Mycotoxin control in food grains

Proceedings of a Small Group Meeting

22–24 June 2004

Nairobi, Kenya

AFRICAN AGRICULTURAL TECHNOLOGY FOUNDATION

FONDATION AFRICAINE POUR LES TECHNOLOGIES AGRICOLES

Participants

Front row seated, left to right: *Bussie Maziya-Dixon, Rosemary Ng'ang'a, Kaffui Akuwa Kpodo, Esther Sakyi-Dawson, Hester Vismer, Nancy Okita*

Second row, left to right: *Mike Hall, Dilip Shah, Gordon Shephard, Paul Muchena, Pascal Fandohan, George Bigirwa, Richard Boadi, Immanuel Kilei, Samuel Bankole, Lucy Namu, Nancy Muchiri*

Back row, left to right: *Phelix Majiwa, Aberra Debelo, Lawrence Kent, Ranajit Pandyopadhyay, Kerstin Hell*

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The proceedings of the workshop were captured and compiled by rapporteurs general Ms Miriam Mulure and Ella Chimbiru.

Contents

List of abbreviations

AATF	African Agricultural Technology Foundation
APAO	An enzyme that detoxifies fumonisins
ASARECA	Association for Strengthening Agricultural Research in Eastern & Central Africa
BEN	Balkan Endermic Nephropathy
Bt	Bacillus thuringiensis
CIMMYT	International Maize and Wheat Improvement Center
CSIR	Council for Scientific and Industrial Research
Def1/MsDef1	Medicago Defensin
DON	Deoxynivalenol
ELISA	Enzyme-linked Immunosorbent Assay
EU	European Union
FAO	Food and Agricultural Organisation
FARA	Forum for Agricultural Research in Africa
GATT	General Agreement on Tariffs and Trade
HBV	Hepatitis B Virus
HPLC	High Pressure Liquid Chromatography
HSCAS	Selective absorption of mycotoxin in the gastro-intestinal tract
IARC	International Agency for Research on Cancer
ICRISAT	International Centre for Research in the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IP	Intellectual Property
KEPHIS	Kenya Plant Health Inspectorate Services
NARO	National Agricultural Research Organisation, Uganda
NGO	Non-Governmental Organisation
OC	Oesophageal Cancer
PBRs	Plant Breeders Rights
PROMEC	Program on Mycotoxins and Experimental Carcinogenics
SDS	Sudden Death Syndrome
SGM	Small Group Meeting
SSA	Sub-Saharan Africa
TF	Task Force
TLC	Thin Layer Chromatography
USAID	United States Agency for International Development
US-FDA	United States Food and Drug Administration
WHO	World Health Organisation
WTO	World Trade Organisation
ZEN	Zearalenone

Executive summary

Food safety and security is a health and economic concern and cannot be taken lightly especially in Sub-Saharan Africa where 80% of the population depends on agriculture for a living. Unfortunately, many are not aware of the dangers posed by the very crops that are meant to give them life. Over the years, there have been outbreaks of food poisoning sometimes resulting in loss of life. Indeed at about the time this meeting was held, nearly 100 people in Kitui, Kenya were reported to have died from causes related to food poisoning. Such incidents can be avoided if methods of planting, harvesting and storage of food crops which block fungal contamination are adopted. The contamination of food crops reduces their quality and leads to production of high levels of mycotoxins that endanger the life of the consumer. Research shows that mycotoxicoses contribute to development of liver sclerosis and cancer. Additionally, they compromise the immune system of humans and animals, making them susceptible to other infections.

Mycotoxins and the complications that they lead to have not received the attention they deserve in many parts of the world. In Africa, this can partly be explained by the presence of more apparently pressing human health issues like HIV/AIDS, malaria and infant mortality. Understandably, mycotoxins research does not appear on top of the agenda. Nevertheless, African countries must accept the dangers posed by this problem in the current forms of agriculture and food processing.

This Small Group Meeting (SGM) was attended by scientists from Benin, Nigeria, Ghana, Uganda, South Africa, Kenya and the United States who shared their findings, experiences and challenges in the field of mycotoxins. They acknowledged that fungi that produce mycotoxins are ubiquitous, in the soil, air and bodies, and that they pose a danger to human health. Much research has been done on maize, groundnuts and cassava which are among the staple foods of Africa; findings indicate that many of these crops are contaminated by mycotoxigenic fungi. There are many factors that contribute to this situation, including food processing.

Papers presented at the workshop addressed the sources of mycotoxins and suggested ways of avoiding contamination of food with fungi that produce these poisonous substances. Suggestions were also made on how decontamination can be effected so that such crops could be put to alternative uses. The suggestions should lead to improved production of safer food crops suitable for local consumption and sale in international markets at competitive prices. Participants in the meeting recommended that governments and funding agencies pay greater attention than has been done in the past to the problem of mycotoxins in food crops in Africa.

Tuesday, 22 June 2004

Opening

Introduction and welcome

Eugene Terry*, Implementing Director, AATF*

Following its formal inauguration on 16 June 2004 in Nairobi, Kenya, the African Agricultural Technology Foundation (AATF) held its first SGM on mycotoxins at its Headquarters at the International Livestock Research Institute (ILRI) campus in Nairobi, Kenya. The meeting was attended by 25 scientists from various research centres in the eastern, southern and western sub-regions of Africa, and from the United States of America.

Dr Terry welcomed all present and was appreciative of the fact that, despite the very short notice given, all invited attended and participated in the meeting by contributing to the deliberations.

AATF's mission and reason for convening the SGM

AATF aims to improve food security and help reduce poverty of the smallholder farmers in Sub-Saharan Africa. AATF is a not-for-profit organisation whose main focus is to promote partnerships and synergies between public and private sectors, with a view to removing the barriers to smallholder farmers' access to existing agricultural technologies and to enhance food security and safety.

To achieve this AATF identified eight problem areas which have been approved by the Board. Among these problem areas is mycotoxins in food.

In broad terms, Dr Terry stated that the meeting would look into and define the various dimensions of problems associated with mycotoxins. There were stated and definitive goals to achieve at the end of the meeting.

General objectives and procedures of the workshop

Phelix Majiwa, *Projects Manager, AATF*

The participants were requested to introduce themselves, indicating their country of origin, institutional affiliation, professional interests and the particular interest they have on mycotoxins. This was a necessary prelude to the discussions that the participants would conduct for the next two days.

Dr Majiwa, the primary organiser of the meeting, indicated that it had not been possible to accommodate all the requests for participation in the meeting. He explained that the decision to hold an SGM was a deliberate one AATF takes as an initial consultative step in the process of formulating project ideas. This was the first meeting meant to focus on a set of projects within the general problem area designated: ***Mycotoxins in food grains***.

The SGM was organised to:

1. bring investigators in this field together in Africa for consultations on, and formulation of research agenda towards addressing the problem of mycotoxins in Africa
2. identify opportunities that could bring the benefits of knowledge in this field to the peoples of Africa in a timely fashion.

AATF's desire is that its efforts would contribute to:

- significant increase in agricultural productivity of the major food crops
- increase in quantity and quality of agricultural products
- such products remaining safe for the intended purposes, that is human consumption and general welfare of the environment.

Timeliness

Although it was by sheer coincidence that the SGM on Mycotoxins was taking place in Kenya precisely at a time when the country was experiencing a case of food contamination, such an unfortunate event served to underscore the timeliness and need to move with speed to avoid any more such happenings. AATF therefore indicated that it would hold a broader and bigger Stakeholders' Workshop on this topic in the near future.

Agenda

The agenda for this meeting was threefold:

- define various dimensions of the problems associated with mycotoxins in Africa
- clarify possible timed interventions to effectively address these problems

- devise the means by which available interventions, and those under development, can be made available to the peoples of Africa.

How to achieve the expected outcomes

There were presentations of approximately 20 minutes each, followed by collective discussions and questions. It had been envisaged that the background information thus provided would be used in more extended but focused groups constituted into task forces. This, however, was changed at the suggestion of participants such that all discussions were conducted in a plenary throughout the workshop.

It was agreed that the meeting would remain flexible but with discussions as exhaustive as possible. Session chairs were called upon to ensure time keeping.

Presentations

Dimension of mycotoxins problem in Africa

Session Chair: ***Hester Vismer***

Recent unfortunate events (Case: Kenya's Eastern Province)

Presenter: ***Immanuel Kilei****, Ministry of Health, Republic of Kenya*

Background to the recent incident in Kenya concerning mycotoxins in maize

Locality of occurrence: Kitui, Eastern Province, Kenya

During the time leading to the incident, the weather had generally been erratic: at the beginning of the year, it had been favourable for the growth of fungi; the maize was harvested before it was completely ready; some of the harvested maize may have been left in the farms where it absorbed a lot of moisture. Consequently, mould was already growing on the maize, some appearing rotten. Majority of the residents in the area are poor and cannot, and indeed do not, choose the quality of the food that they eat. In most instances, they have no alternative.

Probably all the maize consumed in the area at the time may have been grown locally. There had been similar outbreaks between 1978–84; however, in April 2004, the number of cases was alarming. The first case was misdiagnosed as hepatitis B, making it difficult to treat the victims. The situation was compounded by the fact that the community would not allow post mortems to be conducted on the victims.

When the number of the affected individuals rose to alarming levels within a short period of time, the authorities went into homes and took food samples for analysis. These showed toxin levels of 139 to 200 parts per billion. Blood samples tested showed that 80% of the tested cases were positive. To curtail the disaster, the Ministry of Health posted some of its staff on the ground to maintain vigilance and keep records of new cases. The Office of the President then started replacing all cereals in the area with clean food products. Crisis teams of all stakeholders were formed and sensitisation of the general public was carried out in *barazas* (public rallies organised by chiefs at the village level), schools, market places and from house to house.

Possible origins of the mycotoxins

This is purely speculative: there was some harvest of maize before it dried to the required level. Some rains came. When they stopped, farmers cut the stalks hoping to facilitate the drying. The stalks on the ground absorbed moisture and the grain became highly contaminated with toxinogenic fungi.

As to why this occurred at this time is probably because fungi tend to produce toxins at certain temperatures (above 30°C).

Questions and responses

What are the findings?

It was observed that, going by reports appearing in the media, some of the reported deaths may not have been related to food poisoning. It was also suggested that some of the contaminated grain may have originated from elsewhere. It is known, however, that a significant proportion of the maize was locally grown in Makueni and Kitui Districts of Kenya. The types of mycotoxins found here were aflatoxin B_1 on maize grains, and this could be due to the new variety of 41–41 seed. In the past the people had grown Katumani and 511 maize varieties. It is also possible that the people used post-harvest pesticides, although there was no serious problem with crop pests to warrant such usage.

What is the government doing?

In view of the fact that facilities for assessing food safety are lacking, it was suggested that samples be made available to investigators from elsewhere to carry out the required analyses in their own laboratories.

What measures can be taken to avoid such a scenario again?

