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The U.S. Government's Global Hunger & Food Security Initiative

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How Mycotoxins Impact Agriculture, Nutrition and Development

Speakers

John Bowman, *USAID Bureau for Food Security*

John Leslie, Kansas State University

Felicia Wu, Michigan State University

Moderator

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John Bowman

USAID Bureau for Food Security

John Bowman is a senior agriculture advisor at USAID's Bureau for Food Security and manages global projects for USAID’s Office of Agricultural Research and Policy in the areas of horticulture, integrated pest management, food safety and post-harvest loss. Dr. Bowman has more than 28 years of experience in international development having worked in over 40 countries for international agricultural research centers, multinational food companies and international consulting firms.

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John Leslie
Kansas State University

John F. Leslie is a university distinguished professor and head of the Department of Plant Pathology at Kansas State University, where he has been on the faculty since 1984. Dr. Leslie studies the genetics of fungi in the genus Fusarium, a group of fungi that causes extensive damage to cultivated crops ranging from maize to mangoes. These fungi are known from virtually all ecosystems—arctic, temperate, desert or tropical—and often produce mycotoxins that lead to death, cancer, and developmental abnormalities in humans and domesticated animals, as well as creating major non-tariff trade barriers.

Felicia Wu

Michigan State University

Dr. Felicia Wu is the John A. Hannah Distinguished Professor in the Department of Food Science and Human Nutrition and the Department of Agricultural, Food, and Resource Economics at Michigan State University. Her research concerns the global health and economic risks of food-born and feed-borne toxins, and the cost-effectiveness and feasibility of interventions to improve food safety in resource-poor settings.

Overview of Feed the Future Investments in Aflatoxin Research & Development

1) Feed the Future (FTF) has, conservatively, tripled or quadrupled investments in mycotoxin-related areas since inception
2) The total pool of investments is relatively low considering the potentially high levels of damage to health and productivity
3) Our current mix of investments may be “off” – with possible need for strategic re-alignment – in order to bring in more funds

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Key FTF Washington-funded Projects

BFS/ARP

- Peanut/Mycotoxin Innovation Lab
- Nutrition Innovation Lab
- NBCRI with USDA/ARS
- Venganza Research Grant
- New Post Harvest Research Grants (PHL-IL & FPL, KSU and Purdue)

BFS/CSI

- SPS Capacity Building (trade hubs)
- Support to the PACA Secretariat

BFS/MPI

- AflaSTOP Post Harvest Storage Structures

AFR BUREAU

- SSA Regional Env. Assessment of "Aflasafe"

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USAID Aflatoxin Summary

Key FTF Field-funded Projects

- East Africa Regional Mission (APPEAR)
- Kenya/Ghana/So. Africa (SPS Capacity Building at the Trade Hubs)

- Zambia (Maize/Groundnuts: Biocontrol)
- Mozambique (Maize/Groundnuts: Biocontrol)
- Rwanda (Maize/Cassava: Biocontrol)
- Tanzania (Maize – Prevalence/Markets)

CURRENT AFLA-SPECIFIC INVESTMENTS??

2014: $15-20 MILLION/YR
2010: $ 2-5 MILLION/YR

What are Mycotoxins?

- Natural toxic metabolites produced by fungi
- Known since Ancient Greece
- Some are potent carcinogens; others are acutely toxic
- Several toxins are 3-5 orders of magnitude more toxic than fungicides that control them and break down more slowly

Why does USAID care about Mycotoxins?

1) FTF high level of value chain investment in maize/groundnuts

MAIZE – Kenya, Uganda, Tanzania, Rwanda, Ethiopia, Zambia, DRC, EAR, Ghana, Senegal, WAR, Nepal, Haiti, Guatemala, Honduras

GROUNDNUT – Malawi, Zambia, Mozambique

Why does USAID care about Mycotoxins?

2. Growing importance of Post Harvest Loss to FTF

- Productivity loss
- Quality loss
- Loss in ability to trade

Why does USAID care about Mycotoxins?

3. Human health impacts
   - Child stunting /Nutrition
   - Immune system suppression
   - Carcinogen
   - Acute toxicity and death if consumed in larger amounts

Why *should* USAID care about Mycotoxins?

