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HIDDEN HUNGER: THE ROLE OF NUTRITION, FORTIFICATION, AND BIOFORTIFICATION

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I'd like to first thank the organizers of this symposium for recognizing the linkages between agriculture and nutrition. I think it's so important for a nutritionist and agricultural scientist to talk to one another and to learn how we can address problems of nutrition together rather than separately. I think the topic of biofortification brings those two areas together. It's not the only way of linking agriculture and nutrition, but I feel it's a very important way that we can do that.

I want to talk a little bit first about the underlying situation that's causing the micronutrient malnutrition that we've been talking about in this session, and then I want to talk about some of the challenges that biofortification faces, its promise and the challenges. Biofortification is something that's gotten off the ground now, but it's not a proven intervention, so there are several challenges that we face that I want to go through. And then I'll say a few words about the vision.

Throughout my talk I'm going to present some data from Bangladesh. This is the results of some household surveys that we did in Bangladesh about ten years ago, and it shows we divide the diet into three different areas: the cereals, the nonstaple plant foods, and the animal and fish products. This is pretty typical of diets of poor people throughout the world. That brown area where the cereals, rice in this case, are providing 80% of the total intake; the nonstaple plant foods in terms of energy – the nonstaple plant foods 17%; that small red sliver is the animal and fish products (Please refer to power point).

The most important parts of the diet that are going to provide the highest levels, the most bioavailable levels of the micronutrients and minerals and the vitamins are the animal and the fish products. The nonstaple plant foods also tend to be dense in minerals and vitamins, so these should be the sources of the micronutrients in the diet. So this is the underlying reason, because cereals, the staple foods, are not dense; they're not very bioavailable. This is what is leading to all of the micronutrient malnutrition, or at least it's a leading cause of it.

This is the same household, same data, but this pie chart is now showing how these households are spending their money, their food budget for the same food groups. You can see that now this red portion, even though it's only 3% of the energy, it's 25% of their total food budget. Now, in poor households, they might spend 75-80% on their total income on food, so they're already spending 20% of their total income on this animal and fish products. So this is where they want to go. When their incomes increase, this is where they want to spend their money at the margin. So it's not a problem of knowledge really, it's a problem of income and income constraint.

But income constraint is partly a matter of the prices of the foods. What this diagram shows here is what's been happening to food prices in Bangladesh over the last thirty years. I think it's important. We've talked a lot about food, World Food Prize, but we have to think about the different parts of the diet when we think about food. What these brown bars are, I've indexed the prices in the early 70s on a hundred, and these are all controlled for inflation. You can see these brown bars have gone down over time. Rice in Bangladesh today is 40% cheaper than it was in the early 70s. This is a great accomplishment of the Green Revolution that we've been talking about.

But what's been happening to the other parts of the diet, the nonstaple plant foods? You see the bars going up. The animal and fish products, you see the bars going up. Fish today in Bangladesh is twice as expensive as it was in the early 70s. Every nonstaple food that I've looked at in Bangladesh, over time the price has been going up. So the poor are being backed into this corner. It's wonderful that they're paying 40% less for their rice, because it keeps them from going hungry. But the problem is, it's becoming more and more difficult to treat the hidden hunger, because the prices of those foods are going up over time.

So we can look at the underlying cause for that as well. It's a supply situation. Along this axis are percentage increases between 1965 and 1999. So this a hundred percent increase represents a doubling over that time. This blue bar over here shows that population in developing countries has doubled over that time. The brown bars show that the cereal production has more than doubled, so the supply has grown faster than the demand, and the prices have gone down, as we've seen in the previous slide.

We have a real challenge, I think, to at the same time as increasing cereal product, we also need to pay attention to increases in the supply of the nonstaple foods. I think that's a great challenge facing us in the decades ahead.

So I think that we need not to just worry about quantity. Quantity is very important. We need to make sure that we maintain the advances, we keep ahead of the population growth in terms of quantity, but at the same time, if we're going to lead productive and healthy lives, we need also to pay attention to the quality.

So biofortification is a strategy of getting the plants to fortify themselves. There are obvious advantages of that in terms of cost, because the plants, once you do the research, you get the plants to do the work and you no longer have to have the recurrent costs of trying to add fortificants to the food supply, if you're comparing it to fortification, or the recurrent costs of supplements – although I'll argue at the end of my talk that we need all of these strategies if we're really going to effectively treat the problem.

But we have seven key questions that we have to answer to show that this strategy works. We haven't yet proved that this strategy works.