The problem is compounded by the fact that the food is grown in the homes and consumed locally, thus making it difficult to regulate or manage its quality. It is usually possible to regulate the quality of food produced by commercial farmers, as opposed to that produced by the smallscale household farmers. The government is carrying out awareness campaigns at various levels to encourage people in the affected areas to give up the contaminated food, and to avoid eating the food harvested in the fields because of possible contamination.

It is not possible to establish with certainty the sources and nature of contamination.

In response to the concern, the meeting considered some of the preventive measures that could be taken to pre-empt or prevent recurrence/occurrence as follows.

- Ensure that the food produced is safe and kept under storage conditions that avoid fungal contamination.
- Develop grain varieties that are resistant to fungal contamination and growth.
- Make the people aware of both pre- and post-harvest practises that decrease chances of fungal contamination on food crops; in west Africa, for example a major campaign involving seven countries was conducted on how to manage aflatoxins. This engaged support national systems, with the Rotary Club undertaking the exercise on the ground. Expert advice was given by professionals from the International Institute of Tropical Agriculture (IITA).

- Use of local Non-Governmental Organisations (NGOs) in Kenya, for instance, to sensitise people.
- Insure all grain and food storage is cleaned such that the fungi do not grow.

The incident showed the need to have food policies that ensure food safety. This is one of the areas in which AATF will look to cooperating with governments.

Overview on agriculturally important mycotoxins in Africa

Presenters: ***HF Vismer*** *and* ***WFO Marasas***

Food Safety/Security

This is an issue that is becoming increasingly important, both at the national and international forums on agriculture, nutrition and health, because it is no longer "a luxury of the rich, but a right of all people". Available data (FAO 1998–2000), indicate that 35% or more of the population is undernourished, 17 out of 22 countries in which these people live are in Africa.

Mycotoxins

Food safety and security are both complex and multifaceted issues in which mycotoxins play a vital role. Mycotoxins are natural toxic metabolites of fungi (mostly foodborne), some of which are potent carcinogens and mutagens.

Mycotoxins in Africa

Mycotoxins in Africa are mainly aflatoxin, ochratoxin A, fumonisins, deoxynivalenol and zearalenone. The moulds that produce them thrive because of favourable environmental conditions, like drought-stress, humidity and insect infestation of crops at various stages. The levels are affected by the different methods of processing techniques in commercial products. Wet and dry milling processes can reduce their concentration while fermentation could reduce specifically the concentrations of ochratoxin A and patulin.

Mycotoxins are found in animal meat, milk and eggs and also in human breast milk. They affect the liver and kidney, and cause hepatocellular carcinoma, a condition exacerbated by hepatitis B virus infections leading to immunosuppressive and impaired growth in children.

In South Africa, large quantities of aflatoxins were found in peanut butter that had been introduced in schools as part of a school feeding program in the Eastern Cape. The supplement was withdrawn. High levels of fumonisins were found in maize, the staple diet in Eastern Cape.

Crops protected against insect damage, for example maize incorporating *Bt* genes, appear not to be susceptible to contamination with mycotoxigenic fungi, and thus have very low levels, if any, of mycotoxins. Studies done in China, South Africa and Italy indicate that consumption of food containing fumonisins increases chances of oesophageal cancer. In experimental animals, fumonisins were shown to be embryotoxic and teratogenic.

(i) Aflatoxin

This is one of the five most important mycotoxins and is found mainly in groundnuts, edible nuts, oilseeds and cereals.

Toxicological aspects

Toxicological effects are dose-dependant: a high dose is lethal and could cause liver, myocardial and kidney tissue damage; while sub-lethal doses give rise to chronic toxicity such as liver cirrhosis; and low level exposure may cause human hepatocellular carcinogen.

Aflatoxin is also mutagenic and teratogenic: it has immunosuppressive effects in humans and leads to impaired growth in children. Children with hepatitis B virus (HBV) infections or who are carriers of HBV, are at a higher risk of developing liver cancer when exposed to aflatoxin.

(ii) Fumonisins

Fumonisins occur mainly in maize. The International Agency for Research on Cancer (IARC) classified fumonisin B_1 (FB_1) as a Group 2B carcinogen. In other words, it is possibly carcinogenic to humans.

Toxicological aspects

- In farm animals, the effects include leukoencephalomalacia in horses and pulmonary oedema syndrome in pigs.
- In experimental animals: FB_1 is hepato-, nephro- and cardiotoxic in rats and mice, and causes neural tube defects in mouse embryos.
- In humans, it is associated with oesophageal cancer and birth defects (anencephaly and spina bifida) in areas where home-grown maize contain extremely high levels (up to 117mg/kg) of $FB_{1.}$

Mycotoxins and other interactions

Synergistic interaction between fumonisins and aflatoxins has been reported. Genetically engineered maize (*Bt* maize) for insect resistance may contain lower levels of fumonisins when compared to conventional maize hybrids. Conversely, higher levels of mycotoxins may occur in organically produced foods because no pesticides and fungicides are used.

(iii) Ochratoxin A

This occurs mainly in cereals, grapes, coffee and wine.

Toxicological aspects

These include renal diseases, and porcine and avian nephropathy. Ochratoxin A is also associated with renal diseases and urinary tract cancers in humans. IARC (1993) classified ochratoxin as a possible human carcinogen. In experimental animals, embryotoxic and teratogenic effects have been observed. Carry-over effects and accumulation in meat, blood, kidneys and liver have also been established.

(iv) Deoxynivalenol

Deoxynivalenol falls within the highly toxic trichothecene group of mycotoxins and occurs mainly in maize and wheat.

Toxicological aspects

Included are feed refusal and emesis in pigs (vomitoxin), and reproductive defects in pigs (abortion and still births). Possible synergistic effects with aflatoxin have also been recorded.

(v) Zearralenone

Zearralenone is estrogenic causing hyperestrogenism in female pigs. Its residues are found in meat, milk and eggs. It has also been found in maize.

Discussions

The enforcement of regulatory procedures is appropriate for export crops, but has little relevance to the majority of farmers who depend on agriculture in developing countries because they are largely smallscale and subsistence farmers. Of great concern, specifically for Africa, are the economic losses caused by mycotoxins, by way of food and feed losses, and lost opportunities for participating in international trade. This is further complicated by the high costs involved in inspection, sampling and analyses of exports and imports of food crops, detoxification, research, training and extension programs.

There is need for emphasis on reduction of insect infestation, fungal contamination and mycotoxin contamination of food crops when they are in the field and in storage. This is one of the most effective ways to achieve reduction of mycotoxins in foods in Africa, which cannot be done through regulatory measures alone. To this end, solutions should be sought in the development of locally adapted plant varieties that will be less susceptible to fungal contamination.

Conclusion

The importance of mycotoxins and food safety/security issues to Africa cannot be overemphasised. Interventions by educational programmes to adapt agricultural technology to African circumstances and to improve food quality are urgently needed.

Questions and responses

1. **How much of deoxynivalenol has been reported in South Africa?**
   Very few cases. There is very little deoxynivalenol in Africa in general. It is one which

is also not very easy to control through decontamination. The best way is to control it is through growth and storage because once the toxin is in the body, it is very hard to get it out.

2. **How much aflatoxin is found in *Bt* maize?**
   So far no traces of aflatoxin have been found in Bt *maize. Infection occurs during pre-harvest and fumonisins are often found in post-harvest products. This is because most farmers leave the maize to dry in the fields, where moist conditions favour contamination with fungi.*

3. **How much is the insect damage?**
   Insect damage is a very big problem. It has catalysed the introduction of Bt *maize in the Transkei. All the more why* Bt *maize should be a viable option because mycotoxin levels are very low.*

4. **How exactly would one go about detoxifying cereals, and how effective are these methods?**
   Detoxification of contaminated food products is really a last option. Efforts should be directed at good agricultural practices that avoid contamination all together. One approach is screening crops for possible contamination and separating those apparently contaminated from those that are clean. Decontamination is applied in a specific way to each mycotoxin; whichever method is used, the decontaminated food is usually unsuitable for human consumption. Some of the detoxified commodities are reversed when eaten.

5. **At what points/stages do aflatoxins occur in peanut butter in South Africa?**
   The fungi can contaminate crops during pre-harvest, but they do not necessarily produce mycotoxins until favourable conditions set in, which is usually during harvest and storage stages. In maize, how it is handled after the harvest is a major influencing factor in whether it gets contaminated, and the extent to which it could be contaminated.

References

1. IARC (International Agency for Research on Cancer). 1993. Some Naturally Occurring Substances: Food Items and Constituents, Heterocyclic Aromatic Amines, and Mycotoxins. *IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Humans*, 56. Lyon, France: International Agency for Research on Cancer. 571 pp.

Epidemiology and incidence of mycotoxins/aflatoxins in African smallholder farms: Uganda perspective

Presenter: **George Bigirwa**

Dilemma

"The world has many good things…"

"….Good things can be lethal."

"There is nothing as enjoyable as eating good food…."

"…But eating can be hazardous.

"…And not eating is fatal!"

Mycotoxins

Fungi that produce mycotoxins are abundant in soil and water, and inevitably affect agricultural products. Their levels vary from place to place, year to year and crop to crop. Because mycotoxins are ubiquitous in nature, efforts should be directed at lowering the chances of their presence in foods and feed. Mycotoxins are toxic chemical compounds produced by fungi (moulds) during growth under certain conditions. Fungi are abundant in soil and air, and are therefore likely to be a major contaminant.

The severity of mycotoxin contamination varies from year to year, and from one geographical location to another. Growth of certain fungi is favoured by specific moisture levels and storage conditions. Produce stored under conditions that favour mould contamination and mycotoxin production will have low value, and cannot be accepted as commodity for trade locally or internationally. Mycotoxin is therefore costly and needs urgent address.

Research in Uganda shows that mycotoxins contaminate cereals, groundnuts and coffee. Grains and mycotoxins known to contaminate them are:

- maize – aflatoxin, DON, zearalenone, T-2 toxin, fumonisin and citrinin
- wheat – citrinin, DON, T-2 toxin, zearalenone and moniliformin
- barley – citrinin, DON, ochratoxin, T-2 toxin and zearalenone
- rice – citricin, fumonisin and T-2 toxin
- sorghum – ergot and zearalenone
- millet – ergot and cyclopiazonic acid.

Other commodities contaminated by mycotoxins are**:** coffee – ochratoxin; groundnuts – aflatoxins; apples – patulin; soy products – ochratoxin; tree nuts – aflatoxins and tremorges; grasses – ergot and T-2 toxins.

As alluded to above, minimum moisture content is usually required for the growth of some fungi that contaminate crops in storage.

Factors favouring the contamination of crops with mycotoxigenic fungi in the field (on-farm conditions)

- Stress experienced by the crop (nutrition, drought and pests).
- Physical damage to the crop (via pests, harvesting and processing methods).
- Crop variety type.

Some of the stages at which susceptible crops are vulnerable to fungal contamination are:

(i) in the field, depending on weather conditions and type of crop variety
(ii) in storage, depending on the type of storage used (open or closed), duration for which the harvested crop is kept in the storage and the condition of storage
(iii) during transportation: the type (open or closed), duration and prevailing weather conditions
(iv) during processing.

