Improving Nutrition through Agriculture: Cost-Effectiveness of Biofortification

Webinar Transcript

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Howarth Bouis Okay. Well, thank you. Thank you so much for having us over to talk about my favorite topic, biofortification. I don't know if I know anything about anything else.

[Laughter]

Howarth Bouis I hope the people – it's great that we can have so many people online. I hope the audio comes through okay. I'm going to divide my presentation into three parts. The first part, I'm going to motivate why it's important too that agriculture plays a role in solving the problem of malnutrition. That's the first part.

The second part, we don't usually have cost effectiveness in the title, and so Keith and colleagues have done some new work on the overlap between fortification and biofortification, so I'm going to say more than I usually say about the cost effectiveness of biofortification. And then the third part will be the progress that we're making on HarvestPlus.

And I'm aiming to be done, according to that clock, by 1:15. Okay? So I'll keep an eye on the time.

So I – most of the people in the room that you've attended the seminar, you must already be aware of the huge problem of vitamin and mineral deficiencies in developing countries. You've been exposed to all the statistics. I'm going to talk about vitamin A, I'm going to talk about iron, I'm going to talk about zinc, because those are the three minerals and vitamins that HarvestPlus deals with.

Every once in a while you hear a new statistic. I was at the Fortification Summit in Arusha, and I heard the statistic that 450,000 death are attributed to zinc deficiency every year. That was a statistic that I hadn't heard before, and it's – you know, it's an amazing statistic. But I'm not going to show you the maps of micro-nutrient deficiencies, etcetera.

So what I want to do is I want to give some background on what's been going in agriculture, what I think is the underlying cause why we have so many vitamin and mineral deficiencies in developing countries. So this is a slide that I've been showing for a long time. This is changes between 1965 and 1999. This dotted line is 100 percent. This blue line – blue bar is developing country population, right at 100 percent. So population doubled during that period.

Back when our system, the CGIR, was first getting started, people were worried about famines, because they knew that population growth was coming. So we had the green revolution. We had high yielding varieties of rice and wheat and maize. And the great part of the story was we were – these – the production especially in South Asia was able to outstrip population growth.

So what I want to talk a lot about is rather dietary quality, and these bars represent

pulse production. I'm not going to talk specifically about pulses, but it's a holder for vegetables, fruits, pulses, animal products. Production increased of pulses, and production increased by a quarter, but it didn't keep pace with population growth. Neither did vegetable production. Neither did fruit production. Neither did animal and fish production.

So what happens to prices when you have that sort of situation? These are prices for Bangladesh. I like to divide the diet into food staples, non-staple plant foods, fish and animal products. Non-staple plant foods can be dense in minerals and vitamins. Fish and animal products are also dense, and they're highly bio-available. They're the best sources of minerals and vitamins in the diet.

So I've indexed prices at the beginning, when the modern varieties were first being introduced. And we all know that rice prices fell by 40 percent by the end of the 1990s. So it was a great thing for poor people, because rice is a basic staple, for example, in Bangladesh. It's cheaper.

But I want to draw your attention to the green and the red bars. You can see that prices doubled during that period, because you didn't have the same productivity increases. So the problem for poor people is that dietary quality become more expensive. If you're income didn't also grow, it was more difficult for you to afford vegetables and fruits and animal products.

That's the main theme of what I want to talk about. So this is – these are some surveys that we did at IFPRI in the mid-1990s in Bangladesh. This is in rural areas. So 80 percent of energy came from rice, and only 3 percent of energy came from fish and meat products. But if you use the same pie chart and you look at their food expenditures, you can see that already a quarter of their budget, their food budget, which is maybe 20 percent of their income, went for fish and animal products.

So that's what people want to buy. That's what people want to spend their money on, because that's what they enjoy, and that's what they need for good health and nutrition. But prices have been going up, and so even though they spend a fair amount of their budget here, it only represented a very small part of their diet. And so therefore, their mineral and vitamin intakes are too low.

So these are – those were some price information from Bangladesh. These are some data from India. So again, you have the same situation where rice prices came way down. And then we the – we had the price spikes in 2008, 2009. We all heard about rising food prices. It wasn't rising food prices. It was rising food staple food prices. Everybody talks about food security, and they mostly – it's what they're really thinking about is staple food security, energy security.

So now rice prices, instead of being 40 percent lower, they're now around 20

percent lower than wheat prices. And in recent years, in the recent one or two three last years, they've actually come down, and people aren't so worried about the high food prices anymore.

This is – again, this is the data for India, what's been happening with the non-staple foods. And you can see we have the price series all the way out to 2010 here, and you can see that there's just been a general rise in the prices of those foods. So again, it's just getting more and more expensive over time, because demand for those foods are high, the productivity increases just haven't been there.

So we did a simulation analysis. We wanted to see what might happen to iron intakes due to food price increases. So this was the food expenditures that I showed you for Bangladesh earlier, in the 1990s. So you've got about maybe a third of your expenditures on non-food. You've got the food staples, non-staple plant foods, fish and animal products. That's the proportion of your food expenditures.

And we simulated a 50 percent increase in all food prices, like what happened in the 2008-2009 price spikes. So what did the poor do when the rice price goes up? They have to keep eating the same amount of rice to keep from going hungry. That's their first priority. So they have to spend more on rice. So therefore, you have to spend less on these other things. So therefore, you spend less on dietary quality, and not only do you spend less, the prices are higher.

So what this simulation showed for Bangladesh, there's already a lot of iron deficiency here in this previous situation. Iron intakes go down by 30 percent in the after situation.

