A Multipronged Approach for Aflatoxin Mitigation in Africa Centered on Biological Control

Ranajit Bandyopadhyay
International Institute of Tropical Agriculture (IITA)
Ibadan, Nigeria
Alarm over 2.3m bags of bad maize in market
Importance of aflatoxins

Aspergillus

Aflatoxin B1

Occurrence

40% of commodities in local markets exceed ML

Susceptible crops

Maize, groundnuts, sorghum, cottonseed, chili, millet, figs, melon seed, ginger, sesame, cassava, almond, pistachio...

Liver cancer

Death

Up to US$ 670 million are lost from exports

Groundnut exports in metric tons

99.59% decrease

Sorghum

48.23% decrease

291,000

2013

1,193 MT

1970

Source: UNICOFW/Bank World/World Bank, 2016
History of aflatoxicosis outbreaks

Slide prepared by C. Probst and modified by A. Ortega
# Health impacts of aflatoxins in Africa

## Countries

<table>
<thead>
<tr>
<th>Countries</th>
<th>Subject</th>
<th>Sample</th>
<th>Aflatoxin levels: Incidence (Mean)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benin</td>
<td>Children (n=480)</td>
<td>Blood</td>
<td>99% (33 pg/mg)</td>
<td>Gong et al. 2003</td>
</tr>
<tr>
<td>Benin/Togo</td>
<td>Children (n=200)</td>
<td>Blood</td>
<td>98 – 100% (37 – 87 pg/mg)</td>
<td>Gong et al. 2004</td>
</tr>
<tr>
<td>Tanzania</td>
<td>Children (n=166)</td>
<td>Blood</td>
<td>84% (13 pg/mg)</td>
<td>Shirima et al. 2015</td>
</tr>
<tr>
<td></td>
<td>Children (n=166)</td>
<td>Blood</td>
<td>99% (24 pg/mg)</td>
<td></td>
</tr>
</tbody>
</table>

## Findings (association)

<table>
<thead>
<tr>
<th>Countries</th>
<th>Findings (association)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana/The Gambia</td>
<td>Exposure and <strong>immune suppression</strong></td>
<td>Williams et al. (2004)</td>
</tr>
<tr>
<td>Ghana</td>
<td>Exposure and <strong>low-weight, still birth and pre-term babies</strong></td>
<td>Shuaib et al. (2010b)</td>
</tr>
<tr>
<td>Tanzania</td>
<td>Exposure and <strong>reduced weight and height</strong> among breast fed infants under 6 months</td>
<td>Magoha et al. (2014)</td>
</tr>
<tr>
<td>Benin/ Togo</td>
<td>High aflatoxin levels and <strong>lower growth rates</strong></td>
<td>Gong et al. (2004)</td>
</tr>
</tbody>
</table>

## Country Health indicators

<table>
<thead>
<tr>
<th>Country</th>
<th>HCC cases/year</th>
<th>Disability Adjusted Life Years (DALYs) lost</th>
<th>Cost in Million USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigeria</td>
<td>7,761</td>
<td>100,900</td>
<td>380 – 3,174</td>
</tr>
<tr>
<td>Tanzania</td>
<td>3,333</td>
<td>96,600</td>
<td>25</td>
</tr>
</tbody>
</table>
Economic impact of aflatoxin control in Senegal

Compliance has economic incentives

$4.1 million capital investment + 15% recurring cost for aflatoxin control

$281 million added value annually to export for the capital investment

30% price differential to oil cake

Export increase from 25K tons to 210K tons

Courtesy: World Bank
There are moral and economic reasons to address aflatoxins in Africa due to health, trade and food/nutritional security considerations.
Aflatoxin in Groundnut and Maize at Harvest, 2012, Nigeria

<table>
<thead>
<tr>
<th>Aflatoxin (ppb)</th>
<th>Peanut (n = 188)</th>
<th>Maize (n = 241)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distribution (% samples)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 4</td>
<td>54</td>
<td>70</td>
</tr>
<tr>
<td>&gt; 10</td>
<td>41</td>
<td>52</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>29</td>
<td>24</td>
</tr>
<tr>
<td><strong>Descriptive statistics (ppb)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>&lt; LOD</td>
<td>&lt; LOD</td>
</tr>
<tr>
<td>Maximum</td>
<td>3,487</td>
<td>838</td>
</tr>
<tr>
<td>Mean</td>
<td>111</td>
<td>33</td>
</tr>
</tbody>
</table>

Problem starts in the field

And....... increases in store
Multiple practices to manage aflatoxins

- Drought-tolerant & adapted varieties
- Farmyard Manure
- Liming
- Mulching
- Tied ridges
- Biocontrol
- Drying
- Sorting & grading
- Storage
- Testing
- Roasting
- Ammoniation
- Clay
- Diet diversity

Planting → Harvest → Consumption

Awareness, institutions and policy
Aspergillus, crops and biocontrol

Crops will always become associated with *Aspergillus* fungi

Thousands of genotypes
Vegetative Compatibility Groups (VCGs)