Critical factors during harvesting of the crop are physiological stage (completely or incompletely ripe, dry, ready for harvesting, etc), moisture content and mechanical damage. During transportation and storage however, the prime factors are type of storage facility, moisture build-up, temperature alterations, pest control and physical damage.

Questions and responses

1. **Have there been any attempts to detoxify people?**
No attempts have been made to detoxify humans who have consumed food containing mycotoxins; furthermore, people have not been made aware of mycotoxin levels in the different foods they consume. It is surprising that some of the healthy looking grains can have low levels of aflatoxins; in Uganda contamination of maize is by fumonisins.

2. **Have you had any people eating rotten maize?**
No, but they make local beer with mouldy maize.

3. **Are there any studies made on the health of those who drink beer made from grains apparently contaminated with fungi likely to produce mycotoxins?**
No studies have been made on the health status of the beer drinkers.

4. **Why is there a preference for mouldy maize to healthy maize for brewing of the alcoholic beverages?**
The beer is fermented and it appears that mould in the maize, or indeed any grain or crop, enhances the fermentation resulting in a drink preferred by certain individuals. The other factor is of course that instead of throwing the mouldy grain away, farmers would rather use it in brewing.

5. **What methods did you use to determine the levels of mycotoxins?**
   Thin Layer Chromatography (TLC) and Enzyme-linked Immunosorbent Assay (ELISA).

6. **How does one remove fumonisins?**
   These are normally found in the grain husk; therefore if the husk is removed, the fumonisins are also removed with it. As people were made aware of the dangers of consuming contaminated foods, they became more careful and fumonisin levels were reduced.

Mycotoxins in food: Implications for human health in Africa

Presenter: ***Gordon Shephard***

Introduction

Mycotoxins are issues of food safety, health and agriculture. Sub-Saharan Africa is the most affected by hunger. In 1978 mycotoxins responsible for gangrenous ergotism broke out in Ethiopia. In Kenya aflatoxicosis broke out in 1981, 2001 and now in 2004. Chronic exposure to mycotoxins can lead to cancers, growth retardation and immuno-suppression.

Findings

Aflatoxins are found in maize, groundnuts, sorghum, pulses and coconut, which constitute the main staple diets in Sub-Saharan Africa. They are also found in breast milk in Egypt, Ghana, Gambia, Sierra Leone, Kenya, Sudan and Zimbabwe; in weaning foods in Nigeria; and in cord blood in Gambia, Ghana, Kenya and Nigeria.

Studies carried out in Kenya, Swaziland and Mozambique found a link between aflatoxins and liver cancer, hepatitis B and carcinogesis. According to studies in Benin and Togo, when children between the ages of nine months and five years are exposed to very high levels of mycotoxins they appear to have reduced immunity and are stunted.

Food contaminated with mycotoxins has less nutrients and therefore consumption of such food contributes to kwashiorkor. A person who consumes on average 400gm of maize a day takes in 20ng/g (20ppb) of mycotoxins; the dietary exposure is 133ng/kg bw for a person who weighs about 60kg. This increases significantly the risk of liver cancer in such individuals, particularly if they consume foods contaminated with aflatoxin B. Current estimation is that approximately 40 out of 100,000 people get liver cancer each year from exposure to this level of mycotoxins.

Fumonisins occur naturally in Africa in Benin, Botswana, Burkina Faso, Burundi, Cameroon, Egypt, Ghana, Kenya, Malawi, Mozambique, Nigeria, South Africa, Tanzania Uganda, Zambia and Zimbabwe. In Botswana, sorghum is also infected by fumonisins. Elsewhere fumonisins were shown to have caused abdominal pain and diarrhoea in India (where the levels were 65,000µg/kg). Research on maize in the Transkei from the 1950s shows they can cause oesophageal cancer (OC). Similar findings have been made in China, Iran, Brazil and Italy.

Work co-ordinated by the International Agency for Research on Cancer (IARC) shows strong correlations between fumonisins and OC.

Ochratoxin A has been found in healthy people in Egypt, Tunisia and Sierra Leone. It occurs naturally in Egypt, Ghana, Kenya, Nigeria, Sierra Leone, Tunisia and Zambia.

It may cause anaemia, Balkan Endemic Nephropathy (BEN), urinary tract tumors and is a known carcinogen.

Deoxynivalenol (DON) occurs naturally in Egypt, South Africa and Zambia. It may cause nausea, vomiting, diarrhoea, abdominal pain, headache, dizziness and fever, as quickly as 30 minutes after exposure. It has been implicated in outbreaks of gastro-intestinal disease. Contamination of maize and wheat with DON caused scabby grain intoxication in China, and mild gastro-intestinal tract symptoms in Kashmir.

So far, no deaths have been directly attributed to DON and no conclusive evidence exists for its role in OC. Further research is needed on its role in immunosuppression.

Zearalenone occurs naturally in endocrine disrupting chemical. In Africa it has been found in limited surveys conducted in Botswana, Egypt, Lesotho, Kenya, Malawi, Nigeria, South Africa, Tanzania, Zambia and Swaziland. Some limited evidence links it to carcinogenicity in animals. In Puerto Rico, it was linked to an outbreak of precocious pubertal changes in young children. In southern Africa, gynecomastia and testicular atrophy in rural males was associated with it through home grown maize. However its association with cervical cancer is yet to be supported by firm data.

Mycotoxin contamination is widespread in Africa and, although food security is a priority, food safety cannot be ignored.

Questions and responses

1. **Do you think it is a problem to convince governments on the dangers of mycotoxins?**
   People do not naturally have problems with mycotoxins unless they are at insurmountable levels. Furthermore, the effects are not conclusive because the link is long term. Farmers for their part do not see a problem with the fungus. However as the European Union pursues legislation, exporters will have to get on board or risk the loss of market and revenue. African governments have more pressing issues to deal with like AIDS, malaria and tuberculosis to really concern themselves with the issues of mycotoxin levels. Usually they will take note only when there is a crisis relating to mycotoxin food poisoning.

2. **Do we have pre-disposition evidence of mycotoxin causing disease?**
   Experiments that have been done so far are on animals so there is no real evidence on human beings. And it would be impossible/unethical to conduct such experiments in humans. However, the correlation is very strong.

Effects of mycotoxins on nutritional quality of food crops

Presenter: ***Bussie Maziya-Dixon***

Introduction

The most important food crops produced by African farmers in order of tonnage are cassava, yam, maize, plantain, sorghum, millet, rice, sweet potato, banana, potato, cowpea, wheat and beans. This is far short of the required amount leaving millions undernourished. The most vulnerable groups are children and those suffering from HIV/AIDS. About 1.8 million children on the continent die of insufficient nutritional food. Our objective should be to have sustainable food systems and in reasonable supply; foods that are rich in nutrients with proteins, fats, fibre, minerals, vitamins and carbohydrates.

The removal of the germ, bran and endosperm during processing affects the nutritional and calorie value of food. Mycotoxins are metabolites of the growth of moulds which are toxic to animals and humans. Examples include aflatoxins, deoxynivalenol (DON), zearalenone (ZEN), fumonisins and T-2 toxin. The mould changes the colour of the kernels, imparts odour, and lowers protein, fat and vitamin levels in grain. They may not be seen in the processed grain but if taken in high levels, can cause poisoning. Their high level presence in certain products negatively impacts on exports to Europe. Aflatoxins can lead to carcinogenicity and lower resistance to disease in the body. They also cause more degradation under normal food processing conditions. The ideal would be to have selection of a proper decontamination method that will effectively decompose aflatoxins while retaining the nutrients.

Aflatoxins are found in Sub-Saharan Africa and exposure to them could also lead to liver cancer, oesophageal cancer and morbidity in children.

Mould growth can be controlled through regulation of temperature and low moisture levels that would reduce levels of mycotoxins in the product.

Conclusion

More research is needed on traditional food processing methods that will lower mycotoxin levels and the effect on crops. Nutritional levels in food in Sub-Saharan Africa should be raised while reducing exposure to mycotoxins.

Comments

This is very important because it links mycotoxins and nutrition. In essence, the body can clean itself of mycotoxins. However, if there is no proper nutrition the process is not efficient and the body can easily succumb to effects that could have been avoided. Yam and cassava have lower levels of mycotoxins than maize.

Possible interventions

Session Chair: ***Esther Sakyi-Dawson***

Mycotoxins in processed foods

Presenter: ***Esther Sakyi-Dawson***

Introduction

Importance of safe food supply

Over the years food supply patterns have changed and more people are relying on the same food sources. It is sometimes desirable to have highly processed foods with a longer shelf life for ease of storage and safety. We will consider maize and groundnuts which form staple foods for many in Sub-Saharan Africa.

Mycotoxins in fermented maize products

Fermented maize dough and kenkey processing

These are made following certain procedures. In summary, this is done as follows: sort out the good maize kernels and clean; soak for between 1–3 days, dry and mill. Add water and make this into dough at about 50–55% moisture and ferment for 1–3 days. Partially cook a third of it for about 30 minutes and mix with the remaining uncooked dough. Form it into balls and cook in water for 2–4 minutes.

Fermentation of dough in some cases increases aflatoxin and citrinin levels, understandably because the mould would be metabolising during the fermentation. Cleaning, soaking and/or degerming maize reduces the levels of fumonisins and possibly aflatoxin. However, soaking before milling does not reduce aflatoxin levels significantly. In conclusion food processing procedures significantly determine the final level of mycotoxins present in the processed food.

Groundnuts

Groundnuts are found in regions with heavy rainfall. However groundnut oil is not likely to contain aflatoxins. Sorting and cleaning; soaking and separation; thermal and chemical inactivation reduces mycotoxin levels.

Questions and responses

1. **Do these food processing procedures reduce mycotoxins?**
   Boiling reduces aflatoxins. Processing of ugali *is done basically by putting milled maize into boiling water and stirring to the desired level of hardness. The extent to which this*

reduces mycotoxins has not been investigated and doing so would be a challenge because each community cooks it differently. Besides the quantity of ugali *to be cooked determines the cooking time.*

2. **Can you explain 'wet milling'?**
First the bad maize is separated from the good which is then soaked/steeped for three days. This is then dried and milled. If one has to do say 500kg of maize, then the separation by hand may not be effective. It is time a technology that is appropriate and affordable for this process was identified.

3. **Is the protein in the rotten maize tightly linked to the fumonisins or other mycotoxins?**
To a great extent yes, but more research is needed for confirmation.

4. **Did you analyse mycotoxin levels in boiled *kenkey*?**
In soaking/steeping there was some but after boiling it was very low.

5. **Do farmers use fertiliser and if so what are the levels of mycotoxin in the final product?**
Where fertiliser was used, the levels of aflatoxin were very low but it is not common.

6. **Are levels of aflatoxin determined by dry/wet weather?**
This would seem to be the case. In some cases the wet weather contributes more while in some cases the dry weather contributes more. More research is required to determine how this happens. Studies in Benin indicate that the levels rose after long storage of the food.

