on drying and storage.

4. How much **preharvest damage** by toxigenic fungi is there under **field conditions**?

Characterize the local infection levels of hybrid crops.

Identify opportunities for collaboration:

Opportunities to expand this type of approach notably where older maize genotypes are still in use.

5. Persistent issue on **transferring knowledge** to the farm:

   Reaching out to farmer groups to form cooperatives. Drying before storage is critical. Access to basic equipment including tarps remains limited (Jelliffe et al., 2016).

   Implementation of solar dryers for crops has been much more successful in Asia and India than in Africa. This has been attributed to poor knowledge translation and incomplete installations even in pilot projects (Udomkun et al., 2016).

   Identify opportunities for collaboration

   Identifying investors for transferring knowledge to technologies on-the-farm -> missing links should be determined and measures developed to improve the situation.

   Incorporation of knowledge in education (curriculum development) + culturally-appropriate education to young people that will transferred then to the family/farm (Makinya et al., 2019). In general, insufficient research has been done on effective means to provide knowledge translation to farmers in various African countries that is culturally and gender appropriate (Wild et al., 2015). There is evidence that farmers, who are primarily growing for maize consumption are more concerned about food safety in maize than traders (Channa, 2019).

   Improving drying and storage is a proven method for reducing exposure to aflatoxin (Wild et al., 2015).

6. **Data** collection, harmonization & centralization?

   Limited data on preharvest losses; national level costs are large, but invisible to donors and policy makers.

   Data gathering with smartphone/digital tools -> disadvantage: more evidence needed. Working with local start-ups that use digital technologies for example for surveys has been successful (Odhiambo et al., 2021).

   Identify opportunities for collaboration:

   Funding: consider funding schemes & outreach to policy-makers with concept notes relating to the urgent priority of reducing further mycotoxins contamination in storage.

   Consider more the effective measures to improve drying and storage in ASEAN countries and SE Asia (cf. Bangladesh).

   Verification of technologies can be applied for purposes addressing food safety.

7. Can improvements of seasonal **weather forecasts** and weather modelling help to better inform farmer organizations and administrations at national and province level about seasonally increased losses and food safety risks?

    Seasonal weather forecasts are improving. For example with the latest multi-model seasonal forecasts, it is now possible, with relatively good skill in tropical areas, to know beforehand whether the next season will be affected by risk of drought or excess rain. This can help in predicting increased risk of postharvest losses and mycotoxins.

    Identify opportunities for collaboration:

    Developing tools for risky seasons (tools are currently not present).
    Links with predictive modelling workshop conclusions.

8. **Market issue** aflatoxin contamination. Rift Valley – aflatoxin contamination issues (too long storage by traders for price speculation)

    Identify opportunities for collaboration:

    Links to farm or cooperative level storage availability: better storage at farm level reduces farmers' dependence on traders.

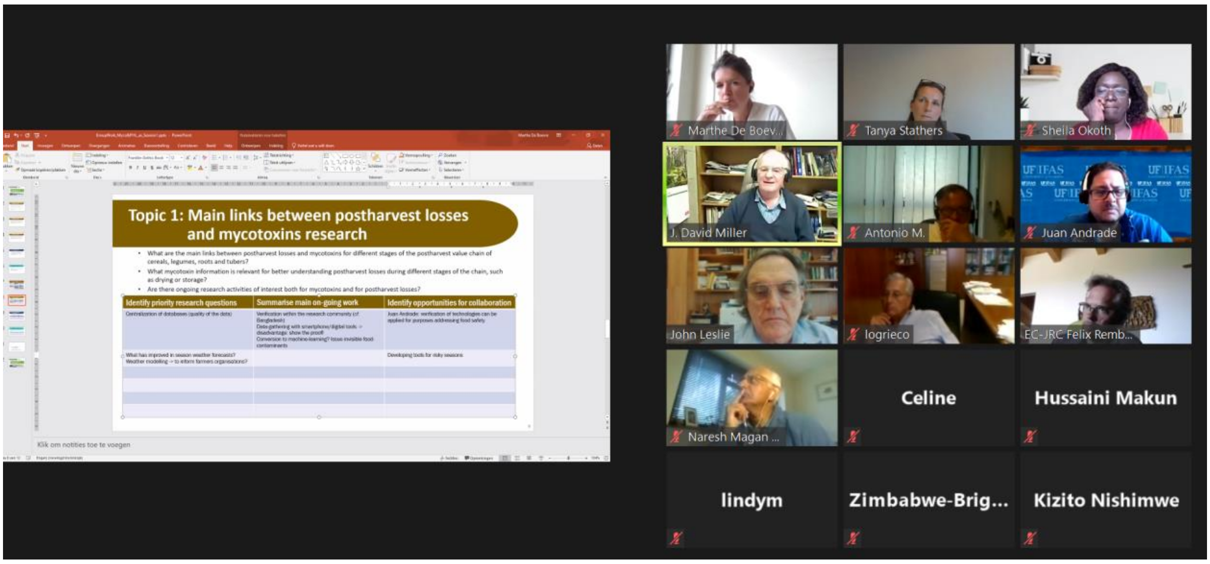
    Address surpluses in one area with good storage and improve mechanisms for sharing rapidly with nearby areas with food shortages.