So when I hear about food price rises and food staple price rises, what I think about is that dietary quality is getting worse and worse. It isn't so much that people aren't buying about the same amount of rice. The problem is is that their dietary quality is getting worse and worse and worse.

So the price of vitamin A is going up over time. The price of iron is going up over time. The price of zinc is going up over time, and many other minerals and vitamins as well.

So that's the – that's the background, okay? So when – we've been at this for many years, some of us trying to convince people in agriculture that they have an important role to play in solving the malnutrition problem. Back in the 1990s, when people discovered mineral and vitamin deficiencies, the nutrition community wanted to implement and are implementing supplementation, fortification, other types of programs. They saw the gap and they said, that's our role, and agriculture said, yeah, that is your role, not our role.

Now it's a different situation today. There's a lot of people that recognize that agriculture has a role to play. We're not going to completely close the gap with agriculture. We still need fortification, supplementation, other types of nutrition interventions. But agricultural has to work with the nutrition community to solve the problem. And so that's the – to me, that's the background that motivates biofortification.

This is – so those of you – you get in audiences where people in agriculture just aren't convinced that they really have an important role to play in nutrition. This is a picture taken from Bangladesh in the 1990s. Some researchers from Cornell University confirmed that this is rickets due to calcium deficiency. So there's an area in the southwestern part of – southeastern part of Bangladesh where this rickets started appearing over a fairly wide area, and no one – it affected no one over the age of 20. It was younger people that it was affecting.

So what happened was with the introduction of the modern varieties, the change in the food system, something happened to the calcium supply in that area, and no one was – in some sense, no one was paying attention. And so this is what happens when you don't pay attention to how your agricultural policies are affecting your dietary quality, your mineral and your vitamin intakes. It's a very visceral image.

So we know we have all the pieces that – we have several pieces of the puzzle to solve the problem. We all want dietary diversity. That's the ultimate solution to the problem. It's going to take decades before the incomes of the poor rise enough to where they can eat the kinds of diets that we're all used to.

So there are these other things that need to take up the slack in the meantime, and as I've said, there are lots of – agriculture has an important role to play, and biofortification is just one piece of the puzzle. It's not – it's obviously not a silver bullet. It's just one piece, and I'll argue a cost effective and sustainable piece of the puzzle.

So first, a little bit – before I get into the cost effectiveness, what is biofortification? It's very simply this orange maize, for example, that's high in provitamin A. Africans eat white maize. They prefer white maize, the whiter, the better, in general. White maize has no vitamin A in it. Africans – vitamin A deficiency is a huge problem in Africa. If we can get African farmers and consumers to substitute _____ growing the orange maize for the white maize. They're just as high yielding. They're just as productive. So they will sell for the same price.

So the value proposition to the mothers is which will you buy for the same price? Will you buy the one that has vitamin A, or will you continue buying the white maize? Will you buy the orange maize and protect your family from vitamin A deficiency, or will you continue growing and eating the white maize? It's just as

simple as that.

Now HarvestPlus, all the crops that I'll talk about – the third part of my presentation is on the progress that we're making. All the crops breeding and releases that I'll talk about are using conventional crop breeding. So to develop these orange maizes, we started with some varieties that we found in Thailand that were orange. We did some high level genetics. We found through market-assisted selection certain genes that were important in raising the vitamin A content of the maize. But it's all conventional plant breeding, some of it very high end plant breeding.

You can use transgenic approaches. You've probably all heard about the golden rice. And that's also an important technique, but for reasons of not wanting to deal with the politics of GMOs, HarvestPlus has decided to just use conventional breeding, not because we think transgenics are dangerous, just simply the politics are very difficult.

So I'm – as Muriel mentioned, I'm trained as an economist, and I've always been attracted by the cost, the potential cost effectiveness of biofortification. The basic idea is you can do the breeding – agriculture research is very powerful, very cost effective. You can do the breeding in a central location. You have the basic varieties that are high yielding and high nutrients. You can make that germplasm available to national agriculture research institutes all around the world. They get adapted to the growing system. They get in the food system. And you don't have recurrent costs year after year after year.

So the – most of the costs are up front in doing the research to develop the varieties, but once they're out in the system, it's very sustainable and very – the recurrent costs are very low. And that's at the heart of the cost effectiveness of biofortification. And I'll go into more detail.

Before we start getting into some of the numbers, the Copenhagen Consensus is a group of economists that every few years rank different types of investments that can be made in developing countries, what are the most cost effective. In 2008, they were asked to pick the 20 most cost effective investments, and 3 out of the top 5 were related to reducing mineral and vitamin deficiencies.

And at the time, our ex ante benefit-cost analyses were convincing enough that even though we hadn't really implemented biofortification at that point, they ranked biofortification as the fifth most productive investment that could be made. So there's a huge drag on the economic development because of the minerals and vitamin deficiencies. So there's huge benefits to be had. And there are different ways of addressing the problem.

So I won't go through those original ex ante benefit-cost analyses, but recently, our

team at HarvestPlus, including Keith, who's going to answer all the difficult technical questions that come up, they did a portfolio analysis. They looked at different types of interventions that could be made, and they looked at tradeoffs and complementarities between biofortification and fortification. They looked at vitamin A interventions in Zambia. We have the provitamin A maize that we're introducing in Zambia. They looked at zinc interventions in Bangladesh. We have a high zinc rice that we're introducing into Bangladesh. And they looked into iron interventions in the state of Rajasthan, and we have a high iron pearl millet that we're introducing in Rajasthan.