7. **Where does one find the largest concentration of mycotoxins in this type of food processing?**
Obviously in the contaminated grain before the apparently rotten ones are separated from those that are not. As the processing proceeds, different mycotoxins are lost in the course of the process.

8. **Do you eat groundnut paste on bread or with other food stuffs?**
It is the more educated who would eat the paste with bread but rural people eat it with cassava or other foods.

Technologies for reduction of mycotoxins

Presenter: ***Kerstin Hell***

Introduction

Research in many parts of west Africa show that mycotoxins are prevalent in maize, cassava and yam chips, cowpea, cashew nut and a variety of processed foods. The control of this food hazard depends on the varieties of the product derived from the food crop. In Benin, approximately 44% of the maize samples tested had high levels of aflatoxins, of the samples of yam chips tested 17% had > 20ppb and 75% had > 4ppb.

The risk of mycotoxins in Africa is high in areas with heavy rainfall, and humid areas in mid-altitude areas. Aflatoxin levels appear to rise with duration of storage under conditions favourable for fungal growth.

Experiments and results in Benin and elsewhere

The International Institute of Tropical Agriculture (IITA) carried out experiments on poultry and showed liver damage, stunted growth and low immunity levels which caused losses to farmers.

An awareness campaign on the dangers of aflatoxins carried out in Benin, Togo and Ghana reached more than 10 million people.

In studies carried out in 16 villages in Benin, aflatoxin exposure was higher in malnourished children and significant levels were found in breast milk. Children between 6–48 months in Benin and Togo who were exposed to maize and groundnuts had significant levels of aflatoxin in their blood, which also caused stunted growth. Those fully weaned had high percentage of aflatoxins, while those breast feeding had very low levels. In general, aflatoxin levels were higher in humid areas than in dry areas.

De-husked maize had very low levels of aflatoxin even after a six-month storage, while processed foods on the shelves had low mycotoxin levels in contrast to fresh foods. The survey found that the more educated farmers were aware of the dangers of mycotoxins than the less educated.

Economic losses caused by mycotoxins were to the tune of US$ 670 million in terms of export. For local consumption the loss is estimated at US$ 10 million because of poor management.

In an effort to control mycotoxin levels research should produce resistant varieties of crops. A basket of technologies supporting management of maize in growth, storage and sorting out should be seen as an urgent goal. In the absence of these technologies drying and storage facilities should be improved.

Future prospects

- Strengthen institutions that work to reduce mycotoxin levels in communities.
- Improve nutrition based on clean food.
- Conduct food basket survey to establish the possible presence of multiple mycotoxins.
- Implement strategies that will reduce the impact of mycotoxins in trade.
- Introduce resistant breeds of crops.
- Have biological control of mycotoxins.
- Place emphasis on detoxification of contaminated food crops.
- Enlarge partnerships both locally and internationally, to work jointly on the problem.

Questions and responses

1. **What methods were used to identify the type of mycotoxin?**
   The methods used for identifying mycotoxin type were HPLC and TLC.

The competitiveness of the strain depends on the uniqueness of the crop and other variables. It is important that sorting be done in order to avoid contamination of the final food product, but the logistics of doing this can be overwhelming.

Contamination, bio-control, farming, post-harvest and processing practices

Presenter: ***Aberra Debelo***

Contamination of groundnuts, maize, soybean, cotton, chilli etc is caused by *Aspergillus flavus* and *A. pafasiticus*. In groundnuts, the contamination can occur at all levels of crop production and reduces the quality of the final product. The pods from contaminated groundnuts are usually fed to animals, leading to contamination of milk produced by such animals. Buffalo milk analysed had high levels of aflatoxins, > 30µg/kg (30–3,964µg/kg). Cattle fed on mycotoxin-contaminated feed produced milk with aflatoxins $B_{1\rightarrow}$ M_1. In another study, aflatoxin M_1 contamination found in cow milk was attributed to small pods feed.

Poultry is also affected by mycotoxins. Studies in Asia and Africa show that consumption of products from such poultry poses risks to human health. Immunity is compromised, presence of hepatitis B or C appears to exacerbate the condition. One approach to management of aflatoxin contamination is through breeding resistant crops. It is desirable to implement biological control, agronomic practices, biotechnology and integrated management at pre- and post-harvest stages. However, to achieve this requires enormous resources in all areas of agriculture.

Wednesday, 23 June 2004

Opportunities for controlling mycotoxins in agricultural food crops

Presenter: ***Samule A Bankole***

Introduction

There are many publications on strategies to use in controlling mycotoxins, but various constraints do not make it possible to implement a number of them in Africa. The immediate problem is to produce enough food to feed the increasing number of poor people living in Africa. Research on mycotoxins does not appear on the agenda of many governments nor donor agencies. In order for this to change, policy makers must first be made aware of the problems caused by mycotoxins.

There are neither enough qualified personnel to conduct tests for mycotoxins nor are there in Africa laboratories equipped with facilities in which tests can be carried out. In order to have impact, methods for sampling, testing and validation need to be harmonised among the different African countries. It must be noted that field contamination of food crops by fungi is influenced by various factors including humidity, evapo-transpiration, water availability to crop, abundance of fungi, oxygen and carbon dioxide levels, inoculum load, and substrate composition.

Contamination of foods by mycotoxins

Observations indicate that high-level contamination of food crops by mycotoxigenic fungi occurs during storage. Probably the point at which it would be most effective to intervene is during pre-harvest because contamination of crops in the field will determine the rate at which they will deteriorate in storage, particularly under conditions of high temperatures and humidity. It is advisable to destroy waste parts of maize that already harbour *A. flavus*, otherwise they remain in the soil and could contaminate the next season's crop. It may be possible to reduce fungal contamination through the use of fertiliser, irrigation when necessary, and weeding at appropriate times to reduce stress to the crops.

Use of non-toxigenic bacteria or fungal species that out-compete toxigenic fungi in the field, and safe storage may be an effective biological control. In an experiment where these methods were tested on groundnut and cotton, aflatoxins were reduced by more than 70% and 68% respectively.

Growing varieties of crops resistant to fungal growth will reduce the chances of occurrence of mycotoxins.

Delayed harvesting of crops makes them likely to suffer fungal infection. However, rapid drying of the harvested crop, physical separation of apparently contaminated grain, improved storage structures, using effective traditional methods, like smoking and local plant products, may reduce the chances of fungal contamination. Synthetic chemicals can also be used in coating cereals to reduce contamination with the moulds.

Chemoprevention is the use of natural or synthetic agents to block, retard or reverse the effects of toxigenic fungi. Use of selective high affinity hydrated HSCAS to bind aflatoxin in animal feeds can protect the animals against mycotoxins.

Detoxification through ammoniation is also effective but residual ammonia can affect the health of the animals that feed on such detoxified material. Detoxification does not work efficiently for all types of mycotoxins.

Barriers to implementation of mycotoxins control programs include the following:

- lack of commitment by governments
- widespread poverty and hunger among smallholder farmers
- little or no funding for research to delineate the best post-harvest practises that will avoid fungal contamination and growth
- lack of trained personnel and suitably equipped laboratories
- lack of information on the dangers of mycotoxins.

Comments

The study on ammonisation is interesting. Contaminated food detoxified through this procedure could presumably affect human health if consumed primarily or secondarily.

Transgenic approach to the control of mycotoxin-producing fungi

Presenter: ***Dilip Shah***

Approaches for control of plant fungi

Fungal pathogens cause significant loses of yield in cereals and legumes, and are a threat to human and animal health. Some of the methods that can reduce fungal contaminations include classical breeding, chemical fungicides, biocontrol and biotechnology.

Plant defensins are small cysteine-rich peptides of 45–54 amino acids that display antifungal activity at micromolar concentrations against many fungal pathogens. These include antifungal peptides/proteins, resistance genes, hypersensitive response/systemic acquired resistance genes and engineered pathways. Plants like *Medicago sativa* produce many kinds of defensins which, if applied in genetic engineering, have the capacity to make the engineered plant resistant to fungal contamination. The other legume *M. truncatula* also appears to have defensins with even stronger *in vitro* antifungal activity. *M. truncatula* has at least 18 defensin genes that produce factors which inhibit growth of *Fusarium graminearum* and *F. solani f. sp. glycines* (Fsg). *Medicago* defensin (Def1) inhibits growth of filamentous fungi. MsDef1 defensin strongly inhibits the growth of *V. dahlia in vitro*.

Sudden Death Syndrome in soybeans

The soil borne fungus pathogen *F. solani f. sp. glycines* is restricted to roots of affected crops, specifically soybeans. The fungus occurs usually in the soils of high yield environments and can cause losses of up to 70% in soybean due to Sudden Death Syndrome (SDS), for which it is the primary cause. Infected plants abort flowers and pod, and also show general decrease in seed size.

Genes encoding defensins have been introduced in hairy roots of soybeans; these are being tested for resistance to SDS. Conditions that favour the expression of optimal SDS symptoms in control plants are also being optimised.

Wheat head scab is hard to control because infections with causative fungi seem to vary yearly, and they result in production of mycotoxins in the affected grains. The presenters indicated that they would wish to show the correlation between *in vitro* antifungal activity and *in vivo* antifungal activity of defensin peptides and test transgenic *Arabidopsis thaliana* expressing defensins for resistance against *F. graminearum*. They are also testing transgenic *Arabidopsis* overexpressing defensins, to see if it shows resistance to head scab; isolate head scab resistant mutants of *A. thaliana* unaffected by flower morphology and characterise the molecular basis for resistance to head scab in *A. thaliana*.

In conclusion all this work is done taking care to avoid negative impact on agronomic properties of the crops, without introducing any allergenicity and toxicity. So far MsDef1 appears to have no effect on membrane potential and action potential, but it may have effect on sodium channels by increasing current duration.

Questions and responses

1. **You mentioned that Monsanto pulled out of a project dealing with transgenic potato, please clarify**.
   People lost interest in the disease resistant potatoes and MacDonald stopped making potato chips from this particular kind of crop because people were not readily willing to eat the chips made from the potato. Apparently, there was no longer much financial incentive to proceed with this line of investment.

2. **Are there specific promoters of the defensin genes that are activated in a tissue-specific way?**
   They have specific promoters, but the expression of the genes are not necessarily tissue-specific to stems.

3. **Are pathogens expressed at the sites of fungal infections and can they be controlled?**
   This has not been investigated in a large range of crops, but should be easy to do by introducing a single copy of the gene into the appropriate crop and following the subsequent events. Where these genes are expressed, the pathogens are controlled.

4. **Do you get *F. graminearum* in Africa?**
   Yes, it is found in the highland areas of Kenya, South Africa and other countries. It is found in roots and stems of maize.

5. **What effect would presence of defensins have on maize used as human food?**
   There are similar peptides in the legume seed. If there are defensins in seed then there is low mycotoxin. People who consume wheat products with defensins are not allergic to the wheat.

