Breaking the Mold: How Mycotoxins Impact Agriculture, Nutrition and Development

Audio Transcript

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PRESENTATION

Julie MacCartee: Hi. Welcome, everyone. Thank you so much for joining us today for the May edition of the Ag Sector Council Seminar Series, which focuses on the issue of mycotoxins and their potentially devastating impact on agriculture, nutrition, and international development outcomes.

The Ag Sector Council Monthly Series is a product of the USAID Bureau for Food Security, and is implemented by the Feed the Future Knowledge-Driven Agricultural Development Project, lovingly known as KDAD.

I'm personally very excited for this topic. Food safety and nutrition are very interesting topics to me, and aflatoxin has always been just a completely fascinating topic. And we're expanding a bit on aflatoxin to encompass all of the mycotoxins here, so we're hoping to have a really great discussion.

And so I'm delighted to see so many people in the room. We're trying out a new kind of seating arrangement for Ag Sector Council as well, which I think will help with networking, and so feel free to let me know any comments you have about the seminar series, any suggestions for the future, any questions about knowledge management at the USAID Bureau for Food Security. I'm happy to help.

And I should introduce myself. My name is Julie MacCartee, and I'm a knowledge management specialist with the USAID Bureau for Food Security.

So my quick housekeeping issues are always just please silence your cell phones so that we don't interrupt the speakers. Also, we are recording this event, and so you'll receive an email after the fact letting you know when the recording is available. Because we're recording, and because we have a large webinar audience joining us today, we always ask that during the Q&A period, which we will hold till after the presentations, just that you wait for us to pass you this handheld mic so that the webinar audience can hear your questions as well.

So with that, I will introduce our introducer, our leader, who is Ahmed Kablan, an international nutrition and public health advisor with the USAID Bureau for Food Security working in the Office of Agricultural Research and Policy. And his work at USAID focuses on the agriculture and nutrition nexus and food safety, and he manages the post-harvest loss, soybean, and nutrition innovation labs for Feed the Future. And he's going to give a brief introduction and introduce our speakers. So Ahmed?

Ahmed Kablan: Thank you, Julie. Good morning, everyone, and thank you for joining us this morning for the Ag Sector Council, and thanks for KDAD for their logistics support and for their support in providing the venue and the technical support.

This topic of mycotoxins and the common, well-known, biggest bad guy of them, aflatoxin, it is an important topic for both agricultural practitioner and the public health community. Examples of what aflatoxin or why we care about mycotoxins, it is, as you know, they are fungus product or proteins, toxins that are produced by Aspergillus fungus that attack grains.

Other causes or the damages, the insect damage, drought, high temperature, are other stressful factors in the environment or in the field. We need to control them, mycotoxin spread, all the way from the field to the table, and the contamination could happen with different kind of mycotoxin at different part of the value chain.

Aflatoxins, also, they are one of the most potent carcinogens that cause very – really very bad case of liver cancer or hepatocellular carcinoma. Also, aflatoxin, a lot of observational studies in humans have been associated aflatoxin with up to 35 percent of stunting. A lot of research is still needed in order to prove the causal linkages between stunting and aflatoxin or mycotoxin. But based on animal studies, show that aflatoxin cause fetal loss, congenital malformation, growth retardation, and early infant death, in animal, not in human.

An example of the human studies was a cross-sectional study in about 785 pregnant Ghanese women, and what they found, that the woman with the highest quintile of the aflatoxin exposure, they were twice as likely to have a low birth weight compared with the women who are the lowest quintile of the aflatoxin exposure. This is just a taste of what aflatoxin or mycotoxins could cause for human health. We will hear more today about this, the health impact, the impact on agriculture, the impact on development, what kind of technology we might need or we can adapt in order to control aflatoxin, and what are the gaps in research and development that we need to cover.

And I'm excited to introduce our speakers, Drs. Felicia Wu, John Leslie, and John Bowman. So when you ask questions, please specify which John you are asking to avoid confusion.

Dr. Bowman, he is our senior agriculture advisor at the USAID Bureau for Food Security, and he manage the global food security program. He's the program area lead for safe and nutritious food, and he has over 28 years of experience, international development work in over 40 countries, and International Agriculture Research Center, multinational food companies, and international consulting firms.

And Dr. John Leslie, he is a university distinguished professor and head of Department of Plant Pathology at KSU, and he has been working since 1984. Dr. Leslie studied genetics of fungi, the genus fusarium, and a group which are a group fungus that are – he will talk about them today. They are also bad for human health, bad for agriculture, and we should not forget about that mycotoxin that are not aflatoxin only.

Dr. Felicia Wu, she is John A. Hannah Distinguished Professor at Department of Food Science and Human Nutrition at Department of Agricultural Food Resources, Economic, at Michigan State University. Her research concerns on the global health and economic risk of foodborne and feed-borne toxins, and the cost effectiveness and feasible intervention to improve food safety.

I'm pleased to present Dr. John Bowman, who will give us the overview and the – kick-start our webinar today.

John Bowman: Thank you, everybody, for coming, also to those of you online. Thanks for participating in this event. It's a very important topic. I've essentially in the last five years I've been here working for Feed the Future, I came in pretty green on this topic, and now I know a lot more, but I think it's just all the experience I've had with various university experts and our development experts out in the missions. It just makes me shake my head and think about all the more questions that are raised in terms of how to deal with this very elusive yet problematic bio-agent.

I've been asked to do the overview. I don't have much time, and I'm typically long-winded, and so I thought I'd give you the take home messages right off the bat, in case I don't get to the end. But these three things, I want to impress upon you that when Feed the Future started up, there was very little work on aflatoxin anywhere, whether out of Washington funds or mission funds.

Back of the envelope type calculations told me that conservatively we've tripled or quadrupled our investments in the mycotoxin-related areas since around 2010, and it's important for you to realize that. But although this total pool of investments, despite the progress within Feed the Future, the total pool of investments I think is relatively low, considering the very potentially high levels of damage to health and productivity which this – to which this agent can cause.

And then the final point is I – we have a wide range of investments now, from Washington funding and field-based funding, but I'm going to make the proposition that it's possible that our current mix of investments at AID may be off a bit. There may be kind of – the balance may be not quite right, and there may be some kind of a need for strategic realignment in order to bring in more

funds to the area, because, again, the high levels of damage to health and productivity are just escalating, and we've done a pretty good job, but we need to bring in more funding to this area. That's crucial. So maybe change the mix of investments so that we can attract more funding to the general sector.

I've got two slides here on essentially – it's the laundry list of all the things we're doing, the major activities in aflatoxin, mycotoxin-related research and development, and they've only given me ten minutes or less, so I can't go through all of these. But I think when you follow up with KDAD at the end of the – there'll be linkage to materials and documents that can give you more details on these projects.

But on this first slide, you'll see some of the major investments we have in Bureau for Food Security and the Agricultural Research Programs Office, and in our sister office, the Country Strategic Implementation Office, MPI, Markets and Partnering Initiative, and Africa Bureau. Again, I'm not going to go through all of these. I do want to just highlight, first of all, the very kind of exciting work that our nutrition innovation lab led by Tufts University is doing, because they're really getting at – they're trying to get at the causal relationship between aflatoxin in the diet and in the blood in relationship to health and nutrition outcomes, such as birth outcomes. And this is one of the very unique projects that we have in this area, and I'm going to make some comments on it later. It's very important.

