Aflatoxin
Identifying the Way Forward

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The TOPS Program’s Conversations about Aflatoxin
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How Does Aflatoxin Get Into Foods?

- Sporulation
- Air Movement
- Spores
- Insects
- Soil colonization
- Fungal mycelium in grain

Aflatoxin B₁
AF structure elucidated | AF biomarkers validated


From Turkey X disease to human impacts

Maternal exposure and birth/ growth effects in offspring
Infant exposure and growth effects

TIME LINE

GAMBIA longitudinal

GHANA X-sect

BENIN & TOGO longitudinal

BENIN & TOGO X-sect

GAMBIA X-sect

Human Cancer Etiology

CODEX

Turkey X pig lamb rat chicken rat
Known Lost Opportunity Costs for Trade

- Nigeria and Senegal were major groundnut exporters in 1960s, BUT by 1980s (when CODEX regulatory standards were imposed) exports fell drastically.

- In Senegal Alone: US$ 4.1 million would be added in capital investment and 15% recurring cost would attract 30% price differential to oil cake.

- With Aflatoxin Management, Export could increase from 25 to 210K tons.

- Increased export volume and price differential would annually add $281 million value to capital investment.

- For confectionary groundnut, adherence to Good Management Practices would increase export value by US$ 45 million annually.

World Bank; Mbaye (2004)
Known Impacts on Animal Health

Livestock and poultry losses

- Liver damage including cancer
- Recurrent infection due to immune system suppression (mechanisms well understood)
- Significant loss in feed conversion ratio leading to reduced growth rate
- Decreased milk and egg yield
- Embryo toxicity (reduced reproductivity)
- 27% higher mortality when aflatoxin not controlled (dogs, poultry, fish, swine-all non-ruminants), Bandyophadyay, 2013
Known Human Health Effects

• Primary Hepatocarcinogen - WHO Class 1
• Acute and deadly hepatitis outbreaks (Kenya 1998, 2004, 2008; India 1997, China?)
• Associated with severity of TB and other opportunistic infection in HIV-positive individuals
• Child growth faltering and morbidity
• Impaired Vitamin A adsorption
• Reduced rate of immune-competency development
WHO Map of Stunting Prevalence (2011)
Low birth rates, growth faltering and stunting

• Mothers exposed to aflatoxin during pregnancy give birth to significantly lower weight babies

• Under-nutrition and growth faltering is an underlying cause of 50% of deaths in children <5 years age (Black et al., Lancet, 2003)

• Growth faltering is not fully explained by dietary insufficiency and infection. Perhaps only 50-60% is explained (Lunn 2000)

• Childhood stunting is significant from a public health standpoint
  - Associated with increased vulnerability to infectious diseases high mortality risk

• Associated with cognitive impairment risk - beyond childhood (Ricci et al. 2006; Khlangwiset et al. 2011).
How do we know and how bad is it?

- Studies from all over the world are coming to the same conclusion:
- Aflatoxin exposure causes
  - low birth weights from pregnant mothers, and
  - stunting in children in the first 1000 days of life.
Some definitions – Aflatoxin-albumin adduct

Aflatoxin-albumin adduct: aflatoxins bind to a blood protein called albumin. Scientists measure how much aflatoxin is in a person by capturing the albumin and measuring how much aflatoxin is attached. Highly robust assay. (AF-Alb in picograms/milligram)
Definition (cont.) – Z Score

• Nutritional status in children, assessed by relative anthropometric measures
• Height and weight most common measures
• A standardized age- and sex-specific growth reference to calculate height-for-age Z-scores (HAZ), weight-for-age Z-scores (WAZ), weight-for-height Z-scores (WHZ) and body-mass-index-for-age Z-scores (BMIZ).
Known Relationship to Child Stunting

- Associated with low BMI in mothers – transplacental & transgenerational
- Lower birth weights – first 1000
- day exposure
- Stunting – linear dose effect
- 28% reduction in height gain

<table>
<thead>
<tr>
<th>Aflatoxin exposure group</th>
<th>AF-alb adduct (pg µg⁻¹)</th>
<th>Ht. increase* (cm)</th>
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<tbody>
<tr>
<td>Lower quartile</td>
<td>&lt;23.3</td>
<td>5.88</td>
</tr>
<tr>
<td>Upper quartile</td>
<td>&gt;101.5</td>
<td>4.21</td>
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</table>
Aflatoxin-Albumin and growth velocity in Benin (Gong et al., 2004 EHP)

