Impact of Aflatoxin on Health and Trade in Africa

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IITA-Ibadan, Nigeria
Outline

• Food systems
• Prevalence of aflatoxins
• Exposure to aflatoxins
• Impact on health and its cost
• Impact on trade and its cost
• Mycotoxin regulations and challenges in Africa
Food Systems

- Large Scale and Regulated
  - Developed countries
  - Trade based
  - Advanced infrastructure
  - Capital intensive

- Small Scale and Unregulated
  - Developing countries
  - Informal markets
  - Subsistence
  - High food insecurity
Prevalence of Aflatoxins in Food

• Aflatoxins are toxic substances produced by highly prevalent and ubiquitous *Aspergillus* fungi

• High levels from Kenya, Benin, Burkina Faso, Cameroon, Gambia, Ghana, Guinea, Mozambique, Nigeria, Senegal, South Africa, Zambia…….

• **Frequency of occurrence high**
  – >30% maize in stores with >20 ppb aflatoxin
  – ~90% stores are contaminated with Afla fungi
  – Up to 50% grain in households with aflatoxin

• **Several African staple commodities affected** – maize, groundnut, cassava, sorghum, yam, rice, cashews

• Food basket surveys limited

• Environmental conditions, traditional farming methods and improper grain drying and storage practices
Aflatoxin Contamination in W. Africa

Primary products
- Maize: 4000 – Benin
- Peanut: 216 – Ghana
- Sorghum: 80 – Ghana
- Millet: 200 – Nigeria
- Tiger nuts: 120 – Nigeria

Food products
- Peanut paste: 3278 – Ghana
- Peanut sauce: 943 – Ghana
- Leaf sauce: 775 – Gambia
- Maize dough: 313 – Ghana
- Kenkey: 524 – Ghana
- Cashew paste: 366 – Ghana
- Peanut oil: 500 – Nigeria
- Yam flour: 7600 – Nigeria
- Local beer: 135 - Nigeria

MTL = 20 ng/g
Aflatoxin Exposure in Africa, Europe & USA

Aflatoxin-albumin adducts (pg AFB1-lysine eq./mg albumin)

- Gambia (n = 950)
- Benin (n = 479)
- USA (n = 48)
- Europe (n = 74)
Aflatoxins

TRADE Vicious-Link HEALTH

Quality reduction → Aflatoxin contamination in food and feed → Malnutrition

Trade Restrictions → Aflatoxin contamination in food and feed → Liver cancer

Malnutrition → Reduced ability to cope with diseases, especially HIV/AIDS

Liver cancer → Liver cirrhosis, immuno-suppression, blocks nutrient absorption, growth abnormalities, etc.

Synergistic interaction with Hepatitis-B & C

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Aflatoxin and Human Health

- Death
- Contributes to 40% of DALYs
- Impairs growth and development of children
- Suppress immune system
- Aflatoxin interacts with HBV
  - 30 times more potent in HBV+ people
  - 5-60 times higher cancer risk
- May impede uptake and utilization of micronutrients in human systems
- Associated with Kwashiorkor in children
Aflatoxin poisoning in Kenya

- Eastern and central provinces – Jan to Jul, 2004
- True magnitude greater than reported
- 317 cases reported with 125 deaths (CFR 39%)
  - 22% patients <5 years; 29% 5-15 years; 49% >50 years
  - 88% in 4 districts: Makueni, Kitui, Machakos & Thika
  - CFR highest in Makueni district (CFR = 49.3%)
- Nearly 50% samples had >20 ppb aflatoxin B₁
- School-feeding program – 26 deaths in 2005
- Significant risk factors:
  - consumption of homegrown cooked maize kernels
  - possession of discolored or visibly moldy homegrown maize
  - storage of damp maize

Nyikal et al. 2004
Distribution (%) of aflatoxin (ng/g) in maize products in Kenya, 2004

<table>
<thead>
<tr>
<th>District</th>
<th>Products (No.)</th>
<th>&lt; 20</th>
<th>21-99</th>
<th>100-1000</th>
<th>&gt;1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makueni</td>
<td>21</td>
<td>13</td>
<td>40</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Kitui</td>
<td></td>
<td>21</td>
<td>32</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Machakos</td>
<td></td>
<td>25</td>
<td>23</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Thika</td>
<td>66</td>
<td>17</td>
<td>13</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>47</td>
<td>19</td>
<td>27</td>
<td>7</td>
</tr>
</tbody>
</table>

Max 25,000 ppb
Or 1200 times
MTL
Climate Change and Aflatoxin in Kenya

The 2004 Aflatoxin outbreak. Increasing aflatoxin in market maize in brown.