The use of food processing procedures that reduce levels of mycotoxins: Based on a study in Benin

Presenter: ***Pascal Fandohan***

Introduction

The case example is from Benin whose chief crops are cotton, palm tree, cashew nut, maize, cassava, yam, groundnut and cowpea. Maize is the staple food with about 280gm per capita. Aflatoxins and fumonisins are common contaminants of most of the food crops, with the incidence of contamination being quite high in some regions. Aflatoxins in particular are known to impair childhood health, including growth, immune response and cognitive capacities. Except for the work by Gong et al (2003), very little research has been done on the impact on foodstuffs in west African. Where appropriate caution is taken and it is possible to significantly reduce the levels of contaminants in food. A typical example is their reduction during preparation of tortillas consumed in America.

Benin: A case study

In Benin there are more than 40 different maize processing methods, 30 cowpea processing methods and 18 cassava processing methods. However, for this study only *mawe*, *ogi* and *owo* were considered.

Food processing

Mawe: Fermented cassava dough used for cooking several dishes in Benin, Togo and Nigeria.

Processing *mawe*: Raw maize is sorted, cleaned and crashed into grits. Hulls and embryo are removed as waste and the remaining grits washed again and milled into wet meal to which water is added. This is *mawe* which is fermented for 1–3 days and cooked for 30 minutes into *makume*.

Ogi: Obtained from fermented suspension of wet-milled maize in water. Raw maize is sorted and the clean maize cooked for 5–10 minutes, soaked for one day, milled and made into dough. The hulls and embryo are considered waste. The rest is sieved into *ogi* that is fermented for 1–3 days and cooked for 30 minutes into *akassa*.

Owo: This is a non-fermented thick paste from whole maize meal. The raw maize is sorted into clean maize, milled into maize meal and cooked into *owo*.

The study was intended to determine aflatoxin and fumonisin levels in these different foods and to identify operations that result in significant reduction in the levels of mycotoxins during processing. Moisture content at each step of the preparation was assessed, in particular those involving the use of an oven, and then followed with assessment of aflatoxin and fumonisin levels at all the steps in the processing.

It was found out that processing maize into traditional products appears to reduce levels of mycotoxins by up to 90%. De-hulling, cleaning and crushing reduced the mycotoxin levels substantially but what was left behind stays through the cooking process. These obviously end up being consumed with the products. Further investigations will be done on mycotoxins during processing of maize, cassava and cowpea into other food products.

Questions and responses

1. **How long does one take to sort and clean the maize?**
   About three hours but this depends on the quantity. If it is for sale it is 20kg. If the amount is large then there is usually no time to clean thoroughly.

2. **How much grain can one sort out in a day?**
   This depends on the amount that is being processed which may be 20–30kg. It was observed in Ghana that if the amount of grain involved is large, say 500kg, it is not practical to sort out effectively. It was suggested that a better more efficient technology be developed and adopted for this purpose. However, given that the users of such technology would be the smallscale farmers and the technology would be applied to a problem which can be avoided, it would be prudent to place emphasis on the production of good quality grain not contaminated with fungi that produce mycotoxins. In this regard, it would be useful also to encourage good pre- and post-harvest practices that discourage fungal contamination.

3. **What is removed during the cleaning process**?
   During cleaning, the damaged and the infected grain are removed. In general, if the grain looks good then little time is spent on sorting and cleaning.

4. **How are mycotoxins expressed in non-edible parts of the seeds?**
   The expression of mycotoxins in non-edible parts of food crops is sometimes insignificant. But if the contamination has been there for extended periods of time, then the edible parts get contaminated with time. The non-edible parts and damaged grain are usually fed to animals, irrespective of the contamination. Ultimately, however, the mycotoxins end up in consumers of products derived from the animals. The ability of the processor to better clean the products is critical because this would reduce mycotoxin levels. Crushing and dehulling of maize grain also appears to be effective in reducing mycotoxin levels. However, fermenting and cooking does not have much effect. Surveys are being conducted to determine the extent to which cassava root rot contributes to this crop's contamination with mycotoxigenic fungi.

5. **How safe is smoking of grain as a means of preserving it and what else is generated in the course of smoking the grain? How much grain can be preserved by smoking?**

This is mostly used for seed, not grain used for food. In the case of maize, it is hung at a distance over fire, typically in the roof. The smoke from the hearth below rises to the maize each time cooking is done. This occurs over a long period of time. As expected, this can be done with only small quantities of the crop.

6. **How about the environment where the contaminated grain is stored, how can it be rendered safe by decontamination, for example**?
Fumigation with fungicides can be very effective in removing mould spores accumulated over years of stored foodstuffs.

7. **Is there technology that reduces the problem of mycotoxins?**
Using commercial-capacity grain drier is one technology which is simple and effective. Using this at a community or village level is probably the best approach, but how this could be managed needs to be critically undertaken before it is implemented. In some instances, using this kind of technology on community-based programs may not work, particularly where the cooperative spirit is not strong. In such instances, individual ownership of such equipment may work better.

References

Gong YY, Egal S, Hounsa A, Turner PC, Hall AJ, Cardwell KF and Wild CP. 2003. Determinants of aflatoxin exposure in young children from Benin and Togo, West Africa: the critical role of weaning. *International Journal of Epidemiology* 32: 556-562.

Technologies that reduce levels of mycotoxins: 'Pioneer/ Zimbabwe' study

Presenter: ***Paul Muchema***

Introduction

Fumonisins are mycotoxins produced by the common fungus *Fusarium verticilliodes*. Fumonisins can be found in maize grain at harvest, and/or after storage in suboptimal conditions.

These mycotoxins are toxic to livestock and have been associated with various cancers in humans. The United States Food and Drug Administration (US-FDA) has determined that fumonisin B_1 acts as a carcinogen in rats and mice.

Outcome of study so far

Pioneer has identified an enzyme (APAO) that detoxifies fumonisins. The gene encoding this protein has been incorporated into a maize variety. Studies show that the presence of this enzyme can reduce the levels of fumonisins in *Fusarium*-contaminated grain.

The enzyme removes the amine group from fumonisin, resulting in a product that is no longer toxic as determined by assays done using mammalian cells.

Method used

The APAO gene was cloned from a fungus growing on maize, and was subsequently optimised for expression in maize by a method called "gene shuffling".

Conclusions

- Optimised APAO is highly specific for fumonisins.
- Pioneer has verified that the APAO enzyme is active and effective in transgenic maize; further evaluation of the effectiveness of this approach to the control of mycotoxins is under way.

Comments

- Enzyme is expressed in all parts of the grain.
- Pioneer has decided not to commercialise this technology.
- The enzyme works within the cell.
- The technology is good.
- Not all the moulds are detrimental.

The meeting consensus was that the technology be looked into further and see how best it could be used in Africa, particularly if Pioneer can donate it for this purpose.

Development and transfer of mycotoxins: Related food safety technologies for Sub-Saharan Africa

Presenter: ***Ranajit Bandypadhyay***

We need food security and food safety especially in the major food crops cassava, yam, maize, plantain, sorghum, millet and rice, so that people have sufficient nutritious food for a healthy and active life. Appropriate technology is needed to help in sorting out and processing food to avoid contamination as well as the growing, harvesting and storage of the product. Proper management of food is essential and must involve national institutions, farmers and policy makers.

If there is a commercial window for African farmers' products, then development will take place. If the control of mycotoxins is implemented, the value of the crop will increase. Resilient grain that is nutritious will increase food safety.

Studies on interventions should be carried out where possible. In addition, awareness campaigns on the dangers of mycotoxins would encourage their control. Use of chemicals and pesticides reduces fungal contamination and ultimately mycotoxins.

Currently IITA's goal is to increase the farmers' income, improve nutrition and sustain food security in eastern and southern Africa.

Objectives are to improve food security and safety by: reducing mycotoxin levels; enhance food export; and strengthen regional capacity in managing the negative trade and health effects of mycotoxins.

The rational for investing in plant breeding and biotechnology is that it will provide an opportunity to achieve technological advances. Besides modern plant breeding cannot operate without biotechnology.

Questions and responses

1. **Is there a way to create awareness even with the government?**
   Yes there is but the government structures are not in place to effectively control mycotoxin levels. First the government must be made aware of the dangers and then have some structure in place that can help farmers keep the required standards. Likewise, technologies, quality systems, increased awareness, and networking are being promoted.

2. **Is the available drying machine intellectually protected?**
   Commercial dryers are protected by IP and one can buy such machine on the market.

3. **How can one measure the impact of controlling mycotoxins on human health?**
   It is not easy to have a proper guideline because people can look healthy yet they are suffer-

ing. As of now there is no direct way of doing it and the mycotoxins in the blood can only be detected within two weeks. Additionally, there are many other factors that contribute to human health, non contaminated food is only one such factor.

4. **How does environmental stress impact on contamination of crops? What can one say about it?**
This is very clear on a study done on groundnuts. If the soil is contaminated then so will the groundnuts and that is why we must work with environmentalists and other organisations. Perhaps the way to go is that every packet of food should have a compulsory trade mark indicating the level of mycotoxins, but measuring every sample can be challenging. For technology to be successful, it must fit in the institutions and into the socio-economic situations of the farmer. Use a straight line adoption pathway, but this is an ideal in that there is a great deal of interaction in the steps, as well as fine tuning. Harvest must be under the best conditions and awareness are crucial. Adoption of pesticides must be regulated.

Draft project

This project is yet to be drafted. Its goal will be to increase food security and safety in eastern and southern Africa to improve income and nutrition.

Objectives

- Improve health by reducing mycotoxin contamination in targeted commodities through improved food security/safety.
- Enhance competitiveness of agriculture and trade of targeted commodities by developing and implementing mechanisms of quality standards with special reference to aflatoxins.
- Strengthen regional capacity in managing negative trade and health effects of mycotoxins.

Comments

- Mycotoxins control needs a wholistic approach.

Questions and responses

1. **How can one measure the impact of controlling mycotoxins in human health?**
It is not easy as there are many factors. However, one could look at the productivity of people, health aspects etc. This is currently being done in Benin where different population samples are being constantly monitored. It was also suggested that impact could be measured by using nutritional status.

2. **Regarding environment/stress, was draught included and for what crops?**
Yes, for maize and peanuts.

3. **How widespread is the adaptability of technologies, particularly in demand-driven technologies?**
This depends on adaptability, benefits and sustainability of the technology. It is also important that all the stakeholders are involved.

Mycotoxin contamination: Legal and intellectual property (IP) consideration

Presenter: ***Richard Y Boadi***

Introduction

The paper presented historical perspectives of mycotoxins injury going back to the ninth century in Europe, Ethiopia in 1977, Russia in 1942–48, Turkey in 1960 and in the US in 1986 where a report indicated ingestion by horses of contaminated hay. In 2003 approximately 20,000 Africans died of food poisoning and in Kenya more than 100 people died in June 2004.