Growth velocity over 8 months - Mean and 95% CI
(adjusted for age, height, sex, weaning status, village, SES)

Height increase over 8 months / cm

AF-alb pg/mg

Height increase over 8 months / cm

p< 0.0001
Relative Mean AF-alb adduct level infants aged 9-36 months, Benin – Modified from Gong et al., 2002
Aflatoxin and growth summary epidemiology data

• **Cross Sectional data** – age 1-5 years of age
  o Stunting significantly associated with AF-alb ($p<0.001$)
  o Dose dependent relationship
    *Gong et al., 2002*

• **Longitudinal** - 1-3 years of age
  o Growth velocity significantly associated with AF-alb ($p<0.001$)
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    *Gong et al., 2004*

• **Longitudinal** - age 0-52 months
  o Stunting significantly associated with AF-alb ($p<0.001$)
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    *Turner et al., 2007*

• **Cross Sectional** - birth weight
  o significantly associated with AF-alb ($p=0.007$)
  o Dose dependent relationship
    *Shuaib et al., 2010*
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Girls to Mothers: Why so many babies?
Median Life Expectancy: 5
Pre-5 Mortality

• 86,301 children
• 28% Poor birth outcomes
• 15% respiratory
• 9% diarrhea
• 7% malaria
We Have Agricultural Technologies and Post Harvest Management Strategies

- **Pre-harvest**
  - Bio- control
  - Fertilizer
  - Crop resistance?
  - Risk management
    - S vs L strains
    - Soil PH
    - Drought stress
    - Cropping cycle

- **Post harvest**
  - Threshing
  - Drying
  - Stores management
  - Sorting/winnowing
  - Floating
  - Cleaning
  - Fermenting
  - Clay supplements (animal feeds)
Players and Motivations

Dev Country Governments

We have to get a handle on this can of worms!!

Will I pay you more?

Marketers

Will you pay me more?

Cheep moi? I’ll pay more!

Consumers

Quality or price?

Public Health

Food Security

So much work!

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What We Don’t Know Yet is How to Achieve Sustainable and Effective Controls in Developing Countries....

Or Do We?

Regulatory Enforcement
Policy
Market Forces
Technology Transfer
Strategic Plan to Drive Sustainability
Leverage Strong Regulatory Enforcement to Sustain Premium Market for Aflasafe maize

1. Supply of Affordable Low-Aflatoxin Maize
   - CADPs and Incentives Push or Pull Mechanisms

2. Enable Market Forces to Drive Sustainability
   - Urban Market Forces

3. Public Health Awareness
   - Health Awareness: Farmer Focus
   - Health Awareness: Industry Focus
   - Health Awareness: End Consumer

4. Enforce Regulatory Policy
   - Policy: Build Regulators Capacity
   - Policy: Develop regulatory framework
   - Policy: Phased in regulatory enforcement mechanism

Year
1 2 3 4 5
Strategic Plan to Drive Sustainability
Leverage Strong Regulatory Enforcement to Sustain Premium Market for Aflasafe maize

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4. Supply of Affordable Low-Aflatoxin Maize
   - Growers produce because economic incentives exist

Year
1  2  3  4  5
Not So Radical Concept

• **Internal** Regulatory enforcement is the cheapest and most direct way to create demand for technology

• Market forces have to create demand
  • Processing industries (baby food, RTUTFs, confections, beer)
  • Feeds industry
  • Urban consumers
Options for future

• Try to educate 100s of millions of people about complex scientific issues, OR
• Area-wide biocontrol as a public health strategy, OR
• Get governments involved in the common good, their primary imperative – Food Safety Regulatory Enforcement
  • Step-wise development of food safety systems, starting with aflatoxin
  • Incremental capability over next 5 years
  • Start with Urban market spot checks with carrot and stick and public exposure
  • Target Urban consumers with food quality motivators and information
Radical Concept

86,301

Farmers whose scale of operation is too small to be able to produce SAFE FOOD, are too small to farm maize (or any aflatoxin sensitive staple) – rethinking paradigms