Well, first of all, let me say that we can approach this both with conventional breeding, and we can approach this with transgenic methodologies.

When I first started looking into the possibilities of these strategies, I had my first appointment at IRRI in 1993 with Gerdev Khush, and I asked him about this. I remember very vividly, he said, "Nobody has ever asked me about how much iron is in rice. Let me go look in my book and see what the value is." And then he gave me my first lesson in plant breeding. He says, "Well, the first thing we have to determine is, is there a genetic variability. If we have low iron rices and high iron rices, then there's a possibility of breeding for high iron rices, using conventional methods."

And this basically shows that when we did our initial germ plasma screening, that there was quite a bit of variation. The minimums in brown rice were five, six parts per million, milligrams per kilogram, and the highest values were 24, 25 milligrams per kilograms – just screening less than 1% of the available germ plasma. And we found that the average among popular varieties was around 13 milligrams. So initially that question was taken care of in the sense that the breeders were convinced that there was plenty of genetic variation to follow a conventional breeding strategy for iron and for zinc.

The second question that we have to address is: Okay, we can breed the high iron – it turns out high yielding varieties – but can we get the farmers to adopt? Well, I'm going to talk about two different cases, and the first case is iron and zinc. At the levels that we're breeding iron and zinc, we don't think consumers will be able to tell visually that there's more iron and zinc. We don't think that it will change the taste, because we're only adding a few parts per million to the product. So the strategy is to put the varieties, to put the iron and the zinc in the highest-yielding, most popular varieties. The farmers will adopt them because they're high yielding, because they're profitable, but at the same time will be loading the iron and the zinc as a public health measure. The analogy that I use is like putting fluoride in the water supply. We get our fluoride when we drink our water. It's not something that we're unaware of, but it's not something that we think about.

So when I went around to talk to the breeders about this, the first roadblock that I came to was – they said, yes, the problem is, there's probably going to be a tradeoff between more iron and zinc in the plant and yield. You breed for better nutrition, you'll get a lower yield and you'll never get the farmers to adopt because it's more nutritious. And I agreed with that. And time after time I visited several centers, and I got the same lecture, and I really couldn't get around it.

But I made one last visit to something called the Plant, Soil and Nutrition Laboratory, and I talked about the problem of micronutrient malnutrition. But this was a group of scientists that knew a lot about the translocation of minerals in the soils, taken up by the roots, translocated into the seed. And I described my visits and my discouragement at following this strategy. A scientist, Ross Welch, stood up at the end of my seminar, and he said, "You know, our research shows over the last couple of years that the plants need these trace minerals as much as the humans do. If we can breed plants that load more trace minerals, particularly zinc, into the seeds, it's a way of improving seed vigor and vitality, and we get higher yields. We're pursuing this strategy to increase agricultural productivity."

I knew right then and there that that really turned the whole thing around, that I could go back to the scientists and tell them about this. This next slide demonstrates this principle. This is a picture taken at IRRI, and in the back rows is the good soil, nonzinc-deficient soil, and in the foreground is a zinc-deficient soil. And there are different rice varieties growing, and the same variety is growing across from one another, so that you can see that these varieties grow well on regular soils, but they're not tolerant to the zinc-deficient soils. But this is our high-iron, high-zinc line that I'll be describing at a trial that we use, I'll be describing in a later slide. And you'll see that it grows just as well on the zinc-deficient soil as it does on the regular soil. So we do feel that this is a way that we will be able to breed high yields and high iron and zinc, and in some cases we may even be able to improve agricultural productivity.

With beta-carotene, it's a little bit different strategy because when you breed more beta-carotene, you change the color from white to yellow. And so you have to convince consumers. You have to say, "Eat this particular variety," and convince consumers to change their habit. So we don't know yet whether we'll be able to change consumer behavior. This is a picture of the golden rice that was harvested recently in Louisiana. To me it's quite beautiful to look at. To me it looks very appetizing. I think that if we attach a nutrition message to this, we do the studies that Dr. Sommer talked about, we demonstrate that it can improve vitamin A status, and we have a strong nutrition communications message, that we can convince mothers to feed this yellow rice to their children, because it's more nutritious. I should think that adults would find it appetizing as well in terms of the color. I don't expect the taste to really be any different. This is a coccidre rice, the white one, and this is coccidre that has the genes that give it beta-carotene.

So the next question is: How much can we affect nutrient intakes. We can breed more in, but are we increasing intake levels by 1%? Are we doubling intake levels? What can we achieve in terms of intake?