We have a suite of breeding projects, both conventional and non-conventional, some in collaboration with the USDA, others in collaboration with the private sector. This is conventional, micro-assisted breeding, and this is IR&A breeding. I also want to highlight the really good work that our – in our sister office in terms of the capacity building work at the trade hubs and the support through the Partnership for Aflatoxin and Control for Africa, support to the secretariat. This is coming – a lot of support coming out of our CSI office at these trade hubs to look at regulatory and harmonization type issues, in addition to basic practices. They're very concerned here in terms of raising awareness at the ministerial level.

I'm going to move to the next slide. These are the field funded projects. We have all of the – all of the regional missions have been very interested in aflatoxin and working on various project interventions because of the trade hub presence, and this is an issue which essentially is very instrumental in stopping essentially the robustness of trade of grains in the region because of standards that are not – that are not harmonized.

So the Africa Regional Mission has the APPEAR Project, which is – I think it's just – it's ending now, but it's been extremely instrumental in working on these regional issues. And then we have a suite of projects that are focused on biological control of the fungus through the use of atoxigenic strains. You'll hear

more about that from the technical experts later. But pretty robust funding out of Zambia, Mozambique, Rwanda, and then Tanzania several years ago put out a very unprecedented prevalence study on the prevalence of aflatoxin mycotoxin in the marketplace.

So again, my back of the envelope estimates is that in 2014, we're at around $20 million per year, and when we first started in Feed the Future, maybe only $2 to $5 million per year. And I can assure you that in 2015, this number is going to jump quite a bit.

What are mycotoxins? Well, Ahmed quickly went over that. Just – I think he mentioned all of this. The important thing to realize, if you're not too familiar with the field, is that aflatoxins are not fungi. They are metabolites or you can also call them poisons produced by fungi, highly carcinogenic, acutely toxic at times, but actually what worries me more is this insidious low – these chronic levels of aflatoxin in the maize-consuming beneficiaries that we work with in many of the Feed the Future countries, maize and ground nuts.

I was asked to say why does USAID care about mycotoxins. Well, when I start to think about this, when we look at the very high level of value chain investment that we have in Feed the Future from the future in maize and ground nuts, I think this is one of the actual – the primary reasons. If we didn't have so much work coming out of our missions, value chain type work, and associated work in maize and ground nuts, we probably wouldn't be doing much at all in aflatoxin, quite frankly. So just highlighting here, you know, maize value chain is extremely important to Uganda, Tanzania, Rwanda, Ethiopia, Zambia, DRC, East Africa Regional Mission, Ghana, Senegal, West Africa, Nepal, Haiti, Guatemala, and Honduras. Ground nut extremely important in Malawi, Zambia, Mozambique.

So even if you knock out the interest that the regional missions have in maize, you're taking about – you're talking about two commodities that are in approximately – of high level importance in 70 percent of our Feed the Future missions. And this is a big problem in maize and ground nuts that just can't be avoided.

Another aspect is over the last five years, Feed the Future has gone down the road of more attention and more funding in the area of post-harvest loss. It was – year one and year two of Feed the Future, there was virtually nothing. Now there's quite a bit of interest and investment, and essentially this whole mycotoxin problem is a post-harvest loss problem. So you've got loss of productivity, loss of quality, and the loss of the ability to trade robustly in grains across the regions.

And finally, you have these basic human health impacts, which I think the

technical experts will go into more detail, stunting, immune system suppression, carcinogenic effects, and acute toxicity and death. So essentially, this is an agricultural problem that is causing severe human health problems.

What's kind of interesting about that statement is I really think it's one of the – this is the foundational or seminal rationale behind Feed the Future, a new kind of agriculture that essentially is – in order to make proper agriculture – proper impact in Feed the Future, our agricultural interventions have to have very positive impact on health and nutrition for amateurs, and this is exactly what research in the area of mycotoxins is accomplishing. It's foundational.

And I really don't think much of anything represents this interface between agriculture and nutrition better than the aflatoxin issue. If you eliminate or mitigate aflatoxins highly in the ag value chain, you will have significant positive outcomes in nutrition and health. And this is essentially the perfect type of subject matter that Feed the Future was conceptually designed to work on.

So some quick conclusions about aflatoxin. Aflatoxin-free staple foods would be an agricultural result with huge nutritional outcomes. So why are the funding levels so relatively low for such a pervasive and important problem? In a nutshell, my thinking on this, the global health community is not convinced that it's a priority equal to that of maternal and child health, diarrheal diseases, pulmonary diseases, malaria, HIV. They don't feel that it's really a primary killer, so they sideline it.

But it is an accelerator, but they – I think the global health community wants a more robust and convincing evidence base that it's an equal opportunity killer, and we don't have that base just yet.

Another important conclusion that I think in order to come up with game-changing solutions in this area, the solutions have to be regional, both from a research point of view and host country ownership point of view, and any type of cooperation we have between USAID and USDA on this issue, should be regional.

So we have the Partnership for Aflatoxin Control in Africa. This was launched at AGOA. We have this really robust investment of the USAID East Africa Regional Mission. We have very strong research collaboration with USDA, which I can't go into detail on. And we have a strong commitment from the Gates Foundation. So all of these are steps in the right direction. I'm going to – those suite of projects that I showed you essentially work – offer interventions in these basic areas: detection, pre-harvest, post-harvest, storage, processing, regulatory, and harmonization interventions.

But the one thing that's really lacking is this evidence base and causality. I mentioned that our nutrition laboratory led by Tufts is working very aggressively in this area, and more needs to be done.

So I just want to close with what I'm putting – I want to put on the table kind of a pressing need that we have, and that is I think we need a lot more joint programming between agriculture and health community on aflatoxin impact in this rubric of the first 1,000 days. We need co-designed operational research between agricultural and health. It has to be co-designed from the beginning.

So we have the role of – what are some things that could be worked on, and role of afla-prone complementary foods, such a maize, ground nut sauce, cassava, sweet potatoes, cow's milk. The role of aflatoxin in stunting cognitive development, impairment of the immune system, this is really the key area. What is the attribution of aflatoxin in these problems? Because other things will affect these problems, like parasite load, pesticide, other toxins in the environment, but what specifically is the attributional role of aflatoxin, and if we can quantify it as being of extreme significance, we can therefore maybe convince the health community to put more dollars in.

So this premise for a discussion that I want to have is we should maybe think about – and I'm – this isn't my mantra or anything. I'm just putting it on the table for a discussion point, that we should probably fund much more work on evidence base and less on agricultural best practices, such as the breeding, the storage structures, the biological control.

And so the proposition is that if we do that kind of work, more donor and ministerial funding that is health sensitive will roll in at much higher levels of magnitude. And then if that does happen, we can ultimately be – those investments can ultimately be reapplied to these agricultural best practice interventions, which we're already doing, but at a low level.