Group 1 main conclusions

The discussion was highly collaborative and there was a high level of agreement on the need for additional research to understand how the production chain is organized and how to avoid loss and fungal contamination at the storage and other postharvest stages in various African regions. It is felt that the scientific evidence does not currently reach policy makers in an adequate manner, nor is it sufficiently successful in leading to improvements at the farm level. Furthermore, postharvest management is not adequately integrated into education programmes. To prevent losses and save crops from insect and fungal attack, information about existing techniques needs to start at the school level. Information about simple and accessible storage technology needs to be available at the community level. In India and Thailand for example, schools and markets are provided with teaching and information material on how to dry grains properly.

At the country level, food availability is often highly variable and dependent on seasonal performance, causing surplus and deficit situations to coexist in neighbouring regions. Improved storage techniques at central and cooperative level can contribute to increase availability where it is most urgently needed.

Improving connectivity and development of digital tools can contribute on the one hand to disseminate food losses and safety information more quickly and on the other to help the collection of postharvest management information.



MYTOX SOUTH APHLIS+ The African Postharvest Losses Information System ASM MycoKey

WORKING GROUP 2: Postharvest management of mycotoxin contaminated grain

Participants: Aida Bakri, Frans Verstraete, Monica Ermolli, Veronica Lattanzio, Habiba Hassan-Wassef, Tanya Stathers

The working group discussion was concentrated on what happens to mycotoxin contaminated grain, however the participants also addressed points related to mycotoxins measurement capacity and infrastructure in Africa, as well as mycotoxins awareness. The following questions from the Workshop Concept note were used as a starting point for the discussion:

> **Postharvest management of contaminated grains**: What happens to mycotoxin contaminated grain? What proportion is lost from the postharvest chain due to mycotoxin contamination? What alternative uses are there for mycotoxin contaminated grain and what is the impact on the value of the grain?
>
> Is there evidence from behavioral research on the consumption of mycotoxin-contaminated cereals? When and why do people still eat mycotoxin contaminated grain or other foods? How do people use mycotoxin-contaminated grains? How do people use mycotoxin contaminated grains if they do not eat them? Is mycotoxin contaminated grain given to animals? Are there geographical differences?

Overall the group identified four *priority research questions*:

1. **What happens** to mycotoxin contaminated grain?

   It was reported that in most rural areas there are no means to measure contamination; in addition, particularly after COVID-19 driven economic problems and increased poverty and food insecurity, there is even less willingness to destroy grains because of possible mycotoxin contamination.

   In general, mycotoxin contaminated food enters and remains in the human food system, especially in situations of limited food availability and access. Grains with mould or insect damage are often sold at lower prices and are therefore consumed by the poorest and often most vulnerable population groups. Overall the majority of mycotoxin contaminated food is consumed, and in the rare cases where contamination is detected (this happens at border inspection controls only – see below) entire containers are simply sent back (and not destroyed).

   Increased awareness about the risks of aflatoxin contamination (especially in the medium and long term) is important to reduce health impacts.

2. Need to improve capacity for **detecting and measuring mycotoxin contamination**

   Many gaps: as already reported under point 1, in most rural areas there are no means to measure contamination. How can we improve detection and definition of contaminated products? Do we have a harmonized approach? What are the standards applied?

Local markets do generally lack the capacity and access to equipment for testing for mycotoxin contamination. This means that visibly damaged or lower quality products are generally sold at lower prices or directed to other uses (such as, animal consumption, beverage production etc…). Contaminated grains are in most cases not detected and even if detected are rarely destroyed.

Identify opportunities for collaboration:

African Organization for Standardization (ARSO), CODEX Alimentarius International Food Standard (CODEX) and the Partnership for Aflatoxin Control in Africa (PACA). PACA 12 country roll-out. The Ministries of these 12 countries can have a common understanding.