It's a very detailed analysis. They're using an ex ante simulation model. But the important thing is they have food expenditure surveys, ideas of what the food intakes are for urban populations, rural populations, farms, non-farms, different socioeconomic groups. And they've looked at all those groups, farmers versus non-farmers, etcetera, etcetera, because we're looking for the niches of the different types of interventions.

So obviously, biofortification's niche is with the farming community. We start with the smallholder farmers who grow the biofortified crops. They eat them. And then they move into the marketing system, and then later on into the urban areas, whereas the fortification, really, their strength starts in the urban areas, and then they reach into the rural areas.

So this is a highly disaggregated model that they're using, and they're seeing how different groups are affected. And they've done the analysis in Zambia, Bangladesh, and Rajasthan.

Another important thing is that they've used a 30 year time horizon. And as I'll explain with some of the following slides, biofortification, in the first few years, biofortification is not cost effective. You spend a lot of money up front. When you first introduce the varieties, you're reaching a small number of people. And the cost effectiveness is only after a long period of time, when you've been able to scale up and they're widely adopted and widely eaten. And that's where the long term benefits come in.

So we'll start with Zambia. There is currently implemented a sugar fortification, and there are various different types of fortification vehicles that are being proposed. There's child health weeks, which include vitamin A supplements.

And the first thing they did was they looked at each intervention as a standalone intervention, without looking at the tradeoffs and complementarities. And they – so the cutoff for whether an intervention is cost effective is usually the cost is something like $200.00 per DALY saved, disability adjusted life year saved. If you can spend less than $200.00 per disability life – DALY, it's cost effective.

So they found that all of these interventions are cost effective, because they're below the $200.00 cutoff. The most cost effective was putting retinol in vegetable oil, but the biofortified vitamin A maize, _____ maize, the estimated cost per DALY saved was $24.00, so it's highly cost effective.

So now to look at the different combinations. Now this is way too complicated to understand this slide, but what they did was they took all different combinations, so you can take each individual, you can take two interventions together, you can take three interventions together, six interventions together, etcetera. You have a whole array of combinations that you can try.

And these represent some of – you know, all the different – not all of them, but many of the different combinations. And you can see that even the most expensive, it comes out the average is $71.00 per DALY saved. So all of these are cost effective.

So the base message is there's plenty of room, even if you implement several different types of vitamin A interventions, they all have their own niches. There's plenty of room to try to address the problem. Okay?

Now in turns out that the most effective combination of two and the most effective combination of three, the most effective combination of four, and the most effective combination of five all included biofortification, because it had a niche in the rural areas with the farmers that the other interventions did not have, or that biofortification had the most strongly.

So I don't know how well you can see this, but this is comparing the reach of sugar fortification with the reach of the vitamin A, the biofortified maize. So what this shows here for the rural areas is that the sugar reached 48 plus 9, 57 percent of the population. The maize reached this percent of the population. I think it's 81 percent of the population in the rural areas. And this orange part, 35 percent are the people that the maize biofortification reached that the sugar fortification did not reach. This nine percent of the people that the sugar fortification reached that the biofortified maize did not reach. Between the two, eight percent of the population was not reached by either one. Okay?

So you can see that there's a huge chunk of the population that the biofortified maize reached that, for example, the sugar didn't, nor the oil. You can make different slides comparing the two different things. And of course, that's for the rural areas. When you go to the urban areas, of course, this chunk for biofortified maize is going to be smaller. Okay? But it's still surprisingly high, 21 percent, because maize is overwhelmingly the food staple that the Zambians eat. I've got to watch my time a little bit.

So when you go over the 30 year horizon, you can see that the DALYs saved are more in the rural areas than they are in the urban areas, but still, there's a substantial number of DALYs that can be saved by the biofortified maize in the urban areas. And I think the simulations assumed that the biofortified maize was only accounting for 30 percent of the total production and consumption of maize in the country. So even though our reach was only 30 percent, it was still a highly cost effective intervention.

We'll move on to – we'll move on to zinc and high zinc rice in Bangladesh. We estimated that it costs $79.00 per DALY saved, and it was much more cost effective than the – putting zinc in the – fortifying zinc in the wheat flour. Okay?

So in Zambia, the vegetable oil was the most cost effective, but biofortification was also not quite as good, but still cost effective. Here, we found that the high zinc rice was the most cost effective intervention compared to the fortification. So it's going to vary by country, depending on the nutrient and the country situation.

So at baseline, 73 percent presently are at baseline in the simulations. Seventy-three percent of the population are zinc deficient in Bangladesh. They looked at how increases in income would improve the diet over a 30 year period. Yeah, income does improve diets, but it didn't eliminate zinc deficiency, didn't come anywhere close. But if you introduce the high zinc rice and it becomes widely adopted, you can reduce zinc deficiency to 26 percent. And adding the wheat flour fortification didn't really – doesn't really affect the zinc prevalency. It's better probably to put iron in the wheat flour. We're not affecting iron through the high zinc rice.

And then it's very – one of the things I – it's very important to note is, as I've mentioned already, the cost effectiveness depends on the level of adoption. If only five percent of people adopt the high zinc rice, it's not cost effective. But if 80 percent adopt the high zinc rice, it's highly cost effective. Okay?

So that's something to keep in mind, and that's kind of the drama with biofortification. Now we've done the grading. We've done the nutrition studies. Can we get high levels of adoption? And if we can, we're home free.

The other thing I want to point out is that – something I mentioned in the beginning is the low recurrent cost. So in these simulations for Bangladesh, this is the cost of wheat flour fortification. So with fortification, with supplementation, you have the same recurrent costs year after year. The population is growing. You're having to fortify a larger and larger supply. So over time, the costs go up. But with biofortification, you have these initial costs, with the agriculture research, but over time, your costs get lower and almost – basically almost disappear.