So more funding on the evidence base will reel in more money that can be applied to ag interventions that can be more robustly applied. So this is a question of balance. We may have a poor balance in what we're doing right now, not enough on these ag health linkages, which we need to build the evidence base. And so possibly we should think about changing that balance. So that's just something we may agree or disagree with, and I hope it comes up in the discussion. Thank you.

Ahmed Kablan: Thank you, John. And now we have Dr. Wu to talk a little bit about the fungus and the health impact.

Felicia Wu: Thank you, Dr. Kablan and Dr. Bowman. It's a pleasure to have the chance to come here and talk with you about aflatoxin, which is my main area of research,

and an area that's just fascinating, if you should try to think about a new area to go into.

What Dr. Bowman had mentioned about the link between agriculture and health is absolutely true in the case of aflatoxin in our food supply. This is an agricultural problem that has severe human health impacts, particularly in sub-Saharan Africa and East and Southeast Asia.

So rather than go over again some of the points that Dr. Bowman had already brought up about the fungi that produce it, what I want to emphasize again in this slide are the human health effects. Liver cancer is the one that we first knew about 50 years ago being associated with aflatoxin. In both humans and in animals, a variety of animal species, we saw that aflatoxin was a very potent liver carcinogen. In fact, it's the most potent naturally known human liver carcinogen.

It synergizes with the chronic hepatitis B virus infection, so if you're an individual who is positive for hepatitis B and you consume a lot of peanut butter or maize that looks like that, then your risk of developing liver cancer is considerably higher than if you had just one exposure, or neither.

Aflatoxin has been implicated in stunting in children, and I'll show the evidence base for that in another slide, with acute toxicosis at high doses, and also modulation of the immune system, and this is where we get into the role of aflatoxin in infectious disease as well.

So how much do each of these effects matter in a global context? Well, first, let's think about the effect of aflatoxin on development outcomes, and why is it that we ought to focus on this quote/unquote accelerator, as opposed to possibly a primary cause. Because aflatoxin is associated with all of these adverse growth impairment measurements in children, stunting, underweight, and wasting, we know that it also causes growth impairment in animals. We have over 50 years of research in that area. Well, aside from the fact that it's causing the animals to suffer, it also leads to less efficient animal protein production, which is very important from an economic standpoint in low – resource-poor regions.

And furthermore, we have pretty good evidence that aflatoxin can adversely affect immune system function. Now this could lead to worse or more adverse outcomes from infectious diseases, whether respiratory diseases or diarrheal diseases, which are major killers in low income nations. So for all of these reasons, because of the contributory role of aflatoxin, this is an important problem to study.

Let's look at the issue of stunting in children. This is defined by the World Health Organization, or WHO, as a condition in which a child is two standard

deviations or more below a particular WHO growth reference. So if you're 48 months old, you have to be this tall, and if you're 2 standard deviations below that or more, than you're considered stunted. Now it's not so much an adverse thing just to be short in and of itself. Rather, stunting that's caused by environmental or dietary conditions is associated with increased vulnerability to infectious diseases, as well as cognitive impairment that lasts well beyond the first five years of life.

A recent study shows that there's close to 200 million stunted children around the world under the age of 5, and as you can see in the dark regions in that map, sub-Saharan Africa and Southeast and South Asia are the parts of the world that have the highest prevalence of stunting. Not too surprisingly, perhaps, there's also a lot of aflatoxin exposure in these countries.

Now we had published a study in 2011 that looked at the entire evidence base of aflatoxin growth impairment in both animals, a variety of animal species, as well as in children. I'm only presenting the data here for the evidence in children. Rather than go through a lot of detail of what's in this table, what I want to point out is that many different things were measured to try to understand aflatoxin exposure. Aflatoxin in food was actually measured, biomarkers of aflatoxin in maternal blood, cord blood, and child blood, and even maternal breast milk. And in every case, the more aflatoxin there was, the more stunting, underweight, and wasting there was in the children who were exposed to aflatoxin.

Now how could we begin to get around the problem of what can we do about the aflatoxin problem? Well, one of the things that we have to remember is because we are dealing quite often with resource poor settings, we need to consider the cost effectiveness of different public health and agricultural interventions to reduce the aflatoxin problem.

The World Health Organization first came up with this metric of how it is that we can measure cost effectiveness in terms of health savings, because they were applying this to whether or not to iodize salt around the world. They basically said, well, if in a particular population the intervention to reduce aflatoxin or to reduce a particular adverse health effect, if it costs less than the gross domestic product per capita on average in that population, multiplied by the number of disability adjusted life years that are saved, then it's a very cost effective intervention. And this is something that we're looking at right now.

Previously – so this is a list of potential interventions to which we could examine the cost effectiveness. It turns out that there are a number of different interventions that can help to reduce mycotoxin levels in the food supply, or help to ameliorate them in the body, if you have already consumed the mycotoxins. There are pre-harvest interventions, such as simple good agricultural practices,

genetically enhancing plants' resistance, not just to fungal infection, but also to drought and heat, which predisposes plants to fungal infection, and bio-control methods.

There are post-harvest methods, such as improved sorting of the obviously contaminated foods, drying and food storage, and then if you have a plate in front of you and you already know that there's aflatoxin in the food, what can you do at that point? There are actual dietary interventions as well. One thing, improving dietary variety, moving away from the maize and the peanuts that have such high levels of aflatoxin. Chemoprevention, dietary chemoprevention, a natural kind that I'm talking about that can be found in leafy green vegetables, cruciferous vegetables, such as broccoli and cabbage and cauliflower, and also in vegetables in the onions and garlics and leeks family. Curcumin, which is found in curry, can also help to inhibit various enzymes that can cause – can cause aflatoxin to become more toxic in the human body, and the polyphenols that are found in green tea.

Finally, vaccinating individuals against hepatitis B helps to counteract that synergistic effect of hepatitis and aflatoxin in causing severe liver damage. I'm not going to go into a huge amount of detail, but if you want to ask questions about them later, we've looked at the cost effectiveness of different types of aflatoxin control methods. And I can see that time's running out. We've published recently on a link between increasing dietary diversity and lower aflatoxin-related liver cancer risks in one part of the world, Qidong, China. This was a part of the world that had a lot of liver cancer originally, and when the population switched from consuming primarily maize to consuming primarily rice and leafy green vegetables, then liver cancer incidence just over the last 2 decades has decreased by 45 percent. And that is from switching to a dietary staple that had a lot of aflatoxin to almost no aflatoxin.

And this is a slide of Dr. Leslie's that shows that in fact – if we were to try to reproduce this effect in Africa, might we turn to sorghum and millet instead of maize, because aflatoxin levels are considerably lower, not just the means, but particularly the ranges, if you take a look at this slide.

What relatively aflatoxin-free crops could become dietary staples in Africa? Well, here's a potential list, and we can talk about that later, if you're interested. But I think I'm just about done, so thank you.

Ahmed Kablan: Thank you, Dr. Wu. And now, Dr. Leslie, just to give us some about aflatoxin or mycotoxin, what they are and their chemistry.

John Leslie: Okay. So I'm sort of the clean-up hitter to collect the other things that are other than aflatoxin. And so the first thing to realize is that in spite of aflatoxin's importance, there are a lot of other mycotoxins. There are estimates of probably thousands of these things actually made, most of which we have no idea at all what they do, or if they have any economic impact at all.