Increase attention to local markets. Today the focus is too much on trade and export markets, so local markets receive low attention.

Only at the border level, is there currently some testing to facilitate acceptance for export.

3. Need to improve **infrastructure** and lab capacity

Many countries are reported to lack the personnel and resources required for conducting proper sampling and testing even though mycotoxin maximum tolerable limit type policies exist. There is a general lack of state of the art sampling and testing practices and a lack of harmonized procedures.

Identify opportunities for collaboration:

AUC/ New Africa Food Safety Authority could help with increasing the mycotoxin control capacity, in particular with aflatoxin testing and sampling.

Need for increased investment in reliable low-cost testing kits:

- enable and encourage traders to use test kits (e.g. foresee an incentive for traders to only sell mycotoxin safe grain? Cooperation with national governments?)

- low-cost testing might be more suitable for the domestic food production chain (i.e. make testing available not only for export commodities but also for domestic markets).

4. Need for increased risk **awareness**

Current status: risk management in African Union Member States is undertaken on a country-by-country basis (no centralized approach as in the EU)

For the future, a strategy is being drafted within the new African Food Safety Authority EFSA-like food authority

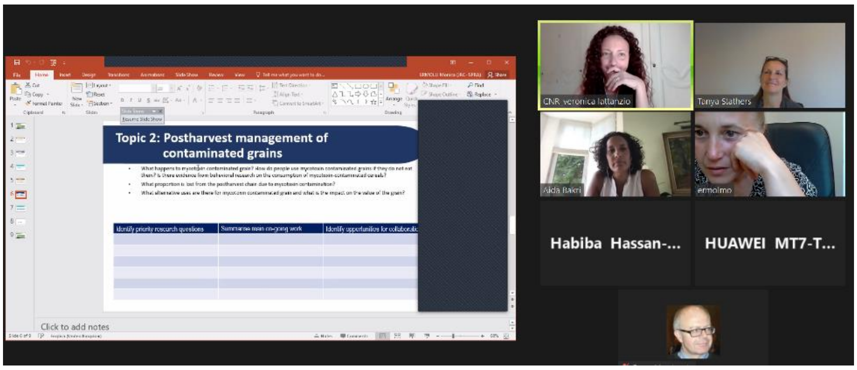
Identify opportunities for collaboration:

AUC/ New Africa Food Safety Authority and FoodSafety4EU (https://cordis.europa.eu/project/id/101000613/it).

Group 2 main conclusions

In many African countries, there is limited capacity to measure mycotoxin contamination (beyond export value chains), and food safety risks further complicate food insecurity problems. In situations with high risk of food insecurity and food production deficits, increased food availability and access are certainly the primary concern. Even in such situations however, mycotoxins awareness is still relevant for local grain purchase for humanitarian assistance (e.g. WFP's P4P program) and postharvest management and loss reduction practices and technologies can help small scale farmers to increase their grain stocks. The mycotoxins knowledge gaps are not new, but with an increasing number of free trade agreements between African regions, there is more risk on one side and also more opportunities for improvement. An effort is needed to increase food safety at various levels from communities to international trade. Such a step requires resources, targeted research and policies. Investment is needed in terms of testing facilities and equipment, schools and trained personnel. Information needs to be made available at the rural community level to increase the awareness about risks associated with eating contaminated food, starting in schools.

The effects of mycotoxin contamination are generally slow to manifest themselves, leading to a situation where only major accidents receive large public attention. As most risks with mid or long term future impacts, mitigation and control interventions tend to be second priority. This means that there is often limited intervention by authorities to restrict the use of contaminated food. Given this situation, bottom up awareness raising and education are believed to be as important as support to regulation and control. There is high expectation and hope in the newly established African Food Safety Authority. ARSO already works with CODEX. PACA is an opportunity for member countries and there is hope that more will join. The group also hopes that through international collaboration there will be extended focus on all mycotoxin contamination, and not only on aflatoxins.



WORKING GROUP 3: Postharvest loss reduction and mycotoxin prevention technologies

Participants: Annette Donnelly, Alfred Bekwake Nwegueh, Archileo Kaaya, Cephas Taruvinga, Gideon Onumah, John Lamb, Kimondo Mutambuki, Kukom Edoh Ognakossan, Olusegun Atanda, Sarah De Saeger

The working group discussion was concentrated on technologies for reducing postharvest losses and preventing mycotoxin contamination or increased occurrence. The following questions from the Workshop Concept note were used as a starting point for the discussion:

Technologies for reducing postharvest losses and technologies aimed at reducing the occurrence and accumulation of mycotoxins: are there similarities and synergies? What actual implementation of these technologies is there in the different geographical regions of Africa? Do we have a follow-up system? How to promote their adoption?