"Foundational" to FTF concept

- Nothing represents the interface between ag and nutrition as appropriately as the aflatoxin issue

- Elimination/mitigation of aflatoxin in the ag value chain will have a significant positive nutrition/health outcomes

- This is the perfect type of subject matter that FTF was conceptually designed to work on – a new breed of agriculture that is intimately tied to health outcomes

Conclusions about Aflatoxin/FTF

- Aflatoxin free staple foods would be an agricultural result with a huge nutritional outcome - so why are the funding levels so low for such a pervasive problem?

- **Global Health Community** not convinced it is a priority equal to MCH, diarrheal and pulmonary diseases. It is not a primary killer but an an **"accelerator**" – requiring a more convincing "evidence base."

- Game-changing **solutions must be regional,** from research and host country ownership to USAID/USDA cooperation.

- **PACA** at AGOA, USAID **EA Regional Mission investment**, **USAID/USDA research collaboration** and **BMGF commitment** are steps in the right direction…

Where should USAID be working in Mycotoxins?

- Detection
- Pre Harvest solutions
- Post Harvest solutions
- Storage solutions
- Processing solutions
- Regulatory/Harmonization
- Evidence base/Causality??

Pressing Need: More Joint Programming with Global Health Community on Aflatoxin Impact in the "First 1000 Days"

Strong need for co-designed operative research between ag and health:

- Role of afla-prone complementary foods such as maize, groundnut sauce, cassava, sweet potatoes, cow's milk in growth impairment
- Attributional role of afla in stunting, cognitive development, impairment of immune system, impairment of digestive system, poor birth outcomes

Premise for Discussion?

- Fund much more work on the evidence base and less on ag best practice, (eg. breeding, storage structures, biological control)
- As a result, more donor/ministerial funding that is "health sensitive" will roll in at a much higher levels of magnitude – which can ultimately be "re-applied" to ag best practice interventions

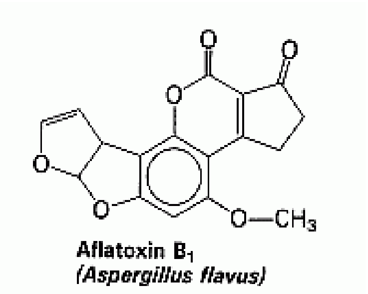
Thus the problem now may be ***poor "balance"*** in the limited funding pool – too little funding in ag/health linkage areas which have the potential to build the evidence base, possibly enabling higher levels of overall donor commitment in the future

Agree? Disagree?

Aflatoxin

- Produced by *Aspergillus flavus, A. parasiticus*
  - Maize, peanuts, tree nuts, cottonseed, spices, copra
  - Exposure highest in warm regions where maize & peanuts are dietary staples (Africa, Asia)

- Human health effects
  - Liver cancer
    - Synergizes with chronic hepatitis B virus (HBV) infection: much higher risk than either exposure alone
  - Childhood stunting
  - Acute aflatoxicosis
  - Modulation of immune system
  - ***How much do these effects matter in global context?***

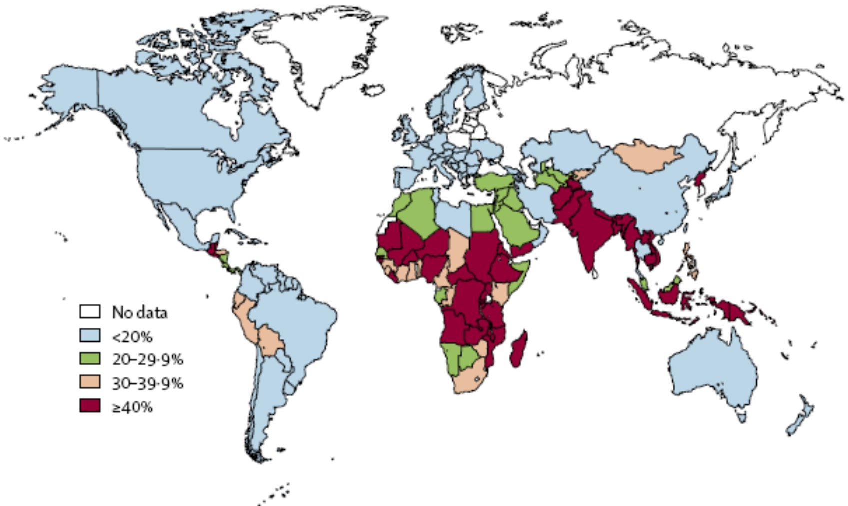


Why do aflatoxins matter for reaching development outcomes?