But here are – I've got slides on just a few of them, and so the ochratoxins are also made by aspergillus species, different ones than make the aflatoxins, also made by some penicillium species. And they've got a very different spectrum of problems. They cause – they're primarily known for kidney failure issues. And you can see there that cacao, nuts, grapes, coffee, and wheat. So the interesting thing is, you don't see maize on that list. Maize is sort of – gets all of these things for the most part, but it doesn't get this particular one.

And the ochratoxins can be very important. They're regulated, and at one time, the Europeans had their regulations set such that – imagine Europe without chocolate, coffee, and wine, and you can see that it could have a severe cultural impact just on them.

Zearalenone is another compound that's widely known. This is made by fusarium, two different species, most commonly. It's known mostly as – this won't kill you, but what it does is it's a pseudo-estrogen that will cause premature development in women, can cause sterility in men. It's a problem with maize and with wheat. And also, these same fungi make another series of compounds that I didn't put up here called the trichothecenes, and trichothecenes are very important, especially in wheat, because they are major trade barriers, and they are – also kill the yeast that goes into brewing. So if you try to malt something that's contaminated with one of these fungi, often, you will not get a successful malt, and your beer's no good, and that can be very important, not only in the US, but in a lot of other places.

Finally, in this – made by – not by these two, but a related trichothecenes, are compounds called T2, T2 toxin, and T2 toxin is perhaps – is one of the nastiest chemicals made by any living organism. It causes – it was the active ingredient in Yellow Rain in Vietnam in the seventies, and was also used supposedly by the Russians in Afghanistan, so that it becomes a very – it's a select agent in the United States. You can't even have very large amounts of it in a lab to work on it unless you've got it under all kinds of lock and key things.

So T2, which can be potentially produced by some of these fungi in some of these countries, has got huge political ramifications that we need to be thinking about, in addition to just the food ramifications, because finding T2 in the – in the food would just cause, you know, all kinds of interesting problems.

And then fumonisins are the last of the other toxins that I'll talk about for the moment. Again, this is primarily a maize toxin. It causes a – the big problem that it causes, I tend to call brain rot in horses, because you end up with just large holes in the brain of the horse, and that poor horse that you see there would be walking in circles and eventually would simply fall over dead, because there's been so much brain damage that's done.

In humans, it's associated with esophageal cancer, and also associated with neural tube defects in infants. And the interesting with the neural tube defects is that those come associated with a genetic defect that's known in humans. Both the fumonisins and the genetic defect block the same enzyme and give you the same phenotype.

A point that we need to recognize, we see all kinds of levels of things that are recommended in the literature for exposure. So for example, with fumonisins, usually for humans what we see as a level in human foods is one or two micrograms per gram, as shown on the left there. And this is something from Wally Marasas' group in South Africa, and you can see that most of us would be in the – well, we can debate whether you're 60 kilos. A lot of you probably are like me and you're significantly more. But the – be that as it may, the issue here is that – notice the amount of fumonisin in the diet actually matters, so that if you've got a very high – if you're eating a lot of maize, if you're eating 400, 500 grams a day on the right side of that table, it doesn't matter how low the level is. You're still probably getting a very toxic amount of the toxin showing up.

So what's considered safe for us is very different than what's going to be that – found in a developing country where the diet is very different. This is a story that has worried me for a number of years, and I call it a trickle up story. So the traders in developing countries are going to purchase the best grain they can buy from the farmers, okay? They buy the good-looking stuff, because that's what they can sell. It makes perfectly good sense.

And what they do then is they leave the farmers with the most heavily contaminated grain, so the farmers can end up with 95 percent of the toxin left in what they've got, and maybe 5 or 10 percent going to market. The developed – so that gives you the better stuff in the cities, and the best stuff gets sold to people like you and me, who eat the least amount of the corn, and, of course, are exposed to the least amount of the toxin, so that it's really a trickle up. Those of us who eat the least and can actually afford, so to speak, the higher exposure, actually have the least.

So sort of a last slide here, to summarize some of the things that we've been talking about, why do mycotoxin matter for reaching development goals? Well, first, it's a very clear interaction between agriculture and health. You've heard

John say this. You've heard Felicia say this. You're going to hear me say this. And it's really, really true. It's one of the most important ties that we've got.

But what it means also is that it's an interdisciplinary tie. You don't find any particular group really owning it, so you don't find the plant pathologists, like I am, owning mycotoxins. You don't find the nutrition people owning them. You don't find the medical people or the vet people. Yeah, we all deal with them. Yeah, they're all important. But they're not on the top of the list.

So one of the critical things that AID can do is they can serve to bring these interdisciplinary groups together to get them working, to realize what the problems are and how to go about solving them. It affects all kinds of different animals and crops. These are not a problem for us. Why? Because we've got a good food regulatory system. But when you go to that local market in rural Africa and somebody's just brought something in, especially if they've just had it ground and you can't even see if it's green or pink or red or something that it shouldn't be, you can't tell. It's just flour, and you're buying it, and it's not checked.

Sub-acute and chronic exposure issues are big deals, okay? It's not just that it kills you. It's that it half-kills you, and keeps you from doing what you could, and developing your potential. And it has a disproportionate impact on the rural poor. The people that we really care a lot about really get hit the hardest by this. The size and the severity of the problem is not well-understood. We can project what it is, but we don't really have a good handle on how bad the exposure is.

Some of the toxins, like T2, have got political implications, and the problems in tropical regions often are different from those that we find in temperate regions. And finally, just sort of a little note down there at the bottom, yeah, you can have trade issues. These are one of the biggest non-tariff trade barriers that exist.

And so with that, just to give you some idea of the types of storage problems you actually can have, and why you might have issues with things sort of misbehaving, there are some examples that I've actually seen from South Africa and from West Africa. And with that, I'll give it back to you, Ahmed.

Questions and Answers

Ahmed Kablan: Thank you. Before we go to the audience for questions, I have a couple of questions to the panel. Two minutes, each question, not more. So John, John Bowman, just to be specific from which John I'm asking for, now we talked about mycotoxins. We talked about an implication. Just I want to understand a little bit more why we need to pay more attention to mycotoxin at USAID, where we work with the other donor community, or ourselves? What are the specific consequences, do you think, or you see to development if we don't pay attention

to these problems as a program for the nutrition and safe food? What you would want to see more in terms of programming? What are the areas for improvement that you see as a gap?

John Bowman: Well, I think in terms of consequences of inaction, you're going to see essentially productivity gains on the front end of the value chain essentially be wasted, because this – again, this is essentially a post-harvest loss problem, and you can try to get at improved productivity by either working the front end of the chain, working with breeding improvements, fertilizer, irrigation, close value chain work with your beneficiaries, or you can help the income situation of the beneficiaries just by essentially improving loss. And so this is a loss situation, and all the productivity gains we're going to make with other projects and other investments on the front end and in the middle are going to be essentially really hamstrung if we don't do anything.