The group identified three *priority research questions*:

1. Are there **similarities/synergies** between these two groups of technologies?

   There are similarities between the two groups of scientists. For example, both groups consider it crucial to find solutions in the postharvest stage, where reduced moisture content is associated with less fungal contamination and therefore less mycotoxin contamination. At this stage, there is a clear link between drying technologies (postharvest technology) and the reduction of damage from toxin-producing fungi (mycotoxins).

   The complexity of the interventions that can be implemented and the general level of awareness of the risks associated with eating mycotoxin-contaminated food concern both groups of researchers. A broader level of awareness is desirable, especially one that includes lesser-known mycotoxins

   Specific interventions for each stage (production, postharvest and processing) where mycotoxin development can occur need to be understood.

   There is a gap between the knowledge made available by scientists and what reaches industry and farmers as possible practical applications.
   Consider the hermetic storage of grain and the reduction of mycotoxin contamination.
   - Who do you turn to when proposing systems to reduce contamination at this stage of production? Farmers by providing postharvest technologies or managers by providing business development services. Access to finance drives these decisions and is very important.

There are two aspects that need to be considered at a high level, the different applicable technologies (developed by scientists) and the ability to raise financial resources to implement these solutions, which are frequently scarce or non-existent. Some low-tech solutions are not even tested. It is important to put resources/technology into applying solutions other than aflasafe, which is effective, but limited in use to large industries because it is too expensive for many smallholders.

The cost of mitigating the presence of mycotoxins is probably lower in the postharvest phase, when it can be treated in the early stages of food production. Simple and inexpensive technologies should be made available to small farmers. Processors in SSA are concerned about food safety, particularly when ingredients are mixed.

2. How is your region in Africa **implementing** the postharvest loss reduction technologies?
   There is a need to quantify the benefit of reducing mycotoxins. An inability to understand why things like contaminated groundnuts can be affected is common, particularly when the contamination is not visible.
   Raising awareness of consequences and toxicity needs greater prioritizing.

3. How can we further **promote adoption**?
   How can people use this technology?
   Can aflatoxin mitigation be incorporated with inputs? As a normal way to increase $ for yield?
   One approach is to promote value chain thinking amongst actors, contract farming, etc. These options provide more incentive to farmers to invest in technologies.
   Good policies are also important.
   Is it important to expand the stakeholders to include physicians, community health workers?
   - The role of influencers is also important – for example lead farmers.
   - Small-scale farmers need to form cooperatives to enable them mobilise resources to afford expensive technologies

Main conclusions
We asked ourselves three questions.

1.) Are there similarities/synergies between these two groups of technologies?
The expert group on techniques to reduce contamination by mycotoxin-producing fungi and the expert group on techniques to reduce postharvest losses. Obviously, there are points of convergence between the two. For example, one point is the reduction of the presence of fungi through drying techniques.
Another important point is the lack of understanding of the complexity of the problem. Each stage of production has its own specificities. There is also a gap to fill between

what scientists make available and what is applied in the field and by operators, used by industry, and marketed.

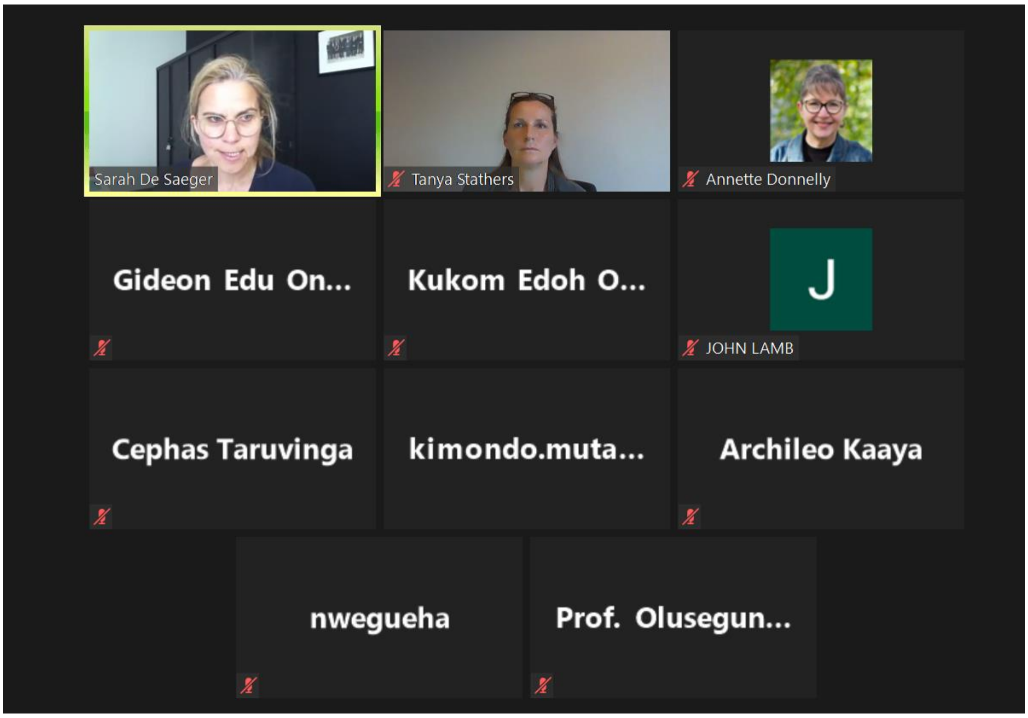
There is an investment problem. It takes time for industry to invest.