Aflatoxin content range (ppb)

- 0.0 – 20
- 21 – >48,000

Propagules / g

- 1 – >1,000,000
Aflasafe composition

Aflasafe ingredients

Product

Product in the field

Non-treated field

Treated field
Aflatoxin reductions

More than 1,500 farmers’ field trials in 4 countries

Treated vs non-treated

95%: <4 ppb
5%: 5 – 20 ppb

vs

>20, >100, >1,000 ppb

In 2017, over 105,000 ha were protected with Aflasafe products
Biocontrol is a **simple** field intervention that **effectively** reduces aflatoxin contamination **from farms until consumption**

- One application per season
- Multi-crop & multi-season effect
- 10 kg/ha
- $12-19/ha
- Willingness to pay: $11-19/ha
This Manufacturing Facility in IITA- Ibadan can supply aflasafe to treat 2 million ha annually.

Large-scale: capacity 5 tons/hour
Product cost: $12 to $18.75/ha
Status of Aflasafe development in Africa

(June 2018)

Strain development process

Products under testing in farmers fields

Products ready for registration

Products registered and commercialization process begun

Countries:
- Ethiopia
- Rwanda
- Burundi
- Uganda
- Kenya
- Tanzania
- Malawi
- Mozambique
- Zimbabwe
- Zambia

Countries:
- Mali
- Senegal
- The Gambia
- Burkina Faso
- Ghana
- Nigeria
- Cameroon
Host-mediated control

- Resistance is the most preferred solution
- Major efforts to breed for resistance since the last 40 years
- Excellent progress made in identifying sources of resistance
- Proteomics, transcriptomics, marker research underway
- RNAi and transgenics provide extremely high resistance
- No farmer-acceptable resistant cultivar available, search continues
- Drought-tolerant adapted cultivars best bet

Thakare et al. 2017
Combining resistance and biocontrol

**Aflatoxin (ppb) at harvest in Low-Aflatoxin Maize Lines With and Without Biocontrol Treatment**

<table>
<thead>
<tr>
<th>Experimental variety</th>
<th>Aflatoxin (ppb)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No biocontrol</td>
<td>Biocontrol</td>
<td></td>
</tr>
<tr>
<td>RSYN2-Y</td>
<td>19.6</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>RSYN3-W</td>
<td>6.9</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>SYN3-Y</td>
<td>18.4</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>TZB-SR (susc.)</td>
<td>57.5</td>
<td>4.7</td>
<td></td>
</tr>
</tbody>
</table>

66-88% AF reduction over Susc. by resistance alone

97% AF reduction over Susc. by resistance and biocontrol combined

74-92% AF reduction over corresponding variety by biocontrol alone
Combining resistance and biocontrol

### Aflatoxin (ppb) after poor storage in Low-Aflatoxin Maize Lines With and Without Biocontrol Treatment

<table>
<thead>
<tr>
<th>Experimental variety</th>
<th>Aflatoxin (ppb)</th>
<th>No biocontrol</th>
<th>Biocontrol</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSYN2-Y</td>
<td>462</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>RSYN3-W</td>
<td>627</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>SYN3-Y</td>
<td>387</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>TZB-SR (susc.)</td>
<td>1,152</td>
<td>163</td>
<td></td>
</tr>
</tbody>
</table>

- **46-66%** AF reduction over Susc. by resistance alone
- **96-98%** AF reduction over Susc. by resistance and biocontrol combined
- **86-95%** AF reduction over corresponding variety by biocontrol alone
Grain drying devices

Interesting developments in grain drying, but no devices scaled up
Grain storage devices

- Newer: Plastic silo (Kentainers), Metal silo
- Traditional: PICS bags, GrainPro Super bag
- Plastic silo (Kentainers), Metal silo
All devices similarly well to suppress aflatoxin increase

All devices have pros and cons

Metal silos are durable, rat-proof, but high initial cost

PICS bags most preferred. Low cost, locally produced and effective

Walker et al., 2018
AflaSTOP project

Comparison of storage devices
Impact of maize postharvest practices

**Postharvest practices evaluated**
- Drying on mat/raised platform
- Hand sorting
- Moisture content testing
- Insecticides use
- De-hulling before milling

Randomized Control Trial, Tanzania
Source: Kamala et al., 2018, WMJ

Good postharvest practices reduce aflatoxins and fumonisins and improve health
Major postharvest loss prevention projects

AflaSTOP:
Drying and Storage for Aflatoxin Prevention
(Formerly the Post-Harvest Drying and Storage for Aflatoxin Prevention Project)

Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss

YieldWise Food Loss
Reducing loss from what we grow and harvest
• Several effective pre- and postharvest technologies are available
• More work required on drying
Institutions

Different scale, type......