- Aflatoxin is associated with stunting, underweight, and wasting in children
- Aflatoxin also causes growth impairment in animals, leading to less efficient animal protein production
- Aflatoxin may reduce immune function, leading to worse outcomes from infectious diseases → major killers in resource-poor settings

Stunting in children

- Definition
  - Child's height for his/her age is 2 standard deviations or more below WHO growth reference (HAZ ≤ -2)
  - Associated with cognitive impairment & increased vulnerability to infectious disease (Ricci et al. 2006)
- Prevalence
  - 195 million stunted children under age 5 worldwide (Black et al. 2008)



Black *et al.* Lancet 2008

Studies linking aflatoxin to growth impairment in children

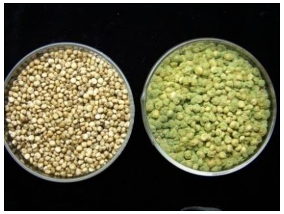
Type of study	Results	Nation & study
Aflatoxin measurements in stored flour, rural homes	Stunting, underweight, & wasting associated with higher AF levels in flour	*Kenya* (Okoth & Ohingo 2004)
Cross-sectional: AF-alb levels in maternal, cord, child blood	Stunting & underweight associated with higher AF-alb levels in these fluids	*Togo, Benin, United Arab Emirates, The Gambia* (Gong et al. 2002*, Abdulrazzaq et al. 2004, Turner et al. 2007)
Longitudinal: AF-alb levels in children's blood	Reduced height gain in 8 mos associated with AF-alb levels	*Benin* (Gong et al. 2004)
AFM1 in mothers' breastmilk	Lower length at birth & in infancy associated with AFM1	*Iran* (Sadeghi et al. 2009, Mahdavi & Nikhniaz 2010)

*Dose-response relationship between AF-alb & HAZ, WAZ

Khlangwiset P, Shephard GS, Wu F (2011). Aflatoxins and growth impairment: A review. *Critical Reviews in Toxicology* 41:740-755.

Are public health interventions cost-effective? WHO guidelines:

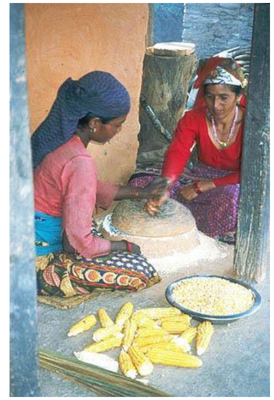
Very cost-effective	Intervention costs < [GDP/*capita* * DALYs saved]
Moderately cost-effective	Intervention costs < [3 * GDP/*capita* * DALYs saved]
Not cost-effective	Intervention costs > [3 * GDP/*capita* * DALYs saved]



GDP: Gross Domestic Product
DALYs: Disability-Adjusted Life Years

Interventions to reduce aflatoxin risk

- <u>Preharvest</u>
  - Good agricultural practices
  - Genetically enhancing plants' resistance
  - Biocontrol
- <u>Postharvest</u>
  - Improved sorting, drying, food storage



- <u>Dietary</u>
  - **Improved dietary variety**
  - Dietary enterosorbents
  - Dietary chemoprevention
  - Curcumin
  - Compounds in cruciferous & Allium vegetables
  - Green tea polyphenols
- <u>Hepatitis B vaccine</u>

Wu F, Khlangwiset P (2010). "Health economic impacts and cost-effectiveness of aflatoxin reduction strategies in Africa: Case studies in biocontrol and postharvest interventions." *Food Addit. Contam* 27:496-507.

Are aflatoxin control methods cost-effective in Africa? 2 case studies

Preharvest biocontrol (AflaSafe, Aflaguard, AF36, etc.)