And then you – the other factor of productivity is the workforce productivity that John just mentioned, the labor potential of all the – you know, the farmers we're working with, it's going to go down quite a bit, particularly due to this chronic and sub-chronic insidious level of ingestion that may not be relatively apparent. You said maybe people are half-dead, or walking dead. I'm not sure how you put it. But that's going to be a huge problem.

And then I think the third aspect is that without – a consequence of inaction is that regional grain trading is never going to be robust, and grain trading in Africa generates a lot of money for a lot of players.

You asked about programming needs. I think just quickly, we would do well to have a lot more collaborative work with the Gates Foundation, and we'd have – we should do a lot more collaborative work with USDA. I didn't have time to present it, but USDA has – it's been a challenge to find under Feed the Future a lot of compatible, exciting work – areas to work with, with USDA as a partner in these developing countries. But this is certainly an area where USDA has a lot of expertise.

Areas of improvement. The evidence base, as I mentioned before, the causality, we have to stress that. We have to work on this huge problem of the willingness to pay for aflatoxin-free grains. What are the incentives that we can build in the grain sector, because currently, willingness to pay is very difficult to find and get a hold of and manage? And then essentially behavioral/cultural change at the village level with the farmers, and behavioral and cultural change at the ministerial level in terms of admitting to the problem, not hiding it, and trying to aggressively, you know, remedy is with donor funding. PACA really helps out a lot in that.

One other quick area I should mention I think that needs a lot of attention is the – what can be some of the alternative uses for contaminated stocks? I don't think enough people are looking at that. Of course, then the real tragedy is that contaminated stocks, once identified by governments or by projects, ultimately end up in the – in the bellies of the – of the villagers, and it's got the devastating outcome.

Ahmed Kablan: Thank you, John.

Ahmed Kablan: Thank you. Dr. Wu, two minutes. You and Dr. Leslie, mentioned the exposure to mycotoxin prominent in developing countries, particularly in the region where staple crops such as maize and ground nuts can make up to 70 percent of diet, not to forget their impact on the child health and nutrition. They get exposed at different stages during the life cycle, from during the – crossing through the placenta, mother's milk, complementary feeding, and etcetera. What do you think could need to be done to deal with this problem? How can we minimize the risk for exposure?

Felicia Wu: Well, that's a good question, Dr. Kablan. There are a number of different ways that we can deal with the mycotoxin problem, and I think that the solution is different, depending on the part of the world. In many high income countries, it's enough that we have set regulatory limits on these mycotoxins in our food supply. In the US, it's the Food and Drug Administration that has action levels for aflatoxin in human food, as well as in a variety of animal feeds, as well as industry guidelines for fumonisin.

These regulatory standards typically work because they're enforced, and that is not the case in many parts of the world. There are 97 countries around the world, for example, that already have regulatory standards for aflatoxin, but do we believe that they're necessarily being enforced? Not necessarily, particularly in subsistence villages, where food hardly undergoes any regulatory inspection, especially if it's just being traded and purchased at local markets or even at the individual farms.

So education is clearly a very important issue, making people aware of the adverse health effects that can accrue to themselves as well as their children as a result of consuming these – the moldy maize and the moldy nuts. In addition to education, there have to be interventions that can be easily implemented. So I gave the example of increasing dietary diversity, and there's a paper that we recently published, if you're interested in it, that looks at how particular foodstuffs, if they're introduced to the diet, not only do they counteract the adverse effects of aflatoxin, but they also add important nutrients to the diet. So if that's of interest, please feel free to talk with me about it later.

Introducing leafy green vegetables, where possible, introducing other dietary

staples that might be native to the region, whether it's rice or teff in some places of the world, sorghum, millet, pigeon pea, other legumes, that are much lower in aflatoxin levels, but are native to the area and can be grown fairly easy. And that's one type of intervention.

Other types of interventions you saw earlier, some pre-harvest interventions, trying to keep the crops as healthy as possible in the field, so that they're less prone to being infected by fungi. Post-harvest, keep the food dry, sort out the obviously moldy kernels, and keep it well in storage. And the dietary ones I've already mentioned. Thanks.

Ahmed Kablan: Thank you, Dr. Wu. Dr. John Leslie, what are the steps we can take to reduce mycotoxin in foodstuffs? I know you mentioned at one point bio-controls. What do you think about bio-controls? Do you think there is a risk of the species, the atoxigenic species, to be converted or to change a certain strand to be toxigenic, or there is no risk or no concern for you?

John Leslie: So another good question. So the – many of you may have heard of AflaSafe or Afla-Guard or AF39 or some of the other things that have been used successfully in the United States, and analogs are now being proposed for use elsewhere. These competitive exclusion programs is what they are, so effectively, the way they work, think of the plant as having a spot inside it that is commonly filled by an aspergillus species, one of the aflatoxin synthesizers.

And if I was to go and wave a magic wand and take all of the aspergillus out, there would still be something else that would fill that niche. So that plant is not sterile, okay? It's got – it's going to have a fungus, a microorganism, in that niche.

And the approach that most of the – most of these things take is, well, just like in soybeans, where the farmer is used to get a particular bacterium to put on as an inoculant to go into the plant, the question is, how can we get the strain that we want to go in instead of letting Mother Nature pick a strain to put in? And effectively, what these programs are doing, then, is they are taking a natural strain from that location, so a strain that you would use in West Africa would not be the same as the one that's used in the US, or that's used in Asia, or something like that. These all need to be developed on a relatively location-specific kind of thing.

So you take a naturally occurring strain that does not produce the toxin, and whenever you mix it with the toxin-producing strains, it will synergistically suppress the amount of toxin that's produced. You then grow the strain in such a way that you can apply it in the fields and effectively overwhelm the rest of the population.

So where under natural conditions, the strain we're talking about might have been, I don't know, let's pick a number, one percent of the population, now it's going to be 50 or 60 percent of the population, maybe even more. And what that does is it means that this non-toxin producing strain is going to be preferentially incorporated into the plants, not because it's more competitive than the other stuff that's there. As a matter of fact, it probably isn't, because they don't last forever. You know, you have to reapply it after a few years, so it loses out.

But what it does is it gets in and it occupies that niche, and it keeps the aflatoxin producers out. And that's a very good strategy, because it's based on the life cycle of the fungus. You're not putting anything foreign into the field, because these are native strains that are native to the area already. And it's something that as long as you're willing to make the application on – you know, every several years as it's needed, is a doable and a sustainable kind of thing.

Ahmed Kablan: Thank you. Now we'll open it for questions from the audience, and please wait for the mic to get for you.

Julie MacCartee: Yes, we breezed through a lot of things, so if you need clarification or have a question, anything from very basic, since I know that some people in the room rate their knowledge of mycotoxins as fairly low, up to more complicated questions, we're happy to take them. And do we have one to start off from our webinar audience, or should we take in room first? In room first? All right. Question? And please state your name and organization, if you will.