In this particular simulation, we put all of the HarvestPlus costs for developing high

zinc rice, we loaded them into the Bangladesh simulation. So when we go to the calculations for India, we don't have any costs, right? Because we've already loaded them in the Bangladesh simulation.

So I'm going to skip over the rest of the slides on cost effectiveness, because I'm supposed to finish in the next five minutes. And I want to talk a little bit about progress that we've made now under HarvestPlus. So we have certain – we picked certain target countries where we had our first releases, so the vitamin A sweet potato, which _____ worked on – our potato center worked on before HarvestPlus got started, but was part of HarvestPlus in the beginning. They already had varieties available in 2007.

But our first varieties that we developed under HarvestPlus completely, under – from the beginning, when HarvestPlus started in 2003, we released our first vitamin A cassava in Nigeria at the end of 2011. So you can see now it's an eight or nine year process to do the breeding, get through the varietal release committees. We've also released varieties in DR Congo now.

Our high iron beans were released in 2012 in Rwanda, and then later in DR Congo. Our provitamin A maize was released in Zambia in 2012. So we've had three years of experience now. High iron pearl millet was released in India, 2012. High zinc rice was released in Bangladesh, 2013. They now have a release in India through the Indian universities in one of the states.

High zinc wheat was sold as truthfully labeled seed last year in India, and will be released in Pakistan this year. I was just in Pakistan, and the variety's been released and will be planted for the first time in November now in Pakistan.

So this is what's been happening in our target countries. HarvestPlus is committed now to raising the funding and doing what it takes to try to scale up the delivery of crops in these target countries.

But we've been sharing the germplasm with national agriculture research institutes around the world. Biofortified crops are now released in 27 countries. I think actually Pakistan is now the 28th country. And we're in multi-location testing in an extra like 18 countries.

Now the pipelines are still – we have our initial releases in countries, but the pipelines are still – we have better varieties coming out in the future, even in our target countries, with higher nutrient levels, and hopefully higher yields as well. We've also invested in these other crops, but not as much as in the main crops that are in the previous slide.

I was – I've been going to China every year for the last 11 years, and we finally got

the Chinese government to agree to invest in its own biofortification program that will part of the next five year plan. Brazil has its own biofortification program. They've had one now for six or seven years. They're working on 11 different types of biofortified crops.

Okay, I've reached my limit, but I have a few other things to go. So that – actually, those are remarks that I should have made on this slide. So the green shows all the different countries where there have been releases and where the crops are in multi-location testing. So it gives you a sense of the global reach now of the biofortified crops.

We had to do nutrition studies. We had to prove to the nutrition community that the biofortified crops could improve iron deficiency, vitamin A deficiency. We've done the studies on the iron crops. There's even been a meta-analysis of the different studies that was presented at Micronutrient Forum last year in Addis. The high provitamin A crops, we still have two efficacy trials in the field, but we have a lot of very positive evidence already on maize, on cassava, on sweet potato. So we're pretty much home on the vitamin A crops.

We're not home yet on the high zinc crops. They were the last to be developed. We have bioavailability studies that show that the bioavailability is what we hoped for and what we expected. We have three efficacy trials ongoing in India. One of them has been completed. They're doing the data analysis. And we'll do a fourth trial in Bangladesh with the high zinc rice that we'll start next year. And so by the end of next year, we should have all the evidence in on the high zinc crops.

We had an especially – just to give you a flavor of some of the results, pearl millet is high in iron anyway, and we have a higher iron pearl millet. And we took a group of children who were aged 12 to 6 and fed them the high iron pearl millet, and within 6 months, we resolved all the iron deficiency in the subjects in the intervention group. So that's been published, and it's there in the literature.

A little bit on the dissemination of orange sweet potato. We did a pilot study in Uganda and Mozambique. We introduced – we had intervention villages. We had control villages. We did baseline studies. We did follow-up studies. After two years, we did the follow-up studies. After two years in the intervention villages, they switched to the orange sweet potato, they doubled their vitamin A intakes compared with the control villages. We measured an improvement in serum retinol in the intervention villages. And that's all been published. It's mentioned in *The Lancet* article on the special edition on nutrition.

But that's not all. It's like – so a researcher from IFPRI went back to the Mozambique area two years – so we did that intervention for two years. We did the follow-up survey. He went back after two more years, so four years after the baseline, so it'd

be two years after we quit doing anything in the area, and he measured the level of diarrhea in the intervention villages among preschool children compared with – the intervention compared with the control, and he found that the incidence of diarrhea was 50 percent lower in the intervention villages, and the duration of the diarrhea was shorter in the intervention villages.

So that just gives some feeling for the sustainability, the why it's so cost effective, because we didn't do anything in the area for two years, but it was still there in the food system. People were getting more vitamin A. And the immune systems were benefited from the higher vitamin A intakes.

I'm going to skip a bunch of slides. I'm going to make this the last slide. Okay. So what's the – HarvestPlus now is involved in trying to scale up all over the world, and we know HarvestPlus staff is small, and so we know that our job is to mainstream, get other institutions to mainstream the use of biofortified crops in their activities.

So one of our main things is to get seed companies, private seed companies, to develop and market their own biofortified varieties. You have hybrid varieties of pearl millet in India. We're finding it's the small and medium sized companies that want to take this on first. They want to increase their market share. The big companies are already comfortable. They don't like to try new things until they tell that it's caught on.