Then there is the problem of the cost of the proposed technologies for small operators. For example, the use of aflasafe, which is very useful for preventing aflatoxin -but not fumonisin- can only be used by large producers. For small producers, it costs too much and is not effective against fumonisin.

Simple and less expensive systems are needed for small producers.

2.) How is your region in Africa implementing the postharvest loss reduction and mycotoxin prevention technologies?
Actually, in many regions, not much is being done, there is a great lack of attention. No tests are carried out. Contamination is not visible.

3.) How can we further promote adoption?
Incentives and benefits should be given to those who work to reduce contamination. We need influencers such as large manufacturers, cooperatives, or doctors or other driving forces who can bring in investment and promote the application of more expensive and efficient technology systems.



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PART III: MYCOTOXINS AWARENESS SURVEY PRESENTATION

Mycotoxins awareness survey in Africa done in collaboration by JRC, MYTOX-South, ASM and Mycokey in 2021

Presentation of preliminary results obtained by the survey* designed to test awareness in African countries of the presence of mycotoxins in foodstuffs and actions taken to counter their presence and reduce losses has been given (*in collaboration with African Society of Mycotoxicology, Mycokey and Mytox-South Networks).

With the aim of gathering information on awareness of the dangers of using mycotoxin-contaminated cereals and how these batches are handled, a survey was launched among five groups of operators in the food chain.

Just under 30 questions were asked of farmers, food processors, food scientists, food traders and food policy makers in African countries. The survey was launched through the contacts of the organising networks and therefore potentially targeted all 55 African countries. However, responses were only collected from 21 countries, many of which had only one response. Only in Kenya and Nigeria did a higher number of responses come from each group of actors. In spite of the efforts made to disseminate the survey by the Networks' secretariats, the highest number of responses was obtained through the involvement of a local service provider who, in Kenya, contacted interested people individually on the spot.

Analyzing the responses obtained from the farmers interviewed (n=35), we note that almost all of them represent small family farms, which attest to knowing the negative effects of consuming mycotoxin-contaminated materials whether used for food or feed production. However, these farmers state that they do not discard contaminated material, do not conduct any tests to measure its presence and try to improve drying and storage conditions to limit the occurrence of contamination.

The food processors interviewed (n=9) are divided into two groups, those belonging to local food processors and those belonging to large food processors. This second category states that they apply tests to measure the level of contamination but that their results do not particularly interest local populations.

Scientists are the class of respondents who answered the most, reaching almost 70 responses (n=68) with a good presence not only in Kenya and Nigeria but also in South Africa. This was in some way expected given that the questions were disseminated by research networks.

Scientists complain about lack of resources (financial, facilities, lack of personnel) to carry out studies in this area. Most claim to have contacts with all the other groups of operators interviewed, especially farmers, to whom they sometimes provide training courses, but there is generally little interest in food safety issues in the communities.

Grain traders are the least represented group. The few figures, however, are in line with expectations. If food traders are interested in mycotoxins, they do so only in the case of exported goods and seem to test only for the presence of aflatoxins. Otherwise there seems to be no interest. Contaminated foodstuffs are still kept and only in very few cases do they leave the food production cycle to be destroyed.

The food policy makers interviewed (n=8) declare that they are very interested in the problem of food safety and mycotoxin contamination issues, that they are aware of the seriousness of the situation and in favour of more careful regulation.