Audience: Hi. Lee, Missouri University of Science and Technology. Thank you, speakers, for taking time today to inform of us a crucial issue. I'm curious about – we talked a lot about kind of this compartmentalizing issues, and whether it's like before farm gate or after farm gate or – on Twitter yesterday, we were talking about behavior change issues versus technical issues. We talked a lot about kind of technical interventions and stuff. So how – where can we identify – how do we go about identifying site-specific issues, like whether it's – I kind of focus on Guatemala, but there's obviously issues, like you said, in Africa and East Asia. As we shift locations, causal factors will shift. How do we set something up where we can identify the – hopefully cheaply, because it goes back to what John number one said as far as if we need to do assessments versus interventions, and I don't see those as two separate things. I think they need to kind of be wrapped in one as kind of do something. So I guess that's kind of my general question. It's a high level question, but –

Felicia Wu: That's a really important question, and one that our research team has run into a lot. Just to give you a case study of why you can't apply the same type of intervention in different parts of the world is that after we published this Qidong, China study, quite frankly, the reason that they made the switch from maize to rice in that region of China is because before 1980, the Chinese government had

said that every county in China had to be self-sufficient in food production, and Qidong could not produce any rice, even though they preferred to eat rice. They could only grow maize, and so that's what they ate.

After 1980, they moved to a more market-based system, where they said, oh, okay, now you can go and purchase food from neighboring counties, and so of course the Qidongese wanted to eat rice. And so they started purchasing rice from [x] County. Aflatoxin levels went down.

Well, that's not exactly the situation in other parts of the world, and so if you suddenly wanted to say, oh, well, this intervention works, switch from maize to sorghum and millet now, it's not – it – there's not the same sort of policy drive. It's going to be a lot more difficult. And I think that one of the key crucial issues is that we have to get down on the ground and understand what the needs of individual populations are, even if this means, for example, household surveys. trying to identify some of those questions, such as how willing would you be, for example, to switch to a different type of crop, or to plant different types of crops, and if not, what's holding you back, for example? Or applying these different interventions. Why or why wouldn't you do so? What are some of the economic incentives, some of the cultural and behavioral incentives? I think that really needs to be seen on a population by population basis.

Julie MacCartee: All right. We'll take one from our online audience, and then come back to the room.

Audience: Great. We have another nutrition-oriented question for Felicia. What is the method by which cruciferous vegetables help detoxify mycotoxins, and do the vegetables have to be consumed at the same time as the mycotoxins contaminated food?

Felicia Wu: That's a very good question, and it's actually different for different types of vegetables. For leafy green vegetables, it's quite a different mechanism by which they detoxify aflatoxin compared with cruciferous vegetables. Leafy green vegetables have chlorophyll in them. Chlorophyll and its derivative chlorophyllin, what they do in the human gut is that they basically bind the aflatoxin, they absorb the aflatoxins, similar to other types of binders, like NovaSil clay, that's been used to reduce aflatoxin bioavailability in animal feed.

So essentially, the leafy green vegetables or the components help to trap the aflatoxin in the gut, and it passes. We excrete it without it getting into our small intestine and then circulating into our bloodstream. That's the mechanism by which leafy green vegetables can help to detoxify, if there's already aflatoxin in the meal, but they have to be consumed at the same time as whatever the aflatoxin-laden food is. Otherwise – I mean, it doesn't just kind of linger in the gut. It passes through.

With cruciferous vegetables, it's different. They do not need to be consumed at the same time as the aflatoxin in the food in order to detoxify. The way that cruciferous vegetables as well as vegetables in the family of onions and garlics and leeks work is that they induce what are called phase two enzymes, such as glutathione-S-transferases, in the liver. Essentially – so not to go into a whole lot of medical detail, but essentially, the aflatoxin goes through your gut. It gets absorbed into the bloodstream, and then it reaches the liver. Now it can cause – at that point, the liver attempts to detoxify the aflatoxin, and it can wind up converting the aflatoxin into its very carcinogenic form, aflatoxin-8,9-epoxide.

If you have glutathione-S-transferase, which is increased when you consume cruciferous vegetables like broccoli and cauliflower and Brussels sprouts, then what it does is it increases the glutathione-S-transferases. They conjugate glutathione with the aflatoxin-8,9-epoxide, and it gets excreted from the body, as opposed to binding to our DNA and causing the DNA damage that leads to liver cancer.

Audience: This is a sort of a comment and a sort of a challenge. I think one of the things I didn't hear discussed, actually, today, was gender, and I think, you know, we talked about good agricultural practices to reduce aflatoxins, but actually, this is really a women's problem, because they're often the ones that retain their grain and are able to dry it properly, and then they might sell it on later when the toxin levels are much higher, as well as feeding it to their children. So reaching poor smallholder women I think is really important.

The challenge is sort of to John Bowman, and I've been discussing this with another agency, How can we get it such that agricultural products – projects that support productivity improvements in maize and ground nuts and things like that actually almost have a safeguard that says you can't do this project unless you implement aflatoxin control measures with it, so that we actually always do both? Because I see many projects that do maize productivity improvement, ground nut productivity improvement, and actually don't discuss aflatoxins at all.

John Bowman: Yeah. It's – that's an important point. I think, knowing as much as we do now about aflatoxin and the – since the effect on – you mentioned gender. There's also the aspect of these – in terms of birth outcomes, if they are – if the women are ingesting more, it's really critical to keep them safe. I mean, I would think that at this point in time, any agricultural value chain project that we support that's working on either maize or ground nuts, it's kind of – it should be kind of an obligation that they at least do some I'd say baseline detective work or some kind of – hire somebody to do some kind of prevalence survey, either directly with their beneficiaries, or at least in the marketplace where the beneficiaries are not only selling, but also, you know, consuming and trading, and this kind of thing.

I don't have any – I don't have any figure in terms of what percentage of our value chain projects let's say would be delinquent in not doing this, but you've probably seen a few examples and you're concerned about it. So that's – yeah, that's not surprising.

So I think there's an obligation, but then there's kind of the problem, because it's a tricky – it's a tricky business, sampling for aflatoxin. It's – and to have a typical value chain project that's trying to do best practices on a wide range of things, and it's not – doesn't have expertise levels built in. Depending on who you hire to do the work, you may get a totally different end result. The sampling methodologies are just – there's a lot of them out there. I think, John, you're one of the experts in that area, and so that would be – that would be a challenge. But I think that the – it's kind of a duty to at least take a crack at it.

John Leslie: I would like to follow up on the methodology there just a little bit, because there have been some real improvements in some of the methodologies in the last three to five years. So one of the big problems that we used to have is hey, here's Felicia. I just found her, and she's been eating stuff in rural wherever for whatever, and she looks just fine. How do I know if she's been exposed to aflatoxin?

Well, in the last five years or so, we've come up with reliable blood and urine tests that we can use to say, oh, well, she's had this much in the last month, or maybe even the last six months, so that we can get that kind of base assay to know what people really have been exposed to.

The other thing that's happened, and you see this at the local grain mills in the United States, at the grain silos, there now are very quick strip tests that can be done in 10 to 15 minutes to assay the amount of these – of a number of these toxins in – that are actually present in the grain that's being brought in or that's being eaten, so that you don't have to take a sample and get it back to a lab in the US or in the capital of the country, if you're lucky, to be able to have the assay done. You can actually have things done relatively quickly, relatively easily, outside of a big technical lab. And that's really important in terms of some of the questions we can ask and answer now are very different than what they used to be.