So we have the same thing in Zambia with the three private seed companies. There are hybrid varieties of maize. Five percent of commercial seed production in Zambia this year is going to be the orange maize seed. And the government has already included the orange maize in their – they sell subsidized seed to farmers, so they've included now the orange maize seed in their subsidy program. So it's an even playing field between the white and the orange maize.

We need international financial institutions to support the scale-up. The World Bank is now writing the scale-up of biofortified crops in their grants and their loans to countries in Africa. We know about one – the grant for Uganda has been signed. They're working on a grant for Mozambique. There are a couple of things going with DR Congo. EFAB is doing the same thing with their loans.

We need to get multi-lateral agencies involved. We've got the Purchase for Progress World Food Program buying now the high iron bean in Rwanda. They're buying locally, storing in their warehouses. By buying the biofortified beans and storing those in their warehouses, they add a nutrition dimension to an already well-functioning program.

So that's what I tell all the agencies. If you just take – you're working on a food staple, and whatever program it is, you substitute a biofortified crop, you've added

the nutrition dimension to whatever your program is.

We have a process now going in CODEX. They've voted now on new work for biofortification. They're developing a definition and standards for biofortified crops, and that's going to facilitate the international trade in biofortified crops.

I've mentioned already these governments are now investing. They have their own independent biofortification programs. We want their scientific – their large scientific establishments, scientists, to contribute to the scientific knowledge and the spread of biofortified crops.

In Africa, the African Union has endorsed biofortified crops. I was a little bit – the Commissioner for Agriculture in the Rural Economy spoke at the Fortification Summit, at the end of the Fortification Summit in Tanzania. And she had of course endorsed fortification, but she said, I think we need more biofortification than we need fortification, because we like our foods fresh, and to have these minerals and vitamins in our – you know, in our fresh foods. So it was a little bit embarrassing, but I was of course glad to hear it.

[Laughter]

Howarth Bouis And finally, I want to mention that we want international NGOs to be involved in mainstreaming. So we've had a partnership now with World Vision for three years. They were – World Vision works in 90 countries. They want to work biofortified crops into their agricultural programs as a way of linking agriculture and their health programs.

And we've just secured our first grant from the Canadian government to work with World Vision in four different countries to introduce biofortified crops there.

So I've gone over time, but anyway, thank you. I'm happy to answer questions.

Moderator 1: Let us take a few questions.

[Crosstalk]

Audience 1: Okay. Hi. Thank you very much for a great presentation.

Howarth Bouis Thank you.

Audience 1: I _____ agenda _____, and I have a couple of questions, one of which is about changing tastes and how you – what other kinds of interventions have to go along with switching people's demand from white maize to other sorts of maize. Having spent a lot of time in Zambia, I know how people prize white maize.

Howarth Bouis Yeah.

Audience 1: And having whole grain is a sort of choice of the poor. And the second one is particularly about the role of women in the family, and how you reach – what interventions you do particularly to reach women, both as determining their children's diet, and also as producers of crops.

Moderator 1: Okay. We'll take one more question back, and then we'll go to the – to the web.

Audience 2: Thank you. It's really _____ on that part of the puzzle, and make a very convincing case on that part of the puzzle, and the cost effectiveness. You do discuss that with regard to the other part of the puzzle, and we _____ livestock, especially on how that compare – that cost effectiveness compared to other intervention, _____ assistance, livestock being able to provide those micronutrients, but also to contribute to the overall productivity of the food systems. Can you say something about that?

Howarth Bouis Yeah.

Moderator 1: Thank you. So maybe you want to take these three questions, and then we'll go online, take questions from there, and come back to the room?

Howarth Bouis Okay. I'll go in reverse order. So on the – if I were – if I were a Minister of Agriculture of a country, that would be the first thing – one of the first things I would attack as a long run strategy. You have to – you have to increase the productivity of the non-stable foods. So agriculture research, whatever infrastructure you needed to put in, you know, but subject to budget constraints, that's – to me, that's one of the most fundamental things that needs to be done.

Of course, there's a big incentive from the private sector, since the prices are going up and up and up. But to me, that's fundamental. But it's not going to – what I'd discovered about poor farmers is that when they grow something that's high value, they sell it because they just feel they can't – it's too much luxury to eat that high value food. So that's very much long term.

And biofortification is something that used to – ten years ago it was long term, but now we have the varieties. Country after country that I go to, they ask, why are you only bringing this one crop? We want all your crops. And now we can – we can bring in all the seeds from multi-location testing. And all that investment has been done now, and we just – Pakistan wanted the orange maize. They said, that's our fastest growing crop. I said, well, you don't – you don't eat that much maize in Pakistan. But they still thought it might be a useful thing to test, etcetera. So that's on the – so to me, they're a highly – biofortification is now relatively short run, but increasing the productivity of the non-staple foods was an important element that needs to be taken care of.

On the taste of the orange maize and the role of the women, first of all, on the role of the women, it's absolutely the women that we're targeting with our messages, because they're the ones, more than the men, that are concerned about the

nutrition of their families. And the women, both as farmers and as the person who's preparing the food, is responsible for the recipes.

Now with the tastes, there are two different cases. You've got iron and zinc, which you can't see and which you can't taste, and you've got vitamin A, which changes the color. So I didn't get a chance to talk about Rwanda, but we've introduced high iron beans. We've introduced ten varieties. We're doing national surveys to confirm that the yields of the biofortified varieties are higher than the normal beans.