• National Food Safety Committees
• Standard setting, implementation and control boards
• International agencies, e.g., CGIAR, FAO, WFP, GAFSP, STDF
• Regional Economic Communities
• National governments and research institutions
• NGOs, e.g., AGRA, GAIN
• Private sector including financing
• Partnership for Aflatoxin Control in Africa (PACA)

Health institutions less involved
In policy-makers agenda:

- Aflatoxin standards: MRLs and CODEX
- FAO codes of practices
- Food safety laws
- Policy briefs by East African Community (EAC)
- Aflatoxin Control Plan for ECOWAS, COMESA and EAC member states
- Mainstreaming aflatoxin mitigation in NAFSIPs

With intentions to implement
Integrated Management

Cost-effective technologies require enablers for adoption and scale-up

**Push elements:**
- Pre-harvest and post-harvest technologies including testing
- Training – farmers, transporters, traders, regulators, consumers
- Awareness – entire range of value chain participants
- Advocacy – regional, national, global
- Policies – standards, harmonization, trade, regulations
- Institutions – regulators, markets, quality assurance, agribusiness

**Pull elements / incentives:**
- Premium market – food/feed processors, poultry/fish industry, export
- Public health – home consumption; urban and rural markets; government procurement, Home-grown school feeding
- Pay for performance
National Innovation System for Adoption

Solutions
1. Policy & Advocacy
2. Laboratory for Certification
3. Inter-governmental Panel on Aflatoxin

Solutions
1. National awareness programs:
   - 1. Testing
   - 2. Training on aflatoxin management
   - 3. Aflatoxin management manual

Solutions
1. Low Awareness on Aflatoxin
2. Ineffective or poorly enforced regulation
3. Absence of Premium Market
4. Invisible Nature of Aflatoxin
5. Subsistence Farming

Solutions
1. Demonstrate product value
2. Innovation platform
3. Market linkage

Solutions
1. Agribusiness group farmers
2. Aggregation for quality control / market access
3. Access to finance, credit and quality inputs
4. Training for Improved productivity and agribusiness
5. Support in GAP for Production
Integrated Aflatoxin Management System

- Public
- Private
- Public-private

- Aflasafe
- Training for aflatoxin management
- Training to improve productivity
- Inputs and services
- Farmer groups/value chain/Finance
- Implementers
- Awareness and sensitizations
- Market linkages
- Policy and advocacy
- Post-harvest management
- Aflatoxin testing
- Aggregation
• 194,310 tons of grains harvested
  • 57% aggregated for sale
  • 27% consumed at home
  • 16% sold in local market

• Productivity: 3.1 tons/ha compared to 1.5 tons/ha national average

<table>
<thead>
<tr>
<th>Grain lots (n = 2,362) with aflatoxin concentration</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;4 ppb</td>
<td>90%</td>
</tr>
<tr>
<td>&lt;10 ppb</td>
<td>94%</td>
</tr>
<tr>
<td>&lt;20 ppb</td>
<td>96%</td>
</tr>
</tbody>
</table>

Meets international standards

More trade

More income

Better health

• 32 agribusinesses
• 49,500 farmers
• Farm size: 1.34 ha/farmer
• 63,000 ha maize grown
• 600 tons Aflasafe purchased

• 32 agribusinesses
• 49,500 farmers
• Farm size: 1.34 ha/farmer
• 63,000 ha maize grown
• 600 tons Aflasafe purchased

More trade

Better health

• 10.7% premium in the market over normal maize
• $1.491 million in net earning from premium

Web links:
www.iita.org    www.cgiar.org
Nestlé Grain Improvement Programme in Ghana (and Nigeria)

Why

• Improved quality and safety of raw materials used in our factories (*up to 50% of maize grains rejected at factory gate in 2007*)
• To use 100% of locally-sourced maize grains

Courtesy: Owen Fraser, Nestlé
Holistic approach to mycotoxins management in maize in the supply chain

Identify the risks
- Establish critical control limits
- Sampling & testing
- Reject non-compliant raw materials

Good Agricultural Practices
- Best variety selection
- Farmers training & technical support
- Post-harvest best practices
- Storage & transport best practices

Technology application
- Mycotoxin testing
- Biological control application
- Application mechanical cleaning & sorting

Significantly reduce & control the level of aflatoxins in the supply chain
Outcome & Social Benefits

- Significantly improved grain quality – rejection at factory gate reduced to less than 4% by 2013
- Over 80,000 farmers trained in awareness of health risks due to mycotoxin contamination in food
- 150 communities trained in contamination prevention
- About 50% are women
- Reduced loss, increased yields and revenue for farmers
- Improved food safety at home
Needs

• More effort needed to create awareness
• Need to test innovations at scale to determine adoption potential
• Cost-benefit analysis of incremental stacking of technologies to better understand value of integrated management
• Opportunities for decontamination or alternate use of contaminated products required
• Work in value chain settings and partner with the private sector
Summary

• Aflatoxins are pervasive in Africa
• More efforts needed to translate knowledge into actions for benefitting African smallholders
• Biological control with other practices can dramatically reduce aflatoxin contamination and improve food safety and security
• Context-specific Institutional and policy innovations must support technology adoption
• Scale-up of sustainable models to commercialize aflatoxin biocontrol underway in Africa