Audience: This is more of a comment, where I'd like to reinforce what Dr. Wu was saying about education. While I tend to agree with Dr. Bowman that the idea of the base evidence could possibly drive more funders and donors into funding this issue, I also think it's time that we really start educating the farmers. I know a few years ago that was more difficult, and that national governments were saying, you know, we don't want to create a crisis in our populations. But I think that there's enough evidence out there and there's enough work being done that we can now

start targeting some of our – more of our projects, not some, most of them, into educating farmers.

There's been some anecdotal and some research evidence on how storage has driven people to more hermetic storage rather than using insecticides, and what we're finding is that where people replaced insecticides with hermetic storage, they're keeping that for themselves, because they understand the health issues. They may continue to sell the other grain that has insecticide in it, but for themselves, they're going, oh, I want my family to be safe.

So I think that there is evidence out there that shows that perhaps educating the farmers could be one way of doing this. I don't have a complete answer for it, but I do think it's time we make sure that farmers know what they're dealing with.

Ahmed Kablan: Thank you.

John Leslie: I'd like to add one other comment that as we start looking for places where there could be potential – part of the problems with mycotoxins is that it's not a uniformly distributed problem. You get a hot spot, and you've got a big problem, and most of the other places are fine. So it's – the distribution is an issue.

And one of the problems that we have as scientists is how do we find an area that's really got a problem for us to be able to look at it? And one way that would be possible with human populations is to look for areas where it's traditionally been difficult to get vaccinations to take, so where you have to go in a second or a third time for the vaccination to be effective, because essentially what that's telling you is that the immune response is low. You're not getting an effective immune response. There's something suppressing the immune system, and mycotoxins would be a good sort of insidious candidate that we would not think much about, and could be checked for relatively quickly and easily compared to the cost of going through with another wave of immunization campaign.

Julie MacCartee: We'll take a question from our online audience.

Audience: This one's for John Leslie, building off your comments on bio-control. Is an environmental assessment needed to test AflaSafe in regions?

John Leslie: Certainly in the United States, an environmental assessment is required, and the – whatever the product name is here, and I get them all mixed up because I hear them all, but the one that certainly is used in cotton and maize in the Southern United States and in Arizona and New Mexico has passed all the various EPA registrations.

And one of the biggest risks that you get from these is the exposure to the spores of the aspergillus. And a key part of the process as I understand is that they grow the – they grow the fungus that they want to disperse on sorghum seeds that have

been moistened, so that the fungus can colonize it easily, but what they do is they let the fungus colonize just enough to form hyphae, but not to begin to sporulate. So then you can distribute the sorghum seeds just on the top of the field, and they've been killed. They don't germinate. And the spore – the fungus then will begin to grow whenever the conditions are right. There's enough water, the temperature's right, that kind of thing. And a sporulation occurs then, so that you don't expose whoever's doing the application to the spore load.

But yes, you do need to – you do need to take some care in dispersing these. There are potential issues that can arise.

John Bowman: And I'd just like to add that – in response to your question that – when we started working in the area of atoxigenic strains, biological control, maybe a couple of years ago we started to look at it pretty seriously, and certain missions decided to invest in it, our main – the main driver of the technology has been work done at IITA in collaboration with USDA, and a lot of groundbreaking work was done in Nigeria.

But then it started to spread to some of our more core Feed the Future countries, and enough work was kind of initiated that the Africa Bureau did decide to do a regional environmental – initial environmental assessment for kind of all the issues swirling around AflaSafe.

So it's – I'm not sure if it's completed yet, but it was – it was in progress, and it's a pretty robust assessment, and hopefully, we'll have – it's meant to have kind of regional types of conclusions. I don't – I haven't seen the final report yet, so I can't tell you what the major findings were, but it was contracted out.

Julie MacCartee: All right. I thought I saw a few hands over here, several, so I'll get in the center first, and I'll come back to you.

Audience: I believe you mentioned you did a cost benefit analysis of the four different interventions, the pre, post, and vaccination and dietary. Did you observe any specific trends, now that we are grappling about, we are doing this, our resources, and what would be the return on investment? Can you just comment on what kind of trend or what criteria you would recommend for us to consider, moving forward?

Felicia Wu: Thank you. That's a good question. We did not have the chance to evaluate all of the interventions to reduce aflatoxin. We evaluated only two. One was bio-control, and the other was a post-harvest intervention package. We found them both – so we evaluated not in terms of market benefits, but in terms of health benefits. If this was being applied regularly, how many liver cancer cases could we hope to prevent? So this didn't even take into account, for example, other health benefits from reducing aflatoxin.

Both of those interventions were shown to be cost effective, so long as we could keep certain costs down. So one of the most interesting things that we found was that when we were doing the post-harvest intervention package and doing the cost effectiveness intervention, the main cost was in the wooden pallets that ground nut bags should be stored on. And if there was some way – so that actually wound up costing more than everything else in terms of how we can improve post-harvest safety.

So is there something we can use instead of these prefabricated wooden pallets that could actually be cheaper, but just as effective, in kind of keeping the ground nut bags off the floor, so that they're not on kind of a wet floor, and increasing the aspergillus flavus, or aspergillus parasiticus, in this case.

Julie MacCartee: Right. We have about ten minutes left for questions, so we'll come back to our online audience.

Audience: This question is for Felicia. On the study of aflatoxin stunting prevalence in Africa, was a multi-variable analysis run for a correlation with poverty, wash practices, protein intake, etcetera?

Felicia Wu: For the particular studies that – there have been several epidemiological studies since the early 2000s. Several of them did control for a number of socioeconomic variables, and others did not. Right now, we're conducting a study that's being funded by the Bill and Melinda Gates Foundation, where we're looking at the relationship between three mycotoxinx, aflatoxin, fumonisin, and deoxynivalenol, and child stunting, while controlling for all of those nutritional factors, controlling for maternal education, controlling for annual family income. And so when we have the results, we will publish those.

Audience: I guess this was just a comment. There's been a lot of talk about agricultural changes, but going back to the behavioral changes, there's a big overlap between Feed the Future countries and the priority countries for global health, and I was wondering if there were opportunities for our colleagues in Feed the Future to maybe help the MCH community understand opportunities, where there could be introduction of education about these things. So, you know, antenatal clinics, there are breastfeeding campaigns, etcetera. These are reaching the mothers, right? And they're surrogates for the children.

And since there are initiatives for both Feed the Future and Global Health to reduce stunting and wasting, it just feels until the agricultural changes are able to be implemented, there's an opportunity for aligning our interventions.

Ahmed Kablan: Yeah. Thank you, Lisa. We can follow up on this thing. I mean, we have five nutrition experts in the Bureau for Food Security. We need to work more between the global health community, and not only the Global Health Bureau,

but the whole community, to bring it together, to work and focus on this issue, and not just brushing over it – and we need to own it, as John Leslie said. No one is owning this issue. That's the problem. Thank you.

Julie MacCartee: I thought I saw another hand over here. In fact, we've got several. So here. I'll come over here.