But I'm told that the average yield of the biofortified beans is a ton and a half, and the average yield is a ton of the regular beans. That's going to drive the spread and the adoption of the high iron beans. We've already been able to make the high iron beans available to 30 percent of bean farmers in Rwanda, and I think it's just going to take off by itself because of the high yields. And that's – to me, that's like putting fluoride in the water system. At some point, most of the beans in the system are high iron beans, and you don't have to convince the mothers or anybody. They're just – that's what the supply is, okay?

You can't follow that strategy with the orange maize, so you have to provide the knowledge of why you would switch to an orange, right? You have to motivate that, and you have to spend money to do that. We're lucky that they like the taste of the orange maize. So we do the blindfold test, and everybody says, yeah, this is the white maize. This is the orange maize. But we got lucky. They liked the taste of the orange maize. So this is anecdotal, but our country manager serves orange maize at home. His uncle came and he sat down and he said, "I'm not eating that stuff." And they said, "Well, this is what we have. If you could just eat this tonight, we'll switch back to white maize for tomorrow's meals." And he came the next day, and they had white maize, and he said, "I didn't tell you to switch."

[Laughter]

Howarth Bouis So it's – you know, they like the taste, and they understand it costs the same amount of money. It's orange, yeah, but it protects my family from vitamin A deficiency. So it's starting to catch on. It's being sold in supermarkets. It's – that's not our target audience, but you need it to be marketed. You need a demand for it, because the farmers want to be able to sell part of what they grow. So I'm optimistic about what's going on in Zambia.

And the last one is about the hybrids, okay? With the hybrid varieties, you have to pay more for the seed, but you get higher yields, and so already, most of maize production in Zambia and indeed in Africa, not all countries, but hybrids are starting to take over the production. Same with pearl millet. We do have open pollinated varieties available. We have been breeding open pollinated varieties for the – for the more vulnerable populations.

But it's going to be much more expensive to distribute those through the NGOs, whereas with the private seed companies, now it's becoming part of the business, and you can just kind of leave it by itself, and you don't have the costs.

Now our other crops are not hybrids, so you've got rice, you've got wheat. The vegetatively propagated crops like cassava and sweet potato, they're much more expensive to distribute and get out to farmers.

Moderator 1: Okay. Thank you. Should we take a question from online?

Moderator 2: Sure. Yeah. So there have been a few questions that have come up around the issue of soils, and so in particular, Anita asks how does the effect – how does the change in soil affect the nutrient requirements for biofortified plants. And then is there any research or can you speak to the ability of farm management practices to improve soil and plant health and human nutrition? So what's the soil/crop connection? Would this be considered biofortification? And is it an area for more research?

Moderator 1: Thank you. And _____, you had your hand up.

[Background voices]

Audience 3: I have a couple of questions. The first one relates to the interactions with _____. For example, maize, _____ _____, and we know that if _____ _____ iron absorption, also impacts on zinc absorption and _____ and other _____. So I'm wondering if you increase the concentration of iron in one of your products, and it does in the end affect the bioavailability and the absorption of other similar nutrients _____ zinc _____ later. So _____ _____ effectiveness, do you factor that into account, that maybe if you increase iron content, you're actually reducing zinc absorption, and therefore compromising the zinc nutritional _____?

The other one relates to the yellow maize, and remember, in Zimbabwe, we had _____ and we ended up importing yellow maize. Even up to now _____ yellow maize, it just did not taste the same. We actually disliked it, but we had no choice. We ate it. But as soon as we got to produce our own white maize, we went back to the white maize.

In fact, even in rural areas – my father is a miller – the whiter the maize, actually, the better. We know that if you – the less white, it's still got some of the nutrients. But people in the rural areas actually prefer the whiter maize, because the whiter maize is more refined, it has status _____. So even if you go there and tell them that, oh, you know, the less white maize is more nutritious, it's good for your health, but the social status and the taste trumps the nutrition status.

So I'm curious about in the end, the overall acceptability of the yellow maize, and _____ situations where people have no options, I think it makes sense, but when you now expand to the general population, I personally –

Howarth Bouis Yeah.

Moderator 1: Okay. _____?

Audience 4: Thanks for the presentation. So as far as in the sense of _____ improve cost effectiveness, you mean _____ _____ how can we accelerate adoption by farmers of those new varieties, and _____ where there is an opportunity in India, I mean, _____, I mean, the issue is that because of the extensive _____ _____ regime that is in place in India, this is heavily _____ _____ production of the food chains. And actually _____ _____ into high _____ fruits and vegetables.

Howarth Bouis Yeah.

Audience 4: I mean, that's a very negative effect of the _____ regime that's in place.

Howarth Bouis Yeah.

Audience 4: Now of course, there's a whole _____ many kind of years of engagement with the government of India to actually change the _____ get rid of it, but for many reasons, it's a very difficult kind of proposition. But _____ if you recognize that negative effect for the purposes of _____, _____ actually change the rules of the game of _____ _____ regime _____ incentives for adoption of biofortified millet or wheat or rice, by actually putting a suggestion on the table that actually _____ human system in India _____ _____ distribution system actually over time, and let's say over five years or over ten years, actually move entirely to biofortified grains, actually _____ human system _____ biofortified grains, and _____ distribution system products _____, instead of _____ that comes with having _____ with _____ accepted, that would make a huge difference.

Howarth Bouis Yeah.

Moderator 1: So _____ maybe you want to repeat Martin's question, since people online may not have heard it.

Howarth Bouis Yeah. So yeah, again, I'll go in reverse order. So the last question was about using the food subsidy system in India, given – despite, okay, we have to take as a given that it's inefficient to have these food subsidies, but given that it is inefficient, can we use this system to drive adoption of biofortified crops? And the answer is yes, absolutely. And that's going to be the main way – if we're successful, that'll be the main way that biofortified wheat and biofortified rice will be adopted.