The results of these surveys are purely qualitative and do already highlight some objective problems, first of all the difficulty in distributing the survey and collecting responses. Directly reaching local rural communities with an online survey is not possible and worked only where an intermediate local partner was used.

PART IV: FINAL RECOMMENDATIONS

Scientific evidence

In Africa, food loss occurs mainly before the consumption stage and for grains and tubers, the losses are generally highest in the harvesting, drying and storage phases. In the same postharvest stages, produce is also sensitive to attack by fungi and insects, although the first often enter the plant tissues even before harvest. Postharvest losses estimates such as those made available by APHLIS, focus primarily on physical grain losses relevant for market and food security analysis, while mycotoxins experts study the incidence and health risk of mycotoxin-contaminated grain i.a. using human biomarkers. A knowledge gap exists about how grains and tubers, contaminated to different degrees by mycotoxins, are handled by farmers and traders and about the multi-faceted impacts of quality losses, which can also be caused by fungi.

It is already well-known that the drying of crops to the correct moisture content is critical for reducing postharvest damage by fungi and insects, as well as postharvest mycotoxin accumulation. To that end, technical solutions to reduce food loss and contamination have been developed by scientists. However, this has occurred without adequate investment and sufficient context-specific understanding of the social-cultural and economic barriers and facilitators to their adoption. So the technologies have faced difficulties surrounding their adoption and uptake in Africa.

Different management tools have also been explored and have been deemed to be feasible at different stages of food production and storage, when considered with respect to farm size. Subsistence farmers can often not use the same tools that can be used by larger enterprises or farms. Simple, fit-for-purpose and affordable management tools must be provided to the smaller entities. Mycotoxins predictive models have been developed at the research level but are currently not yet extensively or coherently used in Africa.

Resources and capacity

Participants agreed that more resources should be devoted to studies on the organization of the African production chain. There was also full consensus among participants on the evidence that, in most regions of sub-Saharan Africa, there is limited capacity to measure and test for mycotoxin contaminations in food or feed. The lack of bottom-up data on food safety issues and mycotoxin contaminations in local markets and commodities was confirmed. In addition to farm-level storage issues, produce is often stored for long periods by traders who are rarely taking into account the risks of mycotoxins contamination. Centralized mechanisms are often missing for storing grain safely or moving it rapidly from surplus areas to others with production deficits.

At the level of local markets, despite regulations existing in some places, testing is lacking and there is little or no capacity to assess the mycotoxin contamination level of foodstuffs. There is a need for accredited or even centralized laboratory capacity, alongside continuous resources for monitoring. Especially in countries with high poverty rates and food insecurity, regardless of contamination or insect damage, mycotoxin-contaminated grains are typically just consumed by household or used for animal feed. Using mycotoxin-contaminated grain as animal feed does not eliminate the mycotoxins from the food chain if the animals are later consumed, and more resources should be put into exploring alternative uses. Very limited data has been collected on the amount of contaminated or discarded material.

Where mycotoxin testing does occur in sub-Saharan Africa, it is predominantly focused on checks to allow goods to be exported to quality-sensitive markets. Foodstuffs used for local consumption or sale on domestic markets are not mycotoxin tested. The recently reached agreement with the African Continental Free Trade Area, could support action to make food safer by facilitating coordination and generating new resources. At the local level, there is a lack of investment in the facilities, equipment, capacity building among all stakeholders (including schools) and staff training needed to ensure food safety. Identifying mycotoxin contamination and the risks associated with it requires systematic measurement and investment.

Policies

The effects of mycotoxin contamination on human or animal health are slow to manifest themselves, and so far, African governments have mainly responded only after there have been disasters linked to acute mycotoxin poisoning, with many victims involved (although this is changing due to growing awareness and evidence around the chronic effects of consumption of mycotoxin contaminated on different life stages). One important approach for avoiding mycotoxin-related health consequences, is to increase the level of education from primary school onwards about and awareness of the risks associated with consuming contaminated food, along with practical strategies for reducing the risks and on-going monitoring of the incidence of mycotoxin contamination.

Many expectations and hopes are pinned on the newly created African Food Safety Authority, which is expected to address continental standardization and coordination of food safety systems (see press Release June 17, 2021. https://au.int/en/pressreleases/20210608/continental-consultative-meeting-held-develop-africa-food-safety-strategy). Just as many expectations are placed on the international collaborations between the African Organization for Standardization (ARSO), CODEX Alimentarius International Food Standard (CODEX) and the Partnership for Aflatoxin Control in Africa (PACA), for example. PACA is seen as an opportunity for all African countries.