Mycotoxin regulations

The General Agreement on Tariffs and Trade (GATT) regulations require governments to act on food provided it is not for protectionist reasons and the World Trade Organisation (WTO) members are encouraged to use international standards to protect human lives. The SPS refers specifically to the *Codex Alimentarius Commission* among others. Only 15 countries in Africa have known regulations with only Morocco having detailed regulations. However, these regulations vary from country to country and could raise international trade issues. Some regions have harmonised regulations like the European Union (EU), Australia and New Zealand. Mycotoxin control mechanisms may involve utilisation of other parties' intellectual property (IP) including patents, trademarks, plant breeders' rights and copyrights.

Patenting

A patent is a monopoly granted by the State for novel products and processes in exchange for a full disclosure. Utilising genes to modify plants and make them resistant to mould infection will involve utilisation of genes that may be patented.

Patents are national rights and the monopoly conferred is confined to the country where the patent is granted. Trademarks are national rights that can be protected, for example in the EU by a single application to the trademark office in Spain. Sub-Saharan Africa (SSA) does not have this kind of unitary registration and there is need for one. The ® symbol is used for registered while the ™ symbol is used for property rights. It is an offence to use ® for unregistered marks. Plant Breeders Rights (PBRs) are designed to protect new varieties and are governed by the International Convention for the Protection of New Varieties of Plants as adopted by countries. To qualify, a plant variety must be distinct from other types. However, if a new plant is discovered aimed at controlling mycotoxins, then one may apply for PBR protection.

Legal implications of mycotoxic injury have not been reported in SSA but the procedure is skewed towards the government. This is because the link between mycotoxins and disease is not clear and it is difficult to prove that mould infection is the cause and there is no other superseding cause.

Use of banned chemicals could constitute criminal liability.

Questions and responses

1. **Is there an understanding of liability of food products?**
   There has been poor communication on this issue so people are unaware of the advantages.

2. **Is there an understanding of IP and liability of products?**
   The technology itself remains IP but sometimes one borrows from other properties and it becomes difficult. Negotiation of IP is not difficult and does not constitute a problem. As research continues, we need to look at vitamins in maize so that we have low mycotoxin levels with high nutrients.

3. **Can citizens sue a government?**
   It would be difficult to institute if they cannot point to some damage. Countries may also have sovereign immunity against suits, but this is not true in all cases.

Thursday, 24 June 2004

Task Force work

Session Chair: **Phelix Majiwa**

The intended work for the Task Forces (TFs) was eventually done in plenary, each participant being requested to find time to review and prioritise the activities (nine in total) that had been identified (during plenary session).

Rationale

The identification of the activities was done within the context of three broad bases, with the primary objective of putting attention on mycotoxins.

Dimension of the mycotoxins problem

With regard to scope and extent of the problem in Africa, the investigators gave focus, as necessary, to various aspects: geographic domain (Africa-wide or specific countries), variation in impact/severity and possible relationship of magnitude of the problem to post-harvest practices, dietary, cooking or food processing preferences. It was also paramount that the effect of this problem be directed first to poor communities/families and the food crops they depend on; then to medium to large scale farming operations where trade could be affected by occurrence of mycotoxins.

Investigators listed the following factors relating to dimensions of mycotoxins as a problem in Africa. This was a necessary exercise as a prelude to defining how the problem identified could be addressed through a variety of possible interventions.

(a) What mycotoxins exist in a country (extent, level, diagnostic tools, etc)?

- Identify and document which mycotoxins are important or problematic in different countries or sub-regions. Consider this in relation to the following crops affected by mycotoxins:
  - Maize
  - Peanuts
  - Cassava
  - Yam
  - Cowpea
  - Sorghum
  - Millet (pearl and finger)

- To what extent is mycotoxin contamination a problem?

- Extent of exposure
  - Data available
    - Quality and coverage of the data
    - On different crops/commodities
    - In different ecological regions
    - Points at which contamination occurs, eg pre-harvest, post-harvest, storage or processing
    - Standardisation of protocols used in investigating the problem
  - Use data to quantify the problem
  - Generation of data to determine or support extent of the problem
    - Well structured and planned surveys at national levels

- Level of exposure depending on what is consumed:
  - Food baskets by region/sub-region – FARA definition of sub-regions
    - Food consumption surveys
    - Link food production to nutritional status
    - Samples analysed must be representative of sub-regions
      - surveys on crops that are representative staples for specific sub-regions
      - standardisation of protocols essential
      - multi-season, multi-year and multi-location
      - crop management practices should be captured
    - Food modelling linked to levels of exposure

- Existence of good diagnostic tools/sub-regional diagnostic labs and capacities (how broad should it be?)
  - Determine centres of excellence on a country basis for testing crops
  - Identification and typing of mould strains
  - Analytical tools for specific mycotoxins (on sub-regional basis)
    - ELISA
    - Which specific mycotoxins should be focused on

(b) Impact of the mycotoxins on:

- Food for consumption by resource poor households
  - agricultural production
  - availability
  - lower commodity value
  - nutritional quality of the commodity
- Human health
  - Acute
  - Chronic
- Trade: large and small scale agricultural commodities for trade
  - WTO framework for international trade
  - Codex standards/guidelines (WHO/FAO)

- Development of regulatory regimes in African countries and trading partners
- Food crops exported out of Africa
  - Commodities affected – peanuts
  - Export value
  - Marketing paths
- Commodity trade within African countries
  - Peanut, maize – west Africa
  - Peanuts – South Africa

Approaches to addressing the problem: Interventions

Here account was taken of the science of the different technological options that may be available now or in the future for addressing the mycotoxins problem namely, established technologies used in the past, the ones used currently and those under development. In the process the following questions, inter alia, were addressed: IP ownership of these technologies; relative effectiveness and portability (adaptability/adoptability) of the different options across crops/foods, geographic domains, cultural/dietary preferences; roles of different entities (AATF/NGOs/technology developers/owners, regulatory agencies, commercial outlets) in accessing and deploying these technologies; main problems that discourage widespread adoption of (effective) technologies for dealing with mycotoxins in different food crops; how the different initiatives for controlling mycotoxins can be linked to achieve maximum synergies for the benefit of African smallholder producers/consumers; time intervals of the possible availability of the technologies for use in Africa (short-term: 1–3 years; medium term: 4–7 years; long term: 7–10 years).

Specifically, the possible approaches were given as follows:

1. Modifications in management practices

- Pre-harvest/Good agricultural practices to reduce infection
  - Selection of appropriate crop varieties
  - Planting date
  - Crop population density/spacing
  - Application of fertilisers/manuring
  - Weeding
  - Tillage
  - Irrigation
  - Crop rotation
  - Use of fungicides/insecticides/herbicides
  - Crop residue management
  - Use of appropriate models

- Harvest practices
  - Time of harvest
  - Method of harvest (cutting/heaping)
  - Mechanical damage

- Post harvest (farmer, trader and processor levels)
  - Farmer/trader level
    - Drying
    - Threshing
    - Sorting
      - Manual/handpicking
      - Mechanical
    - Storage operations
    - Use of pesticides/smoking/botanicals
    - Prevention of insect pests and rodents
  - Processor level
    - Cleaning
    - Sorting
      - Manual/handpicking
      - Mechanical (to be identified and adapted/constructed to suit the local conditions and commodity)
    - Winnowing
    - Sieving to remove screenings
    - Washing (floatation/density segregation)

2. Use of biocontrol agents (still experimental: ready for approval in 3–5 years)

- Will have to undergo registration
- Requires a greater level of awareness for end users

3. Development of fungal resistance (still experimental)

- Identification and characterisation of fungal resistance in plants/crops
  - Use of conventional means – breeding for resistance to mycotoxigenic fungi
    - Crops in which natural resistance occur
      - Maize – basic germplasm for aflatoxins resistance available (IITA)
      - Peanuts – germplasm available at ICRISAT, will require adaptation for different environments
      - Sorghum – germplasm available for west, east and southern Africa at ICRISAT
  - Use of biotechnological approaches – incorporation of relevant genes into the crops
    - Availability of transformation technology for different crops
      - Genes are available for *Fusarium*, not yet for *Aspergillus*
    - Impart resistance to fungal growth to the crop (3–7 years)
      - *Fusarium* – maize and wheat

    - Other crops targeted for transformation (not for mycotoxigenic strains) – banana and cassava
    - The gene construct for resistance to *Verticillium* wilt in potato is available from Monsanto
    - Joint effort between ICRISAT and University of Wisconsin to discover resistance genes in peanuts
  - Inhibition of mycotoxins production in the crop (at concept stage)
  - Detoxification of mycotoxins – specific for fumonisins in maize
    - Technology is available at Pioneer
    - Adaptation trials will be needed
    - Biosafety studies (enzymes) for regulatory purposes need to be conducted
    - Potential countries – Kenya, South Africa, Zimbabwe and Nigeria

4. Resistance to biotic or abiotic stresses

- Insect pest resistance
  - Natural resistance in maize, improved lines of cowpea (cowpea weevil), low levels of resistance in west African sorghum
    [*Data is available on the extent of mycotoxin production in insect damaged maize. Clear relationship established between insect species and fungal species in west Africa*]
  - Transgenic resistance (*Bt* gene in a variety of crops)
    - Maize protected against insects is less predisposed to fungal attack. *Bt* maize is being tested in South Africa, Zimbabwe and Kenya. Use of *Bt* maize has been shown to reduce fumonisin levels. Reduction in aflatoxins has not been measured.
    - Technology is available from Monsanto, Dupont and Syngenta. (Available in different germplasms)
    - Accessibility
    - Affordability to the subsistence and smallholder farmers

- Drought resistance
  - Drought tolerant varieties should be suitable for particular environments
  - Use of marker assisted selection/breeding for drought tolerance
  - Adaptability trials needed

5. Dietary interventions

- Target areas with high aflatoxins exposure levels
- Reduction of the frequent consumption of high risk food (maize and groundnut)
- Different methods (that have less risk) to prepare maize- or groundnut-based food

6. Chemoprevention

- Alteration of mechanism of damage – Oltipraz – clinical trials proved efficacy in China – have to take one pill a day, specific to aflatoxin
- Blockage of absorption of aflatoxin – chlorophyllin – selective absorption of mycotoxin in the gastro intestinal tract – HSCAS

7. Detoxification (detoxified products can only be used as animal feed)

- Physical methods
  - Handpicking and sorting
  - Floatation method
  - Radiation
- Chemical methods
  - Ammoniation (approved method)
  - Ozone
  - Monoethylamine
- Microbiological method
  - Incorporation of probiotics into diet
  - *Lactobacillus* sp.
  - *Propionibacterium* sp.