- Not all *A. flavus* strains produce aflatoxin

- → Competitively exclude toxigenic strains, by strategically applying atoxigenic strains to maize field

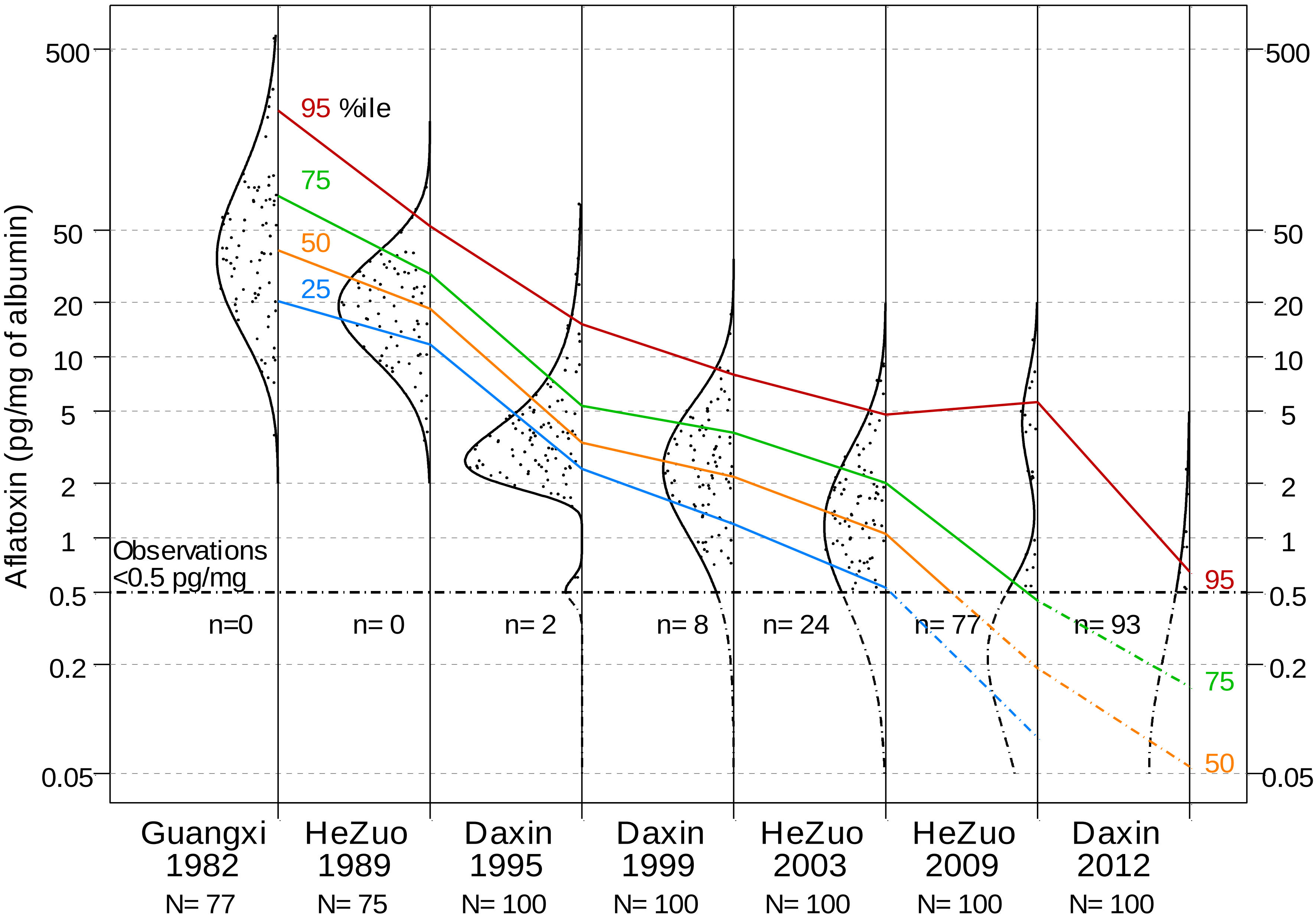
Postharvest intervention package

- Education on sorting & drying nuts
- Fibre mats to dry nuts
- Fibre bags to store nuts
- Wooden pallets to store bags
- Insecticides for storage floor (Turner et al. 2005)