Communication and access to information

Developing and deploying effective means of communication and finding financial resources to increase food safety remain unresolved issues, especially when looking at small-scale production and local community levels. Communication with small-scale farmers and consumers in local communities would benefit from targeted information and broadened access to communication technologies. Digitalization of information and improved connectivity should be considered as enabling priorities for future development investments.

Participants agreed that more resources should be devoted to studies on the organization of the African food value chain. In some Asian countries, education on the techniques to reduce losses from insect and fungal damage starts in schools. Similar educational curricula could be introduced in African countries. Community education is considered necessary to create awareness among people on food safety issues and to provide information on practical actions that can be taken to support healthy food production and postharvest management.

Highlighted recommendations

1. Food safety including postharvest management should be part of the educational curriculum in African schools.

2. Investment in tools and technologies adapted to the needs of small-scale food production, handling, storage and processing enterprises should be put in place, as well as food quality incentives.

3. The African Food Safety Authority should help bridge the legislative, technical and enforcement gaps between African countries, as soon as it is operational.

4. Access to online communication systems, information targeted for small-scale farmers and increased mycotoxin predictive modelling and data collection capacities should become more commonly available in Africa.

5. Influencers should be involved to help shift investments in the food sector and drive demand for and support for promoting production and consumption of safe and healthy food production.

List of Workshop Participants

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Olusegun Atanda, Precious Cornerstone University.
Sarah De Saeger, Ghent University - Coordinator of Mytox-South Networks.
Sheila Okoth, University of Nairobi - President of the African Society of Mycotoxicology.
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ANNEX I. Concept note and workshop agenda

Background and objectives

Mycotoxins are an important food safety concern and can have a major impact on qualitative features and characteristics (such as taste, smell, value, nutrient and anti-nutrient content) of cereal grains and other produce leading to a loss in quality if they increase during the postharvest activity stages in the products value chain. The African Postharvest Losses Information System (APHLIS) computes quantitative losses for cereals and legumes in Africa, but considers qualitative losses only when grains are then physically lost and/or excluded from human consumption. **It is therefore of interest for the APHLIS core team and network members to understand more about the impact of mycotoxins on grain losses in Africa and their consequences for human nutrition.**

Examples of initial discussion questions with experts of the Mytox-South, Mycokey and African Society of Mycotoxicology (ASM) networks are shown in the list below. Depending on the participants' interests and the outcomes of this first discussion meeting, the workshop could conclude by identifying priority research questions to be further investigated. The selected thematic areas could then become a starting point for a dedicated session at the April 2022 joint ASM - Mytox-South conference.

List of questions:

1.) **Main links between postharvest losses and mycotoxins research:** What are the main links between postharvest losses and mycotoxins for different stages of the postharvest value chain of cereals, legumes, roots and tubers? What mycotoxin information is relevant for better understanding postharvest losses during different stages of the chain, such as drying or storage? Are there ongoing research activities of interest both for mycotoxins and for postharvest losses?

2.) **Postharvest management of contaminated grains:** What happens to mycotoxin contaminated grain? What proportion is lost from the postharvest chain due to mycotoxin contamination? What alternative uses are there for mycotoxin contaminated grain and what is the impact on the value of the grain?
Is there evidence from behavioral research on the consumption of mycotoxin-contaminated cereals? When and why do people still eat mycotoxin contaminated grain or other foods? How do people use mycotoxin-contaminated grains? How do people use mycotoxin contaminated grains if they do not eat them? Do they give them to animals? Are there geographical differences?

3.) **Technologies for reducing postharvest losses and technologies aimed at reducing the occurrence and accumulation of mycotoxins**: are there similarities and synergies?

What is their actual implementation in the different geographical regions of Africa? Do we have a follow-up system? How to promote their adoption?

A first survey focusing mainly on information and awareness on the effects of mycotoxins in food and feed from African countries was launched in April. The survey was directed at five different actors in the food production, distribution and regulatory chain, containing some of the questions listed above. Related answers will be presented to promote a debate on their significance and possible use in determining future actions.