Again, these are the data from the Bangladesh. This shows their total vitamin A intake. Right now we're estimating that the adult women are only getting about 40% of their RDA. For reasons that Dr. Sommer described, I use the conversion rate here of 12 to 1 to convert from beta-carotene to retinal equivalents. And what this white area shows is how much extra vitamin A would be provided by the rice in the picture that you just saw in the previous slide. The levels are 6 micrograms per gram; that's 4 times the level that was in the original rice that was published five years ago.

Now, I understand there was a press release by Syngenta. This particular strain, SGR-1, was developed by Syngenta. There's a press release today that says that Syngenta has given this rice to the Humanitarian Board for release in developing countries. The press release also talks about other research that is undergoing where they feel that they'll be able to multiply the density of the beta-carotene in this rice, SGR-1, by even higher levels. This is somewhat hypothetical at this point, but we've now multiplied by four. What if we, instead of multiplying by four, what if this research that's ongoing, what if we multiply by ten? If we can multiply by ten instead of by four, we can actually meet the recommended daily allowance if they eat this golden rice day in and day out. So that's an example of what contribution that we can make to nutrient intakes for beta-carotene.

Now, let's talk a little bit about rice, about iron in rice. I don't know if you can see the data here, but we've estimated that poor people in the rural area in Bangladesh, their daily intake, women, their daily intake is around 7 milligrams a day. The recommended daily allowance is 18 milligrams a day, so they're quite well below the RDA. How much can we add? Well, we feel that a reasonable breeding target is to increase the amount of iron. The increase is 10 milligrams per kilogram, and if women are eating 400 grams a day of dry rice, that means that we can increase their intake of iron by 4 milligrams. So it goes from 7, it goes up to 11. That's still well below the RDA, but in the next slide I want to investigate exactly what the RDA means.

Now, this is a slide that is exactly analogous to what Dr. Woteki presented earlier. Along this axis, it shows the requirements for various individuals. It shows that some people, because all people are different, some people, some individuals may require only between four and six milligrams per day, while other people, because of their individual makeup may require 16 to 18 milligrams a day. So there's quite a wide variation, intra-individual variation in their requirements.

So this is a figure that's drawn for adult women in a developing country. And what this shows along this axis is the cumulative distribution of people who have met their RDA as the iron intake increases. So if the average intake is 7 milligrams that we've recorded in our household surveys, then the estimate from the curve is that only about 30% of the women in the rural areas are meeting their daily requirements of iron intake. But if we can increase the intake from 7 up to 11, 80% of the women will meet their daily iron requirements. If we can move the iron intake up from 7 to 11, that means that we can move 50% of the women in the rural areas from below their energy requirements to meeting their energy requirements and above their energy requirements. So there's quite a potential, I think, for doing good at the levels that we can breed in these varieties.

Now, the next issue – when you look at intakes, and again this is an issue that Dr. Sommer brought up – you have to study the bioavailability of the nutrients. You can increase their intakes. We have some idea of what we think the recommended daily allowance is, but you have to study how much of the nutrient is absorbed and whether it actually affects nutritional status. This is referred to a the bioavailability of the nutrients.

So this is an issue that we've been grappling with that has been debated over the last ten years or so. Some nutritionists were arguing that the bioavailability of the iron would only be 1 or 2% because of the substances that bound the iron. We knew that the strategy wouldn't work if the bioavailability was only 1 or 2%. We needed something on the order of 7, 8, 9, 10% of bioavailability for the strategy to work at the levels of iron that we can breed into these plants.

So we finally were able to do an efficacy trial in the Philippines. I don't have time to go through all the details, but a group of religious sisters in the Philippines agreed to do the study. Basically what we found was that the bioavailability was 8% in this study. We were able to improve the iron status of the subjects in the study after they ate this rice over a nine-month period. So this doesn't prove that bioavailability won't be a problem, but it's good news – it shows that we got the kinds of numbers that we were hoping to see in this proof of concept study.

Then I think the final question is whether the strategy is cost effective. I think what we can do it. To demonstrate the cost effectiveness of the study, we're trying to add the biofortified food to the food supply and shift the distribution – this is the distribution of iron deficiency – to the right. Okay, now how far can we shift the distribution to the right? Well, we don't really know at this point. We have a little bit of an idea from the Philippine trial. But we can do some back-of-the-envelope calculations on what the benefits would be.

Let's take a country like India. What if we biofortified the wheat and the rice, the basic staples in the diet? Economists estimate that if we can move a person across that line in the previous slide from deficiency to sufficiency, that's worth $20. Each person each year, it's worth $20.