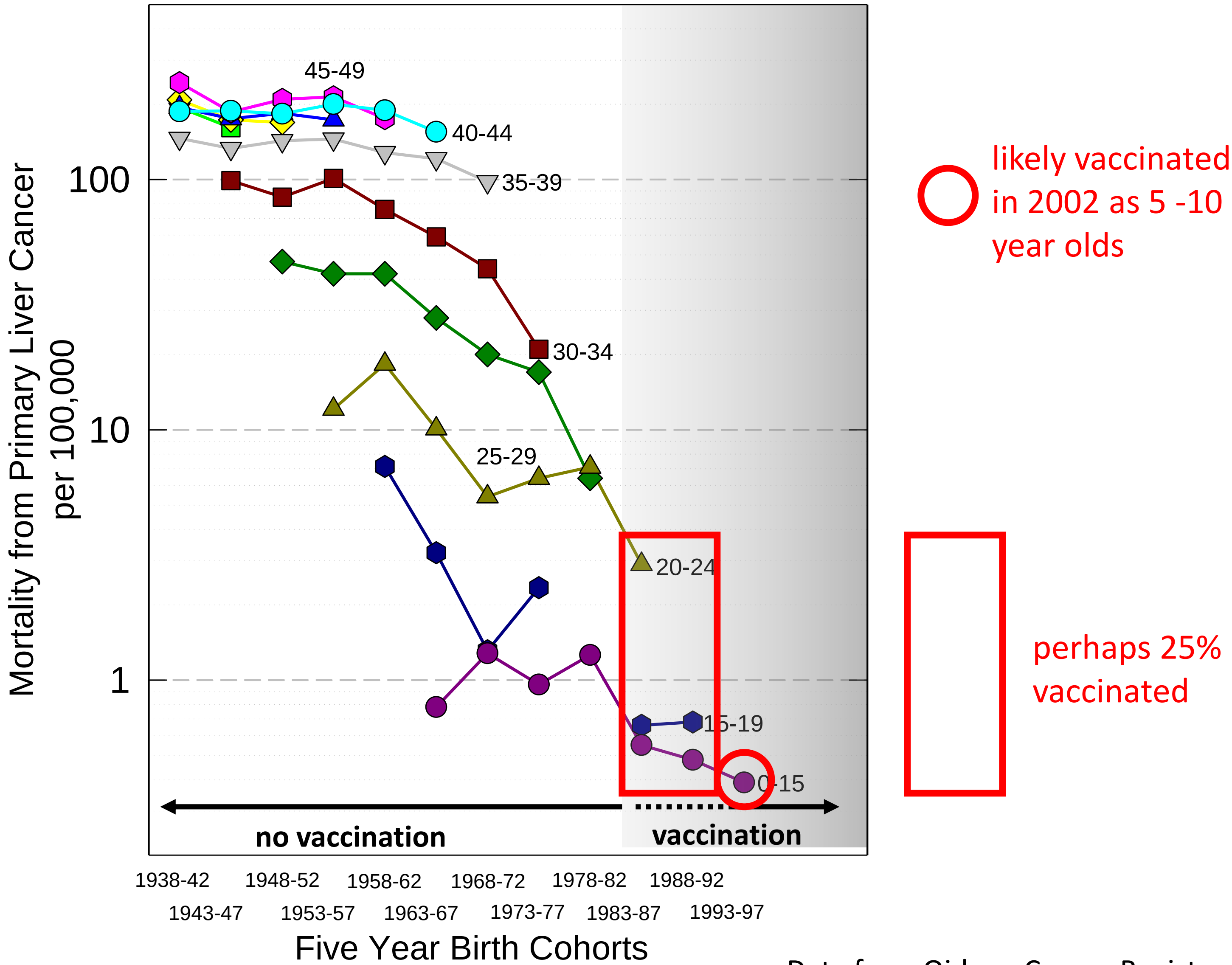
Case study of diet diversity → lower aflatoxin-related liver cancer: Qidong, China

- 1940-1980: Agrarian socialism in China
  - Each county must be self-sufficient
  - No imports/exports allowed between counties
- Qidong: soil unsuitable for planting rice
  - Consumed 82-124 kg maize/yr infected with *Aspergillus flavus*
  - **HIGH AFLATOXIN EXPOSURE**: 99% maize > 20 μg/kg AF
  - Not allowed to purchase rice
- 1980: China relaxes agrarian socialism
  - 1987: >97% Qidongese consume some rice
  - 1998: <9% Qidongese ate any maize
  - 2012: hardly any maize consumed