List of invited experts

Aditya Parmar	Natural Resources Institute (NRI), University of Greenwich, UK.
Ahmed Nanoh	Sierra Leone Chamber for Agribusiness Development, Sierra Leone.
Aida Bakri	ADS-Insight, Belgium.
Alfred Bekwake Nwegueh	IRAD Cameroon, Cameroon.
Altus Viljoen	Stellenbosch University, South Africa.
Amare Ayalew	The Partnership for Aflatoxin Control in Africa (PACA), Ethiopia.
Andrade Juan	Soybean Innovation Lab (Feed the Future Lab), US.
Annette Donnelly	Soybean Innovation Lab (Feed the Future Lab), US.
Archileo Kaaya	Makerere University, Kampala, Uganda.
Bradley Flett	ARC-Grain Crops Institute, South Africa.
Brighton Mvumi	University of Zimbabwe.
Catherine Brabet	Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), France.
Charles L. Wilson	World Food preservation Center, US.
Charles Singano	Department of Agricultural Research Services (DARS), Chitedze, Malawi.
Cheikh Thiaw	UFR Sciences Agronomiques, Elevage, Pêche-Aquaculture, Nutrition, Senegal.
David Bamwirire	National Agricultural Research Organisation (NARL-NARO), Uganda.
David Miller	Carleton University, Canada.
Dieudonne Baributsa	Purdue University, Feed the Future (FtF) lab, US.
Donnelly, Annette	Soybean Innovation Lab, Feed the Future Lab (FtF), US.
Frans Verstraete	European Commission, DG SANTE, Belgium.
Habiba Hassan-Wassef	National Research Center, Egypt.
Hussaini Makun	African Centre of Excellence for Mycotoxins and Food Safety, Nigeria.
Jack Harvey	Kansas State University, US.
John Lamb	Agragen, Washington D.C., US.
John Leslie	Kansas State University, US.
Joseph Akowuah	Feed the Future (FtF), Ghana.
Juliet Akello	International Institute of Tropical Agriculture (IITA), Zambia.
Kimondo Mutambuki	KALRO, Kenya.

Kizito Nishimwe	University of Rwanda, Rwanda.
Kukom Edoh Ognakossan	Ecole Supérieure d'agronomie (ESA)-Université de Lomé-Togo.
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Olusegun Atanda	Precious Cornerstone University, Nigeria.
Patrick Njobeh	University of Johannesburg, South Africa.
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Ranajit Bandyopadhyay	The International Institute of Tropical Agriculture (IITA), Nigeria.
Samuel Edgar Tinyiro	National Agricultural Research Organisation – NARO, Uganda.
Waongo Antoine	Institut de l'Environnement et de Recherches Agricoles (INERA), Burkina Faso.
Wilfred Abia	University of Yaounde I, Cameroon.

Organizers

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Carl Lachat	Ghent University, Belgium.
Celine Meerpoel	Ghent University, Belgium.
Felix Rembold	European Commission - Joint Research Center (EC JRC), Italy.
Lindy Rose	Stellenbosch University, South Africa.
Marthe De Boevre	Ghent University, Belgium.
Monica Ermolli	European Commission - Joint Research Center (EC JRC), Italy.
Olivier Maes	European Commission - Joint Research Center (EC JRC), Italy.
Sarah De Saeger	Ghent University - Coordinator of Mytox-South Networks, Belgium.
Sheila Okoth	University of Nairobi - President of the African Society of Mycotoxicology, Kenya.
Tanya Stathers	Natural Resources Institute (NRI), University of Greenwich, UK.
Thierry Nègre	European Commission - Joint Research Center (EC JRC), Italy.

Workshop agenda

14:00 – 15:00

- (10 min.) Presentation of APHLIS + project with focus on postharvest losses for crops and value chain stages where mycotoxins are of interest. (5 min.) Question and answers session

- (10 min.) Presentation of ASM network and ongoing research activities that are of relevance for the discussion. (5 min.) Question and answers session

- (10 min.) Presentation of Mytox-South network and ongoing research activities that are of relevance for the discussion. (5 min.) Question and answers session

- (10 min.) Presentation of Mycokey project outcomes of relevance for the discussion (5 min.) Question and answers session

15:00 – 15:10 Break

15:10 – 16:40

- (50 min.) Discussion about overlapping interests and main research questions (possibly in working groups, depending on number of participants). The 3 thematic areas listed in the Concept Note will be the starting point of the discussion/ brainstorming.
  (10 min.) Report of the Conclusions

- (30 min.) Discussion about opportunities and preparation of upcoming events
  - 2022 African Society of Mycotoxicology conference
  - Follow up of 2020 mycotoxins predictive modelling workshop
  - Follow up meetings for specific points for which there is a high level of interest

16:40 – 16:50

Presentation of the results of the Mycotoxin and Food security Survey in the African countries in relation to the above list of questions.

16:50 – 17:00

Final remarks – Conclusions and greetings.

MYTOX SOUTH APHLIS+ The African Postharvest Losses Information System ASM MycoKey

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