8. Processing techniques

- Cleaning
  - Sorting
    - Manual/handpicking
    - Mechanical (to be identified and adapted/constructed to suit the local conditions and commodity)
  - Winnowing
  - Sieving to remove screenings
  - Washing (floatation/density segregation)
- Steeping (effective for fumonisins)
  - Change steep water often during a 48-hour steep period
  - Use as much water as possible to steep maize
- Dehulling and degerming (effective for aflatoxins and fumonisins)
- Cooking/boiling (effective for aflatoxins and citrinin)
  - Moisture content and cooking times are critical
  - Are aflatoxins and citrinin metabolised into other toxic compounds with heat treatment?
- Industrial (medium to large scale processing)
- Sorting
  - Use of electronic sorters based on colour or density (already in use for peanuts)
- Fermentation
  - Ochratoxin A and patulin levels are reduced during wine making

- Wet and dry milling
  - Dry milling (effective reduction of aflatoxins and fumonisins in grits and flour but high in germ and hulls
  - Wet milling
  - Fumonisins in starch fraction not detectable but high in gluten
- Combined use of elevated temperature and pressure (extrusion cooking)
  - Fumonisins are effectively reduced

9. Awareness creation

- Awareness about findings of surveys on prevalence and effects of mycotoxins in staple foods and feed
- Targeted approaches for different stakeholders
  - Community opinion leaders
  - Farmers
  - Consumers
  - Policy makers
  - Researchers
  - Extension workers
  - NGOs
  - Donors
  - Media
  - Traders
  - Processors
  - Health workers
  - School children
- Awareness about toxigenic fungal infections and effects on:
  - Human health
  - Trade
- Awareness of preventive measures

Criteria for prioritisation of interventions/activities

1. Availability of technology that can be applied in the short, medium and long term.
2. How big an impact /measure of returns upon implementation of an intervention.

Other elements to consider:

- What are the implicit IP/regulatory/liability issues, if any
- The activities should be multi-locational (sub-regional); this is because AATF is going to work closely with sub-regional agricultural research organisations.

Interventions/activities

1. Comprehensive literature search on studies in Africa (inventory search)
2. Survey in three sub-regions:
   (a) (i) Use data from previous work as background.
   (ii) Use common protocol.
   (b) Determination of mycotoxin types and impacts.
   (c) Food basket survey and other indicators of health.
3. Study on nutritional impact of mycotoxins: Benin study can be used as a model.
4. Study on economic impact of mycotoxins.
5. Dietary interventions.

Table of interventions

	Interventions	Task Force leaders
1.	Diagnostics	
2.	Awareness creation/modification of management practices (behaviour change?)	(Kilei/Pascal/Ranajit)
3.	Processing techniques	Kafui (Pascal, Gordon, Esther, Samuel)
4.	Development of fungal resistance	(Lawrence/Ranajit)
5.	Resistance to biotic and abiotic stresses	(Hester)
6.	Use of biocontrol agents	(Lawrence/Ranajit)
7.	Dietary interventions	
8.	Detoxification (animal feed)	
9.	Chemoprevention	

Note:

- It is the responsibility of the TF leader to identify people who can contribute to the development of the interventions.
- Membership to any group is open to those present and any others from outside of the meeting group.

Project formulation

The goal here was to consider how the apparent problems identified could be matched with (technological) control options, and to clarify the critical path to delivering existing technologies and capture all these in the form of specific project activities to be undertaken – with clear objectives.

Closing remarks

Dr Terry applauded the energy and intellect put into organising the meeting and conducting the proceedings, and especially given that the response was good despite the short notice.

He said that the meeting was successful as the objectives were met; and arising from the discussions, there was a basis for calling a larger stakeholders' meeting.

Interventions, activities and criteria were established and priorities set as well as TF leaders identified.

Prelude

Responses to the closing remarks

Q. 1 **Why did we not use proprietary and delivery as one of the selection criteria for the interventions?**

Terry: *AATF is not worried as long as we have used certain considerations that will lead to these factors. We wanted to be as inclusive as possible and tease out areas in which we can play a role. We did not want to be accused of being too narrow in our focus.*

Q. 2 **Product concept: Seed of high quality cowpea ... would seem too broad?**

Terry: *Indeed, this then allows you to prioritise within that area. What you may want to do really is to see how you can broaden or narrow the product concept of mycotoxins. Moreover, the Terms of Reference must be very well and carefully crafted, as was done in the case of the cowpea product concept.*

Q. 3 **The issue of capturing the synergy between different interventions: How do we do it as a multi-disciplinary approach to solve a problem?**

Terry: *Within this meeting, you have yourselves found synergies. Secondly, each TF must have a de-segregation for the interventions you are involved in and bring this out during the stakeholders' meeting; with a view to discussing it as extensively as possible. This is the third SGM we have had, and only had one large stakeholders' workshop on cowpea; hence this is still a learning process for all of us.*

Q. 4 **Are donors going to be involved in the stakeholders' workshop?**

Terry: *In some cases, in the past, there are some donors who showed ready interest and in such a scenario, we can tie that together with ease. Secondly, this is not where to seek out donors: donors would, ideally, be brought in when you have a business plan. We do not want to go the old way of doing things – of shopping for donors first, and then you end up not being focused. We prefer to put things together and then bring it out/sell it to the donors.*

Q. 5 **Speaking as a donor, the USAID representative felt there was need for donor-sensitisation. The participants wanted to know if he had any ideas that he could share on that proposal.**

Terry *Not quite, I have lessons to take back to the donor office and possibly share this with other donors. It was suggested to the donor representative that the donors could consider holding a donor's consortium to discuss some of the things that have come out of this meeting.*

Other comments

It was noted that AATF agreed they could play the role of sensitising donors into solving some of the short-term interventions.

Linking agriculture health and nutrition: If this is put in juxtaposition, it is possible to win and force those agencies that have been working in 'silos' to break the barriers and collaborate and support each other.

As a concluding remark, participants were unanimous in compliments to the Publications and Communications Unit for good publications. The Unit in turn expressed the willingness to capture the stakeholders' meeting in the same manner.

Way forward

Linking to technological solutions

Looking at the mission, problems need to be linked to technological solutions. This can be in any form, but will be underpinned with the two pillars (i) **access to these technologies** and (ii) **delivery**. There is a tricky situation here because of proprietary – ACCESS OF TECHNOLOGY FOR TRANSFER TO POOR FARMERS.

The other tricky part is the DELIVERY. There is very little that AATF can contribute to technology that is already in the public domain. How can this be linked to the delivery? If, perhaps, the technology was made available by AATF or in collaboration with AATF? A good example here is Esther Sakyi-Dawson's Network on (Post-harvest Technology Marketing) that form a quantum involved in the delivery. This is a model that can be used. Indeed, focus must be on areas that have been neglected in the past – bringing the private and public sector together.

Stakeholders' meeting

It was agreed that AATF would work with the TF leaders on the Terms of Reference and, in consultation, agree on the stakeholders meeting to be convened by AATF.

Project funding

Any project (with access, propriety and delivery) at the end of the stakeholders' meeting would have AATF pay up to 75% for concept development.

Project formulation

Decide on what, who and how.

Implementation

AATF pays up to 25% of the project costs.

Annex 1

Workshop programme

Nairobi, Kenya, 22–24 June 2004

Tuesday, 22 June 2004			
Time	**Agenda item**	**Chair**	**Presenter**
0830	**Welcome and introduction**	Eugene Terry	
0900	The AATF: Its mission, and the reasons for convening a Small Group Meeting on Mycotoxins		Eugene Terry, Implementing Director AATF
0930	General aims and procedures of this workshop		Phelix Majiwa, AATF
1000	**Group Photograph and Coffee Break**		
	Dimensions of mycotoxin problem in Africa	Hester Vismer	
1020–1040	Overview on agriculturally important mycotoxins in Africa		Hester Vismer
1050–1120	Epidemiology and incidence of mycotoxins/aflatoxins in African smallholder farms		George Bigirwa
1130–1150	Mycotoxins in food: Implications for human health in Africa		Gordon Shephard
1200–1230	Effect of mycotoxins on nutritional quality of food crops		Bussie Maziya-Dixon
	Possible interventions	Esther Sakyi-Dawson	
1230–245	Mycotoxins in processed foods		Esther Sakyi-Dawson
1250–1310	Technologies for reduction of mycotoxin contamination: Bio-control, farming, post-harvest and processing practises		Kerstin Hell
1320 –1350	**Lunch break**		
1355–1415	Guidance for Task Forces		Phelix Majiwa
1420–1630	Task Force break-out group meetings		
1630 –1645	**Coffee break**		
1645 – 1710	Task Force Report 1		

1710–1735	Task Force Report 2		
1735–1755	Task Force Report 3		
1830	**Cocktail – ILRI Snooker room**		

Wednesday, 23 June 2004			
	Possible interventions (cont)	Esther Sakyi-Dawson	
0900–0920	Opportunities for controlling mycotoxins in agricultural food crops		Samuel Bankole
0940–1010	Approaches to the control of mycotoxin-producing fungi		Dilip Shah
1015 –1030	**Coffee break**		
1030–1050	The use of food processing procedures that reduce levels of mycotoxins		Pascal Fandohan
1100–1130	Development & transfer of mycotoxins – Related food safety technologies for SSA		Ranajit Bandyopadhyay
1140–1210	Mycotoxin contamination and control: Legal and IP implications		Richard Boadi
1230 –1330	**Lunch break**		
1345–1630	Task Forces break-out to finalise their reports		
1635 –1645	**Coffee break**		
	Task Force Reports	Phelix Majiwa	
1645–1700	Task Force Report 1		
1700–1715	Task Force Report 2		
1715–1720	Task Force Report 3		
Thursday, 24 June 2004			
0830 –1200	An outline of a project on mycotoxins in Africa	Eugene Terry	
1200 –1230	Closing	Phelix Majiwa	
1230 –1310	**Lunch break**		
Free afternoon			
1900 –2100	**Dinner – Jacaranda Hotel**		

Annex 2

List of participants

Name & contact address	Biographical sketch	Tel/Fax/Email
Dr Ranajit Bandyopadhyay Plant Pathologist IITA Oyo Road, PMB 5320 Ibadan, Oyo State NIGERIA		Tel: 234 2 241 2626 ext 2844 Fax: 234 2 2412221 Email: r.bandyopadhyay@cgiar.org
Dr Samuel Bankole Department of Biological Sciences Olabisi Onabanjo University PMB 2002 Ago-iwoye, Ogun State NIGERIA		Tel: 234 8 055609115 Email: sabankole@yahoo.com
Dr George Bigirwa Plant Pathologist NARO Namulonge Agricultural Research Institute PO Box 7084 Kampala UGANDA	• Plant pathologist, working on maize and rice • Working with NARO based at Namulonge Research Institute • Head of Maize and Rice Research Program • Professional interest: Plant pathology (Epidemiology)	Tel: 256 77 405600 Fax: 256 75 726 554 Email: gbigirwa2@yahoo.com
Richard Boadi AATF PO Box 30709-00100, Nairobi Kenya	• A member of the bars of the State of New York and the Republic of Ghana. • He is a graduate of Cornell University (LL. M.) in the United States, Ghana Law School (B.L.), and the University of Ghana (LL.B.). • Has worked as senior attorney with the New York State Office for Technology, Contract and Commercial Law Attorney with the New York City Human Resources Administration, Teaching Assistant with the University of Ghana's Faculty of Law, Junior Barrister with Reindorf Chambers in Accra and Assistant Legal Officer with the Ghana Copyright Office. • Currently Legal Counsel at AATF where he advises the Board, management and staff on current technology transfer policy and legal developments at national, regional and international levels; he drafts, reviews and negotiates agreements to which AATF is party; he creates and fosters networks with licensees; and he handles other in-house legal needs of the AATF.	Tel: 254 30 4223700 Email: r.boadi@aatf-africa.org