Since 1980, aflatoxin biomarkers decreased dramatically in Qidong

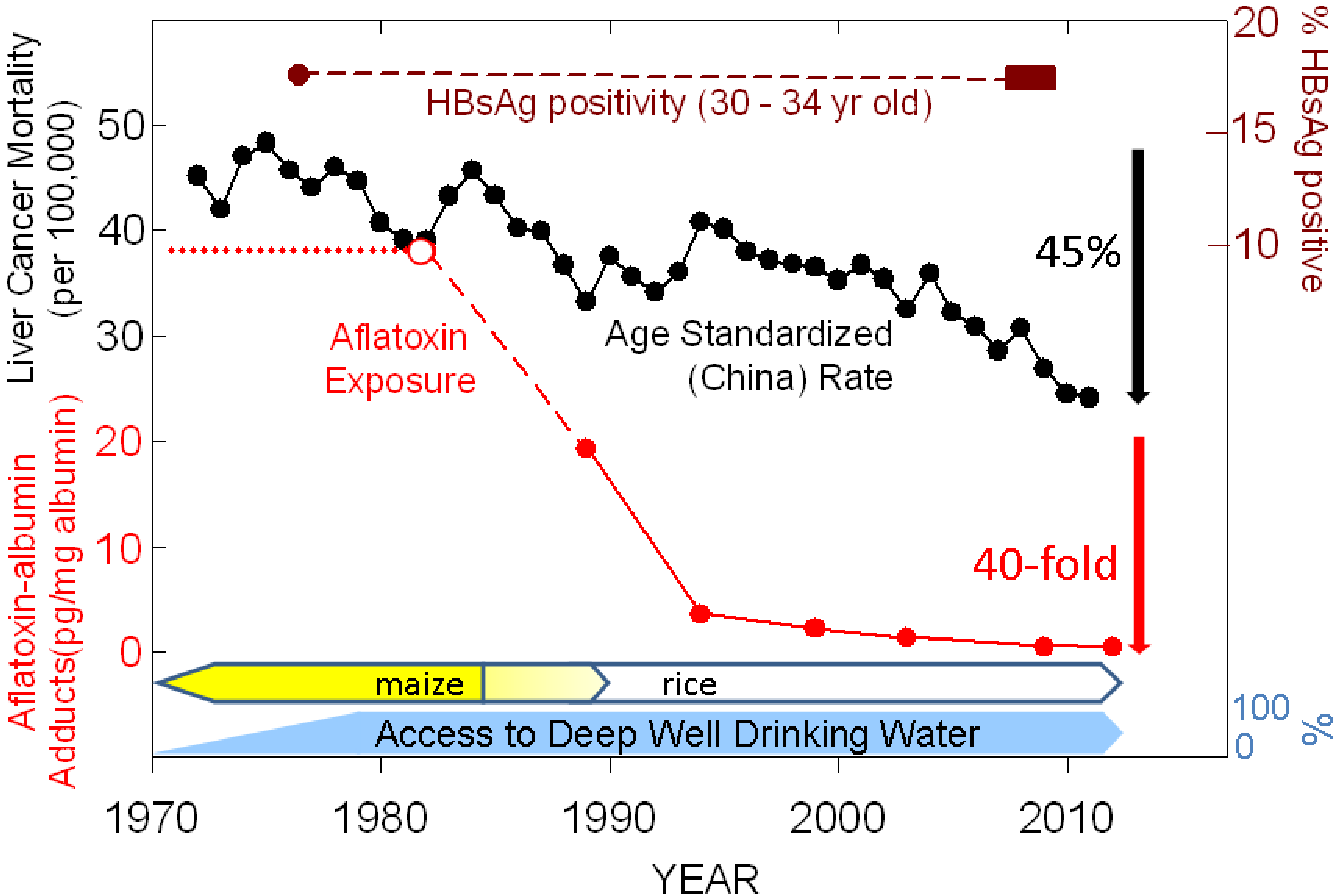


Most of the decline in liver cancer has occurred in birth cohorts never vaccinated against HBV



Data from Qidong Cancer Registry

Reduced aflatoxin exposures, not HBV status, are associated with declining liver cancer mortality in Qidong.



True in Africa as well:
Aflatoxin Exposure – Field experiment

Crop	Aflatoxin (ng/g)			Samples > 20 ppb aflatoxin (%)	Exposure (ng/kg bw/day)
	Mean ± SD	Median	Range		
Maize	36 ± 100	4.2	1 – 480	17	207.1
Sorghum	9 ± 14	5.0	1 – 90	5	50.6
Pearl millet	4.6 ± 1.8	4.4	2 – 8	0	26.5

Risk from sorghum is 4-fold less, and pearl millet 8-fold less than maize (consumption: 147 kg/year; BW: 70 Kg)

What relatively aflatoxin-free crops could become dietary staples in Africa?