It's very difficult for us to – we can equal the yields of the best varieties, but it's very difficult for us to beat the yields of the best varieties, in the circumstance of India. So if the government officials would give preference to the purchase of biofortified varieties, they'd still be basically the same price, because they're just as productive, and you get the added value of the zinc in the wheat and in the rice. It makes sense.

And the government officials, and we've talked to government officials about this,

and they say, yes, let's try it. I need 200 million tons next week, and let's do it. And so that's the problem right now, is we've just released the varieties. We don't have enough seed. We're trying to multiply the seed and get to the point where there's enough to where we can seriously start getting into one of the state programs or getting our foot in the door. So that's going to – if we're successful in India, that's absolutely going to drive the success.

At the same time, the food subsidy system has been giving preference to wheat and rice, and excluded millets, and millets are actually much more nutritious. And then we've got a high iron millet. So I was – we met with – in August, we met with the state government in Rajasthan, and they've agreed to do a pilot where they take the wheat, they substitute high iron pearl millet for wheat in some of the districts in Rajasthan, and we're going to do a comparative analysis, an intervention and a control, and see if we can record an improvement in iron status through that.

So yeah, you hit – you absolutely hit the nail on the head there with India.

On the – again, you asked about – the orange is not popular, but that's just what – this is what's not popular, is this yellow maize. We do have a separate – it is distinguishable in terms of its color. But the important thing is that people like the taste. When they try it, they seem to like the taste. They don't like the taste of this, because it's not really – a lot of the stuff that was sent as food aid wasn't bread for human consumption.

So that's what the – that's exactly what the drama is. We have to reach a certain threshold of people that try it and like it and eat it, and then if it really is a good product, it will spread, because the value proposition is too good. You get vitamin A, it tastes good, and it's the same price. So all I can say is come back in five years and we'll see what happened in Zambia.

Incidentally, FAO just gave us a big grant to now introduce orange maize into Zimbabwe. So it's right next door. We'll see what happens.

On the phytates, yeah, we had huge debates on phytates in the 1990s, when we were trying to convince people to invest in biofortification. Some people said the absorption would be way too low because of the phytates. Other nutritionists said it depends on your iron status. If you have low iron status, you'll absorb a higher percentage. If you have high iron status, you'll absorb a low percentage. There were debates about whether the meal methodology, test meals over a few days, whether that really accurately measured the bioavailability, if people had a chance to adjust over a longer period of time.

And I can say that now that studies are in, and it shows that the latter group is correct, that people with low iron status absorb at a much higher rate than the

people with high iron status. We measured absorption rates as high as 15 percent when we did a high iron rice study in the Philippines, and it was done in 2001-2002. So –

Audience 3: I was thinking about the zinc/iron interactions, not that if you increase _____ iron, then you compromise the absorption of zinc or calcium or others, because –

[Crosstalk]

Howarth Bouis Well, these – we're adding at levels that are normally in diets. We're not adding – we're not fortifying with iron and zinc at the same time at high levels. So all of our efficacy trials we're having – basically having positive results on our efficacy trials. I'm not a nutritionist, but this is what I know about the results of the efficacy trials.

So there were several questions about soils and farm management practices. We've tried putting – another way of adding zinc to the seeds is putting zinc in fertilizers. So you can put zinc in fertilizers. It gets in the soil, and it makes its way into the seeds. We've done several experiments with that. It does increase seed zinc content, but not by enough to make that much of a difference.

But we have found that when you spray zinc during a particular period of plant growth, you can – if you add it to insecticides or whatever you're spraying for, you can massively increase the seed/zinc content through spraying. The problem is we haven't found a – we haven't found a motivation for farmers to do that, an economic motivation for farmers to do that. They have to spray during a specific period of plant growth. Why would they do this? To feed their families with higher zinc? No. That's not going to motivate them to spray. So we haven't found the economic motivation.

Maybe in India, if you could bring in your wheat and your rice that has higher zinc content, then that would give a motivation to the farmers, if you had that as part of your food subsidy program.

The – it's often asked whether we're going to deplete the soils of zinc and iron. You can deplete soils of nitrogen and phosphorus with just a few crops, but it's a completely different situation with trace minerals. There are enough trace minerals in the soils for thousands and thousands of crops. The amounts, they're actually minute. They're trace amounts that you're adding. You need them for your health, but they're physically just trace amounts, and you're not significantly depleting the soils. So maybe I'll stop with that.

Moderator 1: Okay. All right. Rose, if you can check if there's a question online, and while you get that together, let me mention two things. One, the PDS issue, I think what Martin said about biofortification and what you answered, similar conversations are happening around commercial fortification as well. Can we do commercially fortified wheat now, for example, and use that _____ PDS system _____?

And second, on soils and micronutrients, there is research ongoing on _____ fertilizers for soil that would go into the soil and then into the crops, and into the food systems as well. So there are a bunch of other things that are important as well.

And now there are a couple of burning questions, so I will request that you be really, really brief. Let's start with the online question, and then yourself, and then yourself, and then we'll finish.

Moderator 2: Okay. So just two brief online questions. One is is there any risk of losing nutrients during processing of any of these crops? And also, how can the private sector and the food industry become involved and better contribute to this?

Audience 5: Yes, I'm interested in opening up the CODEX discussion. With the CODEX discussion, it seems like one risk you run with that is this question of whether or not genetic engineering can be used in biofortification, just because of the controversy around that in CODEX. I have the scars to show you.