Audience: My question is at what point do you actually begin to do the BCC? Because considering that a while back when we began to talk about – when we began to discuss issues of aflatoxin and the impacts on health, several of my colleagues, including myself, actually stopped eating ground nuts, because we had actually got that information. So at what point do we actually begin to do the BCC? Because if we do the BCC before we have all this information, you'll find that the communities who are most vulnerable in terms of under-nutrition will actually stop eating the ground nuts, they'll stop eating the maize, and this is some of their key nutrients. So at what point does that actually come into play?

Ahmed Kablan: Anyone want to take the question?

John Leslie: One of the biggest problems that you have with mycotoxins in general is that they won't kill you today, and if you don't eat, that might. So the question is do I eat this today and worry about liver cancer in 20 years, or do I starve today and know that I won't get liver cancer, because I'm dead next week? So that's one of the biggest problems in dealing with the mycotoxin issue, is that the time horizon is long, and it's not one we're used to thinking about.

We have to be careful about not being alarmist as we're putting out things, and yet we still have to have enough urgency to what we're doing to get some changes to happen. I don't know how else to describe it. Maybe you've got a better description.

Felicia Wu: No, I think you described the problem really well. And actually, the question was asked really well, too.

John Leslie: Yeah.

Felicia Wu: Maybe – and that's where the education comes in. It's – if for no other reason – I mean, aside from interventions that can reduce the likelihood that aflatoxin is in your food, but maybe to encourage some dietary diversity, for example, so that it isn't just a matter that they have to eat the maize and the ground nuts, but maybe there might be some legumes, maybe there's some other type of staple cereal, that they can rely on then.

And it's not the easiest thing to incorporate agricultural diversity and dietary diversity, but I think it's really, really critical, and the educational component is

critical to that, to motivate individuals to want to adopt these aflatoxin-related interventions, as well as to improve dietary diversity. Education is key.

John Leslie: Even with our diets, what we in this room eat, for the most part, even if we had contaminated foods, most of us would not have a major issue with a lot of the exposure because our diets are varied. How often do you eat corn? Cornbread, corn pudding, corn whatever? I don't know. If it's once a week, it's probably a lot. That's very different than twice a day, seven days a week, with maybe a little chicken one day a week, if you're lucky.

John Bowman: I might want to be a little contrarian here and kind of want to sway towards the side of maybe it's important to be an alarmist, especially in the case of gender. It's one thing if you're an expectant mother, and if – I feel we're not doing our job properly if you – if you haven't really raised a high level of fear and concern in here of look, you – this – you've got to get help from the project or from your health post or your ag post to check into the situation on the grain, because it doesn't have to be moldy, even. It can be very high level, and even – and even very toxic, leading –

John Leslie: It can look wonderful.

John Bowman: And it – and they have – they have to at least be told this, and so – that in terms of options, if all they have to eat is that stuff that's there in front of them, no matter what the detection level is, you know, they – there has to be – still, I would want to know if I'm expecting or if I've got an infant or two, you know, that I've got to desperately – if I believe these people, I've got to desperately look for something else.

So – and there, the health community and the nutrition community, the advisors, can help us aggies find something – a solution to that puzzled look on that woman's face. But I don't know. I would – based on kind of what I know, I would not be afraid of being pretty alarming.

John Leslie: There have been some pretty spectacular headlines in the Accra newspapers over the years about aflatoxin exposure, so –

Ahmed Kablan: One last question?

Julie MacCartee: All right. We'll take one last question from our online audience, but I'd just like to remind everyone in person, if you wouldn't mind filling out the survey near your seats, it's just always helpful for us to help improve these events for the future. So your suggestions are always welcome.

Audience: So the last question is not the shortest of questions, but I think it's an important one. It's a market-oriented question, and it's, once a country starts exporting grains to an international market with higher standards for mycotoxin contamination, does it cause an increase in aflatoxin exposure in the exporting

country population, since the high quality grain is no longer available? Or does such a practice encourage lower aflatoxin among all supplies?

John Leslie: Boy, I don't – do you know of a case study where people have actually looked at that? I don't know if I know of a case study, but that's certainly what you would expect, is that there's a finite supply of grain of different qualities, and certainly some of the countries where I've seen the evidence, much of what they grow would not meet the international standard and could not be exported. So you would certain get rid of – they would certainly sell what they had that was the good stuff.

Felicia Wu: To add to Dr. Leslie's points, I can hear two different voices in that question. One is a negative and one is a positive.

John Bowman: Yeah.

Felicia Wu: On the negative side, I think most of the evidence is anecdotal. Yes, if you're – if you really want to sell your grain and your nuts, you are going to sell the best quality stuff to the markets, including international markets, and keep the worst quality stuff at home.

On the other hand, on the positive side, there is one very positive anecdote, and that has to do with pistachios being produced in Iran. There – in the 1990s, and particularly in 1997, there were sky-high levels of aflatoxin in Iranian pistachios, and they were attempting to export these pistachios to the European Union. The EU rejected these pistachios because they had up to 400 parts per billion aflatoxin, and the standard we have here in the US is 20, and in the EU it's 4. Four hundred. So they pretty much said, we are not going to import any pistachios from Iran in that particular year.

What happened in that case? Technology forcing. So they were drying their pistachios in a different way. They were storing the pistachios in a different way, processing them completely differently, such that by the time 2004 rolled around, the quality of the pistachios coming out of – being produced in Iran was much, much better, lower levels of aflatoxin. So that's a positive example of how these regulatory standards can actually promote technologies to reduce aflatoxin.

John Leslie: And a project that I'm currently involved in, and I see a colleague back there, he's involved as well, is one in Afghanistan, where the Afghanis used to export large amounts of dried fruit and raisins, especially to the EU. And they've been getting all of their shipments rejected for high levels of aflatoxin, and one of the things that we're looking for for them now is how to get things back to where they were, because they used to be a major supplier of the European market, and that would be a very important source of cash for the country.

Ahmed Kablan: Thank you, everyone. Thank you for attending the webinar. We – and for – thanks for our presenters. We heard a lot of interesting and exciting things, a lot of teaser points, and a lot of actions that need to be taken. We need limits. We need limit enforcement, so we can address the point of the problem of having the food available and clean. It's not only we want to have limits and regulations and rules, but we need to enforce, we have enforcement in the US, we have enforcement in Europe, we need to enforce it there.

And that will lead to more of an education, education for the public, education for the farmers, and important education for the policy and decision makers, in order to act on these things, and to put policies in place. We need – back to the alternative use for contaminated crops, the point that John Bowman raised. It's very important to find alternative use for them in order to have – help the farmers sell their contaminated crops for alternative use, and that will encourage them also to adopt improved technologies, if there is an income coming to them back, instead of telling them, your crops are rejected, go take it back home and consume it or food it for your animals.

We need more evidence to drive the actions and to drive policy and to drive decision makers, more evidence in linking it to health impact. We know the evidence or the anecdotes exist, and the economic impact of it, the agricultural impact of it, but more evidence linking it or taking it from an association to a causation between the stunting and mycotoxins. We know the linkages which exist, causative linkages with cancer.

But again, these limits we have in the US, the 20 parts per billion in the US, 4 in Europe, those are for cancer prevention, not for stunting. Whether or not for prevention of stunting or effect on stunting could be lower or not, that is a question to be answered. Thank you for everyone, and stay tuned for the next seminar in the series in six months from now.