In India, a population of $1 billion, if we can over 1% of 1 billion people across that line in 1 year, that's 10 million people times $20, or a value of $200 million. But we think we can do better than that. We think that probably 10% of the people to move across that line is a reasonable estimate, and because it's a sustainable strategy, let's say, let's take a calculation for ten years, so that's 10% of the population is 100 million people times $20 times 10 years – that's an economic value of $20 billion.

Under the HarvestPlus program, we want to spend somewhere between $10 million and $15 million a year to work on six crops in developing countries all over the world, or a total investment for all crops for all countries of maybe a hundred, hundred and fifty million dollars over a decade. And if you get a return in just one country over ten years of $20 million, you can see that that's a very cost-effective strategy.

Let me just end by summarizing what I think the advantages of biofortification are.

First of all, it's low cost and cost effective. It's a strategy that reaches the rural populations first and works its way to the urban areas as those biofortified crops make their way into the marketing system. It targets the poor because it's their diets that are dominated by the staple foods. And, finally, it's sustainable. You do the research, you get the varieties out there in the system, and then they're there. The recurrent costs go down. You make the initial investments, and then the people benefit from the nutrients in those crops year after year after year.

I do want to make the point, though, that biofortification is not itself the final solution. We feel that it's a new tool, a new strategy that's going to complement supplementation, that's going to complement food fortification. But in the end, the final solution to significantly reducing micronutrient malnutrition is to get the dietary quality up, make plant foods affordable, make animal and fish products affordable by lowering the prices and by raising the incomes of the poor.

So our vision is that we really, we hope that through the biofortification strategy, nutritionists and health specialists will start to look to agriculture as one of the tools, one of the ways that they can meet their public health and nutrition goals. Right now not a large part of the nutrition community really looks to agriculture when they look for solutions to the micronutrient malnutrition problem. But by the same token, we hope that the agricultural community, the agricultural scientists will realize more and more how their actions impact importantly on health and nutrition. And so they'll formulate their investments, their policies with an eye toward how they can also help in the fight against malnutrition in developing countries.

Thank you very much.

AMBASSADOR QUINN

Thank you very much, Howarth. You didn't mention the donors that are supporting that biofortification work. Could you do that in a minute, I mean 30 seconds or so? One of the interesting things is that the Gates Foundation, which has been funding fortification, stepped in also on biofortification, and we were very pleased that they were willing to do that.

DR. HOWARTH BOUIS

Well, we were making these sorts of arguments for many years, but in the end you have to get the funding to make this happen. For a long time when we went to the nutrition donors, they said, "Well, this is an agricultural project, so you should go to the agricultural donors." We went to the agricultural donors, they obviously said, "No, this is for nutrition. Go to the nutrition donors if you want this funded."

Well, after really a decade of doing this, what really broke the ice finally was that first of all biofortification was accepted, was approved as a Challenge program by the CGIAR. They wanted programs that addressed global problems that involved inter-institutional, interdisciplinary research, and biofortification fit this to a tee. So we were approved, and as part of the approval process, the World Bank agreed to give $3 million a year to each approved Challenge program.

So then we went to the Gates Foundation. We proposed to spend $50 million over the first four years, $12.5 million a year. So we had a quarter of that funding from the World Bank. Then we went to the Gates Foundation, and they agreed to fund half of the program. So about a year ago they agreed to give us $25 million over four years. And then this year, USAID has agreed to contribute $3 million a year. Canadian CEDA recently announced a grant, and they will be giving, I think, $2 million a year. And the DIFID, the English government, is giving $1 million a year.

So we actually have now reached funding of $55 million over the four years, and we didn't really think we could achieve $50 million of that, maybe just two years ago. So now we have the funding to really try to implement this strategy.

AMBASSADOR QUINN

Then we should also recognize that USAID spent a decade providing albeit low levels of funding, but funded it for ten years, hoping that something valuable and viable would come from it. And I think the effort now looks to be very viable and perhaps potentially quite valuable as well.

Catherine, do you have any summary comments you would like to make?

DR. CATHERINE BERTINI

I think the prospects that we've seen are very exciting, and hopefully we'll take not only this knowledge that we've gained today but also some ideas for action in terms of how we can go back home and fine ways in order to implement some of the ideas that are presented. And then that we, those of us who are able to come back next year, that we can report back on the progress that we've all helped to contribute to in this area when we talk more about it in 2005.

Thank you.