So I'm interested in that, and I'm interested in what you hope to get out of that, beyond the definition. Is it meaning that you have to achieve a certain level of biofortification? Is that what you're hoping to get? But how also are you going to deal with this controversy around genetic engineering?

Moderator 1: All right. Thank you. Next – last question?

Audience 6: I have two. Okay. I'll ask one. _____ it's very – it's become very expensive for small _____ farmers to grow just _____ _____ for the nutrients _____, and many of them are actually struggling _____. I wonder how far _____ _____ making these types of _____ _____ in terms of requiring NPK? I don't know, I see a situation where it's a _____, but may become a source of expensive vitamin A _____ _____ sell today to the whole _____ _____.

Moderator 1: All right. So over to you, Howie, and then I'll turn it over to Steven so that he can summarize all the wonderful things that have been said _____.

Howarth Bouis Okay. So with the – so again, I'll go last back. We're not trying to – we're trying to be the least invasive possible, so if farmers are growing a particular crop and they're using fertilizer, we just give them a variety that – you just switch – replace one for the other, and you continue using fertilizer. If you don't use fertilizer, again, you just substitute one for one. We're not asking them to use more fertilizer, less fertilizer, do more plowing, less plowing. You just keep your practices the same. You just substitute the biofortified variety.

Now farmers are facing many problems, and that's the job of the agriculture research community, to give them better and better technologies to help them meet their problems. So for example, we're – our centers are breeding for climate

change. They're breeding drought tolerant varieties, submergence tolerant varieties. The beans are heat tolerant, so that they can adapt to climate change.

What we're doing is we're piggybacking on the best varieties that are coming out, because farmers eventually will be adopting these climate adapted crops, and we need to make them biofortified. Otherwise, people will forget about our biofortified varieties, and are going to – they're going to adopt the climate adapted crops. So that's kind of our approach.

On the CODEX, I think one of the main things is to come up with standards. As biofortified crops become popular, we're afraid that people will start selling things that are not – they'll label them as biofortified, but they won't be biofortified. So we need some kind of standards to avoid that, and also with the international trade.

Audience 5: You mean a minimum level of nutrient has to be –

Howarth Bouis Yeah. Yeah. And it's up to the – in the end, it's up to – obviously up to the CODEX process. HarvestPlus isn't going to say, this is what we want the standard to be. It's going to be the negotiation process that goes on. You understand it much better than I do.

Now with – you're right, the genetic engineering is a huge problem. The developing countries tend to love the idea of biofortification. Europe is a little bit wary, because they're afraid we're pro-GMO. The US is a little bit worried because they think we're anti-GMO. So we're having a biggest problem with the United States and Europe. But the developing countries, they're all – they're pretty much 100 percent for us.

So what we're trying to do is say the mode of production is not part of the definition.

[Crosstalk]

Audience 5: That's _____ labeling.

Howarth Bouis And that's how we're trying to get – you know, get around that problems. So we have – you know, Anne McKenzie, she's very skilled and knows the CODEX.

Audience 5: Yes, she has the scars to show, too.

Howarth Bouis _____ that's why we're trying to get around that. And the question on the retention, absolutely, a lot of the nutrients are lost in the storage and the processing. So for example, in the vitamin A maize, when it's freshly harvested, let's say it has 15 parts per million provitamin A maize, and some of it's eaten right away. But when it's stored, it loses over time, over several months, it loses – it loses the levels of vitamin A. When it's processed into flour, it loses some of its vitamin A.

So when we set the target levels, we take the – for the breeders, we take the losses

in processing into account. We assume that 40 percent – on average, 40 percent of – no, 60 percent of the vitamin A is lost on average before it's consumed. But the 40 percent that's left provides half of your vitamin A requirement. So yes, we absolutely take account of the losses in processing.

We want the food industry to be involved in buying the biofortified crops and putting them in their products, mainly because that creates the markets for the farmers. We don't think – a lot of the processed foods don't have that much of the nutrient left in them when they're sold on the supermarket shelves, but because the food processing companies are buying them, that helps generate the market. And absolutely, the farmers want to be able to sell part of what they produce. Otherwise, they're not going to just adopt the biofortified crops for their own families.

Moderator 1: Okay. Thank you. _____ _____ Steve.

Steven: Yeah. I think what I'm hearing is the need to get both the science and the art right, and you describe that as the drama, right? And so the science has now delivered a lot of results, and the drama is now maybe the most challenging thing, with perceptions, adoption, distribution systems, seed, particularly for potatoes, things like that.

And in some ways, the – I'm thinking the World Bank's role is more about leveraging the science instead of dealing with the drama.

Howarth Bouis Yeah. Absolutely.

Steven: It's one thing, we can finance _____ and whatever, that's going to take some years, and whatever, but we are trying to interact with subsidy systems, with – ISC is working with food companies. So I think that's maybe an area where we need to be looking at, is beyond this line.

I think the point you made about in circumstances where you're getting a higher yield or a bigger disease resistance, then the science takes – the science trumps the art, right? So it's _____ crops.

Howarth Bouis Exactly.

Steven: Right? And to the extent to which the next generation of breakthroughs are of that nature, then the sort of burden of adoption will be low. I'm not going to end with a question, but I'll _____ _____, so _____ question on the – thinking about the cost side. But I just want to thank everybody, and the folks who were connected, and their questions, and thank Howarth for a very interesting, thought-provoking presentation. And we're very happy you were here.

Howarth Bouis Okay. Thank you. Thank you.

[Applause]