Blue circles – aflatoxin deaths

Drought, high temperature stress and unseasonal rains increase aflatoxin in maize and groundnuts

Increase of duration and area under drought would further accentuate the aflatoxin problem

INCREASING RISK OF AFLATOXIN OUTBREAKS IN MAKUENI AND MACHAKOS

Maize cultivation
Climate change
No Change
Shorter growing season
Serious droughts
Medical epidemiology – Aflatoxin

- Focused on children
- Transversal (across zones): Survey 16 villages, 4 zones; 497 children; 9 months to 5 years
- Longitudinal (across time): 2 zones; 4 villages; 200 children; 3 times (Feb/Mar, May/Jun, Oct/Nov); 16-37 month
- Ethical approval from Governments
- IITA-NARS-University of Leeds collaboration in Togo and Benin
Blood aflatoxin-alb in 6–48 month old infants in AEZ

Benin and Togo
n = 480
16 villages
30 per village
Afla-alb adduct level and weaning status

Gong et al., 2003
Effect of aflatoxin exposure in children

- **Stunting** - 40% more frequent in the high exposure zone
- **Underweight** - 45%; no differences between zones
- **Sex**– No difference

<table>
<thead>
<tr>
<th>Aflatoxin exposure group</th>
<th>AF-alb adduct (pg mg⁻¹)</th>
<th>Ht. increase* (cm)</th>
</tr>
</thead>
<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>
</tr>
</tbody>
</table>
Factors related to aflatoxin exposure

- Aflatoxin content of maize
- Maternal education and socio-economic status – no effect
- Maize-based weaning food
- No. of *A. flavus* colonies of more toxigenic strain in stored maize
Confounding Toxicological Effects

• Poisoning modes
  – Acute poisoning
    • Clear symptoms
  – Chronic exposure
    • Indirect symptoms usually attributed to other agents
      – Immune suppression -> infectious diseases
      – Nutritional interference -> vitamin deficiencies
      – Developmental interference
  – Cumulative exposure
    • Genetic and carcinogenic

• Medical professionals need better information
Wrong Emphasis on Aflatoxin and Human Disease  
(Gong et al)

<table>
<thead>
<tr>
<th>Health effect</th>
<th>Possible deaths (No.)</th>
<th>Relative public attention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological weapon</td>
<td>0 (?)</td>
<td>Very high</td>
</tr>
<tr>
<td>Acute aflatoxicosis</td>
<td>100’s</td>
<td>High</td>
</tr>
<tr>
<td>Hepatocellular carcinoma</td>
<td>10,000’s</td>
<td>Medium</td>
</tr>
<tr>
<td>Growth impairment/ immunosuppression</td>
<td>100,000’s (?)</td>
<td>Low/None</td>
</tr>
</tbody>
</table>
Animal Health Impact of Aflatoxin

- Livestock and poultry losses
  - liver damage including cancer
  - recurrent infection due to immune system suppression
  - reduced growth rate
  - losses in feed efficiency
  - decreased milk and egg yield
  - embryo toxicity (reduced reproductivity)
  - death (cattle, turkey, poultry, swine..)
## Social cost (A$) – Spoilage and Human*

<table>
<thead>
<tr>
<th>Sector</th>
<th>Maize</th>
<th>G-nut</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spoilage</td>
<td>70.9</td>
<td>36.8</td>
<td>107.7</td>
</tr>
<tr>
<td>Human – premature death</td>
<td>112.7</td>
<td>73.2</td>
<td>185.9</td>
</tr>
<tr>
<td>Human – disability/morbidity</td>
<td>63.8</td>
<td>41.5</td>
<td>105.3</td>
</tr>
</tbody>
</table>