Dr Aberra Debelo ICRISAT PO Box 39063 Nairobi KENYA	• Educational background: - BSc in Plant Science, Alemaya, Ethiopia (1977) - MSc – Agronomy, Alemaya, Ethiopia (1982) - PhD – Crop Science, Oklahoma State, USA (1992) • Professional experience: - Maize Breeder and National Maize Program Coordinator (1982–1986) - Sorghum Breeder, and National Sorghum and Millet Program Coordinator (1992–1998) - Deputy Director General, Ethiopian Agricultural Research Organisation (1998–2003) - Coordinator, Eastern and Central Africa Regional Sorghum and Millet Network of ASARECA • Publications: Authored and co-authored several scientific papers • Professional interests: Crop breeding – resistant varieties	Tel: 254 20 524 566 Fax: 254 20 524001 Email: a.debelo @cgiar.org
Dr Esther O Sakyi-Dawson Department of Nutrition and Food Science University of Ghana, Legon GHANA		Tel: 233 21 513 290 Cell: 233 24 4367 242 Email: cowpea@libr.ug.edu.gh
Dr Pascal Fandohan Programme on Agricultural & Food Technology PO Box 128 Porto-Novo BENIN		Tel: 229 21 41 60 Cell: 229 03 25 44 Email: lta@intnet.bj
Michael Hall, PhD Regional Biotechnology Advisor USAID Regional Economic Development & Services Office Nairobi KENYA		Tel: (+254-20)-862-400 or 402 Fax: (+254-20)-860-562 or 949 Email: mhall@usaid.gov

Dr Kerstin Hell IITA Biocontrol Centre for Africa 08 BP 0932 Cotonou BENIN	• Post-harvest biologist with IITA • Trained as an agronomist in Kiel, Germany • Worked in a GTZ-project supporting the National Plant Protection service in Benin, mainly doing work on post-harvest pests and leading extension efforts for effective storage techniques and safe use of storage pesticides • Joined IITA as a PhD student to study aflatoxin contamination of maize and strategies for their control • Since 1999, is a project scientist focusing on testing of strategies for the control of aflatoxins, researching the impact of aflatoxins in child health and well-being, looking at biocontrol of post-harvest pests and diseases, and evaluating the uptake of post-harvest technologies • Professional interests: Mycotoxin control, fungal/insect interaction, post-harvest systems, adoption of technologies and food quality	Tel: 229 35 01 88 Fax: 229 30 45 74 Email: k.hell@cgiar.org
Lawrence Kent Director of International Programs Donald Danforth Plant Science Center 975 North Warson Road, St Louis, MO 63132 USA	• Masters Degree at Princeton University • Economist with nearly 20 years experience in agricultural development and policy reform projects, including ten years in Africa • Currently serves as the Director of International Programs at the Donald Danforth Plant Science Center where he helps manage projects to develop and test transgenic virus-resistant crops in collaboration with African and Asian partner institutions • Manages the regulatory approval strategies component of the USAID-funded Program for Biosafety Systems, which seeks to assist developing countries to build operational biosafety systems • Professional interests: Agricultural economics and agricultural biotechnology transfer	Tel: (314) 587-1894 Cell: (314) 761-3851 Fax: (314) 587-1794 or (314) 587-1989 Email: Lkent@danforthcenter.org
Mr Immanuel Kilei Ministry of Health Afya House – Room 417 PO BOX 30016 Nairobi KENYA		

Dr Kafui Akuwa Kpodo Food Research Institute PO Box M20 Accra GHANA	• Senior Research Scientist and Head of the Food Chemistry Division of the Food Research Institute – CSIR of Ghana. • Has been involved in Mycotoxin research for over 15 years and was instrumental in the establishment of the Mycotoxin Unit at the Food Research Institute which is equipped with HPLC and TLC for the analysis of aflatoxins, fumonisins, ochratoxins, citrinin and zearalenone. The lab is currently seeking accreditation to ISO17025 • Has coordinated and been local Project Leader for various projects on mycotoxins at the Food Research Institute. Among these are: - a just ended EU-funded project titled "Biological degradation of aflatoxins in fermented maize and sorghum products" - Peanut Collaborative Research Support Program projects on mycotoxins with Texas A & M and Alabama A & M Universities in the United States • Professional interests: Research into mycotoxins in agricultural crops in Ghana and seeking ways of reducing mycotoxin contamination in food	Tel: 22 21 7010557 22 21 777330/761209 Cell: 233 24 650635 Email: kpodofri@ghana.com
Dr. Phelix Majiwa	• A molecular biologist with over 20 years of professional hands on engagement in work on the molecular biology of parasites, pests and pathogens of human, livestock and crops, most of it at the International Livestock Research Institute Nairobi, Kenya • Longstanding and keen interest in safe application of biotechnology, specifically molecular biology and genomics, for the improvement of human welfare in the developing world. • Technical expertise in the area of initial identification and development of molecular diagnostics and vaccine candidates, and the deployment of these for better understanding of the epidemiology and control of diseases common in the developing world	Email: majiwap@arc.agri.za
B Maziya-Dixon, PhD IITA PMB 5320, Oyo Road Ibadan, Oyo State NIGERIA		Tel: 234 2 241 2626 Fax: 234 2 2412221 Email: b.Dixon@cgiar.org

Paul Muchena Pioneer Overseas Corporation, ART Farm, Tevotidale Road, P Bag BW 6237, Borrowdale Harare ZIMBABWE	• Maize Development Scientist for Pioneer, responsible for Central and East Africa • Also responsible for registration of Pioneer products in the region, including genetically modified products • Has been working on maize issues for more than 25 years • Professional interest: Maize breeding and evaluation	Tel: 263-4-339301, 339303, 339359. Fax : 263-4-339102 Cell: 263-11-603535 Email: Paul.muchena@pioneer.com
Nancy Muchiri AATF PO Box 30709-00100, Nairobi Kenya	• Public relations practitioner with over 14 years experience • BA degree and postgraduate Diploma in Mass Communication from the University of Nairobi. • Diploma in Management from the Kenya Institute of Management. • Three years with SOS Children's Villages, Kenya an affiliate of SOS-Kinderdorf International, where she established and headed the Fund Raising and Communications Department • East Africa Portland Cement Company Ltd as head of the Public Relations section for 11 years, providing corporate and product communications needs.	Tel: 254 20 4223700 Email: n.muchiri@aatf-africa.org
Lucy Namu KEPHIS PO BOX 49592-0100 NAIROBI KENYA	• Senior Analytical Chemist, working with KEPHIS • Background is analytical chemistry (with biochemistry) • Professional interests:Developments in mycotoxin analysis in foods, with emphasis on quality assurance and food safety in developing countries	Tel: 254 20 – 884545/882308 Email: kephis@nbnet.co.ke
Rosemary Ng'ang'a Kenya Plant Health Inspectorate Services (KEPHIS) PO BOX 49592 Nairobi KENYA		Tel: 254 20 884545/882308 Email: kephis@nbnet.co.ke

Dr Dilipkumar Shah Domain Member Donald Danforth Plant Science Center 975 North Warson Road St Louis MO 63132 USA	• PhD, North Carolina State University (1976) Major: Genetics • Post-doc Positions (1976–82) - National Institute of Environmental Health Science - University of Chicago - University of Georgia • Science Fellow: Monsanto Company (1982–1996) • R & D Director for Ag Sector, Monsanto, India (1996–2001) • Domain Member, Donald Danforth Plant Science Center, St Louis, MO (2001–present) • Professional interests: Plant-pathogen interactions and plant molecular biology	Tel: 314 587 1481 Email: dshah@danforthcentre.org
Dr Gordon S Shephard PROMEC Medical Research Council PO BOX 19070 Tygerberg 7505 SOUTH AFRICA	• Graduated with PhD in Chemistry, University of Cape Town (1973) • Joined Program on Mycotoxins and Experimental Carcinogenics (PROMEC) of the South African Medical Research Council in 1989 • Worked extensively on mycotoxin analysis in staple foods, especially fumonisins in maize • Professional interests: Analysis of mycotoxins, mycotoxin contamination of staple foods	Tel: 27 21 938 0279 Fax: 27 21 938 0260 Email: Gordon.shephard@mrc.ac.za

Dr Eugene R Terry Atecho & Associates Consultant 4109 17th St NW Washington DC 20011 USA	• Plant pathologist and an agricultural research and development specialist with 36 years of professional experience in research, research management, technology generation and dissemination • Has held leadership positions in capacity building and institutional management in universities, international agricultural research institutes and international development agencies. • Holds a BSc in agriculture and an MSc in plant pathology from McGill University, Montreal, Canada and a PhD in plant pathology from the University of Illinois, Urban-Champaign, USA. • Has been associated with the University of Sierra Leone • Held Plant Pathologist and Director of International Cooperation and Training at the International Institute of Tropical Agriculture, Ibadan, Nigeria. • First Director General of the West Africa Rice Development Association, Bouake, Cote d'Ivoire, for nine years • The World Bank in Washington DC, first as an Advisor (Agricultural Research and Extension Group-ESDAR), and then later as Crops Advisor, in the Rural Development Department. • Was Implementing Director of the African Agricultural Technology Foundation. • Currently Chairman of the Board of Trustees of the World Agroforestry Centre in Nairobi, Kenya. • He served (until November 2002) as a Trustee of the International Water Resources Management Institute in Colombo, Sri Lanka.	e.terry@cgiar.org
Dr Hester Vismer PROMEC Unit Medical Research Council PO Box 19070 Tygerberg 7505 SOUTH AFRICA	• Chief Specialist Scientist and Sub-program Leader of Microbiology at the PROMEC Unit of the Medical Research Council, Cape Town, South Africa • Obtained an MSc and PhD in medical mycology • Has extensive experience in medical mycology, mycotoxigenic fungi, mycotoxins and mycotoxicoses • Has special interest in medically important fungi and the mechanisms of toxin production by food-borne mycotoxigenic fungi • Professional interests: Mycotoxigenic fungi and mycotoxins and medically important fungi	Tel: 27 21 938 0287 Fax: 27 21 938 0260 Cell: 082 469 3756 Email: hester.vismer@mrc.ac.za

AFRICAN AGRICULTURAL TECHNOLOGY FOUNDATION
FONDATION AFRICAINE POUR LES TECHNOLOGIES AGRICOLES

PO Box 30709-00100, Nairobi, Kenya
Tel: +254 20 422 3700, Fax: +254 20 422 3701
Via USA – Tel: 1 650 833 6660, Fax: 1 650 833 6661
Email: aatf@aatf-africa.org
Website: www.aatf-africa.org