- Instead of only focusing on how to reduce aflatoxin in maize & peanuts, how can we feasibly ***increase dietary diversity*** or switch staple crops altogether?

- Africa's indigenous crops
  - Sorghum
  - Millet
  - Cowpea
  - Pigeonpea
  - Fonio (West Africa)
  - Teff (northeastern Africa)
  - Rice (some varieties native to Africa)



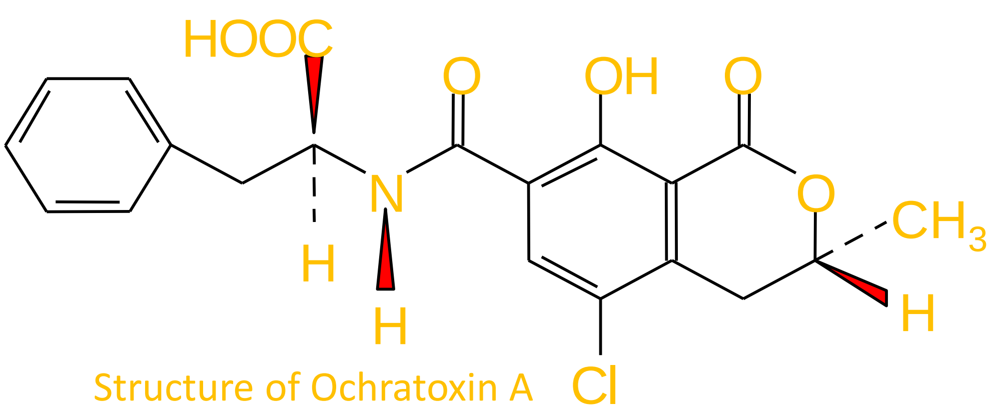
- These come with potential problems, but rarely *Aspergillus*

Wu F, Mitchell N, Male D, Kensler TW (2014). Reduced foodborne toxin exposure is a secondary benefit of dietary diversity. *Toxicological Sciences* 141:329-34.