*Human life difficult to cost. But, partial costing of economic surplus forgone: √Cost of productive capacity lost due to mortality; Cost of productive capacity due to morbidity/hospitalization ×Cost incurred by Govt. hospitals; intangibles: pain, suffering, anxiety, quality of life….
Social cost (A$) – Animals and Total

<table>
<thead>
<tr>
<th>Sector</th>
<th>Maize</th>
<th>G-nut</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry meat*</td>
<td>28.9</td>
<td>2.5</td>
<td>31.4</td>
</tr>
<tr>
<td>Poultry egg*</td>
<td>6.6</td>
<td>0.6</td>
<td>7.2</td>
</tr>
<tr>
<td>Pig meat*</td>
<td>36.2</td>
<td>3.1</td>
<td>39.3</td>
</tr>
<tr>
<td>TOTAL</td>
<td>319.1</td>
<td>157.7</td>
<td>476.9</td>
</tr>
</tbody>
</table>

*Increased mortality and reduced feed efficiency
Trade Losses due to Aflatoxins

- Export compliance with food safety and quality standards.
- CODEX standard: 20 ppb; EU: 2 ppb
- African exports: EU (51%) & US (22%)
- World Bank estimate of lost trade
  - 2005 study: ~ Tens of millions of $
- Some countries active to meet standards by putting in place relevant institutions
- Best quality exported; poorer quality consumed domestically.

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EU Rejections of Imports According to Risks

SOURCE: EU Rapid Alert System For Food and Feed (RASFF, 2005)
Meeting Aflatoxin Standards Benefits Exporting Nations

- Cost of compliance is a source of concern for several developing countries.
- These challenges are manageable, and compliance is a worthwhile investment.
- Nigeria and Senegal major groundnut exporters in 1960s, but completely lost the export market since 1980s.
- **Senegal**: US$ 4.1 million added capital investment cost and 15% recurring cost would attract 30% price differential to oil cake.
- Export would increase from 25K tons to 210K tons.
- Increased export volume and price differential would annually add $281 million value to groundnut export for the capital investment.
- For confectionary groundnut, adherence to Good Management Practices would increase export value by US$ 45 million annually.
- Fair Trade groundnut export from Malawi.
Factors influencing mycotoxin regulations

- Availability of toxicological data
- Availability of food consumption & exposure data
- Availability of survey analytical data
- Availability of methods of sampling and analysis
- Trade contacts with other countries
- Sufficiency of food supply
Food intake determines exposure

(After Marasas et al., 2008)

<table>
<thead>
<tr>
<th>Fumonisin B (mg/kg)</th>
<th>Probable Daily FB Intake (μg/kg body weight/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Europe (10)*</td>
</tr>
<tr>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>1.0</td>
<td>0.2</td>
</tr>
<tr>
<td>2.0 (ML)</td>
<td>0.3</td>
</tr>
<tr>
<td>4.0</td>
<td>0.7</td>
</tr>
</tbody>
</table>

*Maize intake (g/60 kg person/day)

- **Safe**
- **Nephrotoxicity (0.8 – 2.0)**
- **> PMTDI**

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Mycotoxin regulation in Europe & Africa

- All EU member states have regulations for 12 mycotoxins.
- 15 African countries have regulations (59% pop).
- Most countries not regulated, but say that regulations needed.
- Does not mean problem does not exist.
- For small-scale & subsistence systems regulation has failed.

Source: FAO, 2004
Standard setting institutions

**JECFA**
- Expert panel evaluates data, seeks more data if necessary, makes recommendation on PTDI

**CODEX**
- Members debate on JECFA recommendations, sets maximum tolerable limits (MTLs), codes of practices

**National governments**

**Regional Commissions**

**WTO and SPS regulations**
- Evaluate CODEX recommendations, propose, legislate and enforce MTLs
Mycotoxin standards

- National governments decide based on JECFA & CODEX recommendations
- Important for trade
- Harmonization critical, such as in MERCUSOR countries
- ALARA (As Low As Reasonably Achievable) principle
- Leaves room for dispute
Loss disputes – World Bank vs. EU

- Aflatoxin limit: 4 ppb in EU vs. 20 ppb
- Otsuki et al. (WB) modelled (econometric) loss for 7 African nations as US$670 million

A Race to the Top?