Ochratoxins

Aspergillus ochraceus

Kidney failure
Cacao
Nuts
Grapes
Coffee
Wheat

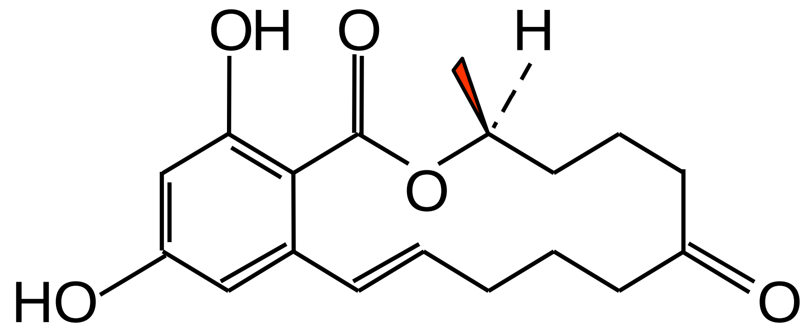


Structure of Ochratoxin A

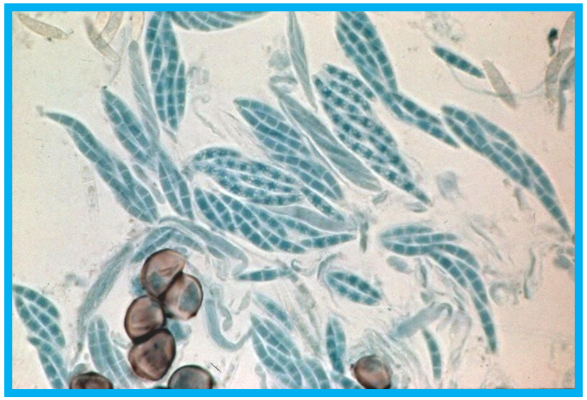
Zearalenone

F. graminearum

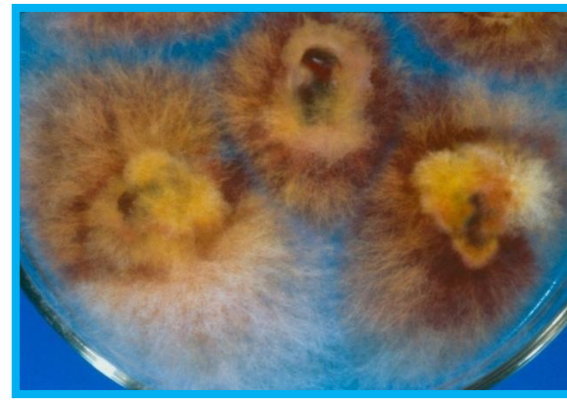
F. culmorum

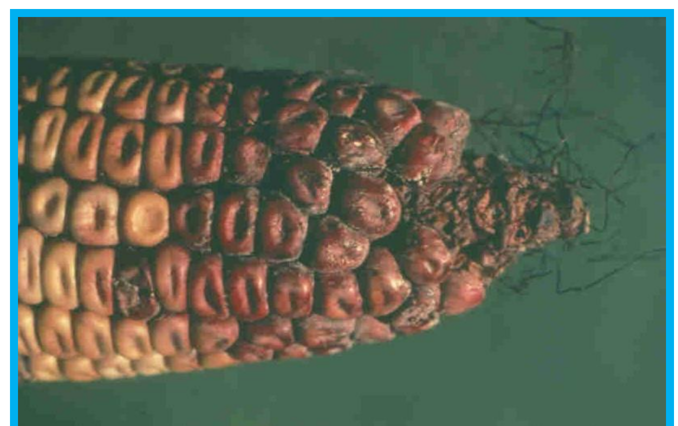


Structure of zearalenone



Hyperestrogenism
Pseudoestrogen
Maize
Wheat

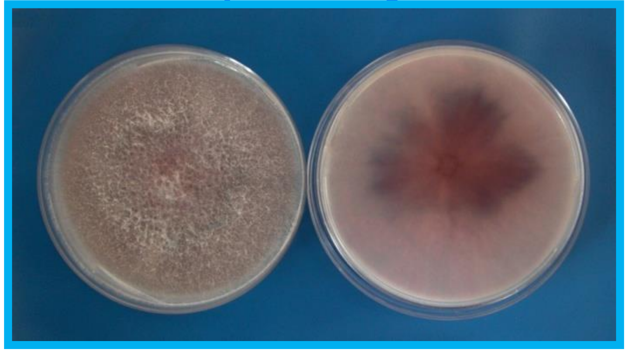




Fumonisins

Fusarium verticillioides

F. proliferatum



Esophageal cancer
Neural tube defects
Leukoencephalomalacia
Pulmonary edema
Grains – especially maize

Interaction between Fumonisin Contamination and Maize Intake

FB (µ/g)	Maize intake (g/60kg person/day)							PDI (µg/kg bw/day)
	10	50	100	150	200	400	500	
0.2	0	0.2	0.3	0.5	0.7	1.4	1.7	
0.5	0.1	0.4	0.8	1.3	1.7	3.4	4.2	
1	0.21	0.8	1.7	2.5	3.3	6.6	8.3	
2	0.3	1.7	3.3	5.0	6.7	13.4	16.7	
3	0.5	2.5	5.0	7.5	10.0	20.0	25.0	
4	0.7	3.3	6.7	10.0	13.3	26.6	33.3	

PMTDI = 2 µg/kg bw/day (JECFA, 2002)

A Trickle-up Story

- Traders in developing countries purchase the “best” grain from the farmers who end up with a little cash and the most heavily contaminated grain

- Developing countries sell developed countries their best quality agricultural products to get hard currency

- Consumers in developed countries eat the most diversified diets and have regulatory systems that usually allow the lowest level of mycotoxins in their foods

Why do Mycotoxins Matter for Reaching Development Goals?

- Clear interaction between agriculture and health
- Humans, domesticated animals & crops affected
- Not a common problem in developed countries
- Sub-acute and chronic exposures are major issues
- Regulations may exist, but be unenforced or unenforcable
- Disproportionate impact on the rural poor
- Size and severity of problem not well understood
- Some toxins have political implications
- Problems in tropical regions often different from those in temperate regions
- May limit trade

Storage is a Problem!

Audience
Questions and Answers

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