A Case Study of Food Safety Standards and African Exports

Tsunehiro Otsuki
John S. Wilson
Mirvat Sewadeh

Implementation of the European Union’s new aflatoxin standards will reduce African exports to Europe of nuts, cereals, and dried fruits, products highly sensitive to the aflatoxin standards. The EU standards would reduce health risks by only about 1.4 deaths per billion a year but would cut African exports by 64 percent, or $670 million, compared with their level under international standards.
• Following request from the EU, the WB revisited the study
• Losses for Africa, recalculated as several hundred thousand US$
• Countries most affected are Argentina, Brazil and USA
Kenkey – Ghana’s national food
Victim: Aflatoxin awareness campaign

Aflatoxin as sensational news

The Kenkey Debate: Must We Tell The People? (1)
WFP denies reports of sending toxic maize to Kenya

The United Nations World Food Program (WFP) said in Nairobi Friday it is taking precautionary measures following food poisoning in eastern Kenya caused by toxic maize.

In a statement issued here, WFP, which supplies the food for the east African nation's school feeding programs, said all its food was always tested for aflatoxin before being handed over to the Kenyan Education Ministry.

"WFP is confident that no aflatoxin is present in any of the food provided by the organization to WFP-supported programs in Kenya," the UN agency said.

The WFP statement follows the seizure of hundreds of bags of maize and peas donated by the US government and supplied by the UN agency after samples from one of the schools were found to be contaminated.

WFP confirmed that it supplied the food for the schools program, adding that it was concerned about reports associating it with the contaminated food.

WFP attributed the possible contamination to "poor storage conditions and inadequate handling, particularly during the rainy season, as well as mixing of maize from many sources, increasing the risk of aflatoxin contamination, which can spread to previously unaffected commodities."

WFP at the same time expressed doubt about the findings by the government chemists and requested that an international testing firm be called to repeat the tests on the grain and pulses supplied to the schools.

The UN agency said schools have been advised to separate all commodities with
Need for mycotoxin testing and monitoring

- Protect consumers from undue exposure
- Promote regional and international trade
  - Stringent regulatory standards in importing countries (e.g., EU)
  - Rapid Alert Reporting System globally reports food safety issues (on internet) – poor country image
- To promote regional and international trade
- To encourage national development of agro-based economies
- To protect consumers from economic exploitation
Sampling protocol for aflatoxin

<table>
<thead>
<tr>
<th>Weight of the lot (t)</th>
<th>Number of incremental samples/Weight of the aggregate sample (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 1</td>
<td>10 (1)</td>
</tr>
<tr>
<td>&gt; 1 to ≤ 3</td>
<td>20 (2)</td>
</tr>
<tr>
<td>&gt; 3 to ≤ 10</td>
<td>40 (4)</td>
</tr>
<tr>
<td>&gt; 10 to ≤ 20</td>
<td>60 (6)</td>
</tr>
<tr>
<td>&gt; 20 to ≤ 50</td>
<td>100 (10)</td>
</tr>
</tbody>
</table>
Challenges of Regulations in Developing Countries

- Poor regulatory and control systems
- Lack or inadequate national standards and regulations
- Informal and dispersed markets, low volume
- ~90% producers consume production at home
- Inadequate inspection and enforcement capabilities
Challenges of regulatory labs in developing countries

- Inadequate infrastructure – building, electricity, water, telecommunication, computerization
- Lack of trained personnel
- Sustainability of laboratory supplies
  - Mostly imported
  - High costs for good quality
  - High cost per test (HPLC: ~ $150, ELISA: ~ $80)
  - Reference standards – issue of biohazards and terrorism
- Instrument maintenance and repairs
  - Lack of technical expertise, reliance on overseas engineers
  - Long downtimes, low output
- QA/QC and laboratory accreditation for international acceptability
- Political will – convincing policy makers; competing needs
Summary

• Aflatoxins in food and feed pervasive in Africa.
• Negative impact overlooked – chronic, unseen.
• Serious effect on children’s growth & development.
• Export potential of primary raw material unrealized.
• Institutions related to food safety very weak.
• New approaches, tools and coalition to manage aflatoxin.
Thank you

IITA Campus, Ibadan