What is Wrong with Biofortification

Published 24 April 2023, with Jeremy Cherfas.

Hidden hunger — a lack of vitamins and minerals in the diet — afflicts two billion people around the world, with lasting effects on health and well being.

Biofortification — engineering or selecting varieties of staple crops so that they produce higher levels of micronutrients — might make perfect sense to tackle hidden hunger, which is strongly correlated with the amount of energy people get from staples. Putting more micronutrients in those staples ought to be a good thing. Except that there's little evidence that it works, and yields of biofortified staples are generally lower than those of unfortified varieties. That's a waste of land that could be used to grow the fruits and vegetables that contribute to a more diverse diet, which does improve micronutrient deficiencies.

All this and more is brought out in a recent paper in the journal Global Food Security. I interviewed one of the authors. The title of the paper is "What is wrong with biofortification". No question mark. So that was a good place to start. What is wrong with biofortification?

Guest Jeremy: Well, we focus on four things, really. One is about the yield. There seems to be a yield penalty. That is, you don't get as much total crop from a biofortified food as you do get from a non biofortified variety. Another worry is genetic uniformity. A third is about their suitability for the very poor subsistence farmers who are probably the ones who most need more micronutrients in their diet. And finally, there's almost no evidence that it actually works, that it actually improves the health and well being of the people who eat biofortified foods. In fact, it's really strange to ... It's really difficult to find evidence that it works.

Host Jeremy: All right, Let's start then with yield. I mean, surely breeders take that into account.

Guest Jeremy: Yeah, you'd think so. And yes and no. There are a couple of things, though. One is the sort of theoretical limit to how much the plant can put into the part that we eat. And there's some good evidence that the more micronutrients go in, the lower the yield. Or to put it another way, with a higher yield, you actually get less of whatever it is you're looking for. So rice, for example, if you get a higher yield, you get less zinc in each grain of rice. And the same is true for beta carotene and yield in cassava, in maize and in sweet potatoes. The more is in the crop, the lower the total yield. So a biofortified crop is likely to be lower in macronutrients in the calories that you really need from them. But more to the point, when breeders say their that their biofortified variety provides a good yield, quite often they're checking against out-of-date varieties that are not even being grown much anymore.

Host Jeremy: Hang on a minute. What do you what do you mean by that?

Guest Jeremy: Well, when you want to release a new commercial variety in many, many countries, you have to prove its value. You have to show that it's better than existing current popular varieties. And my colleague Maarten van Ginkel, who is a breeder, he looked through loads of examples of this. And for example, he looked at wheat. So you've got high zinc and high iron biofortified varieties of wheat now. And the yield of those is 82% for zinc and 72% for iron of the check variety, which was released over a decade ago in 2011. Okay. So if you make a normal assumption that breeding progress in yield is somewhere between half a percent and 1% a year, then over the course of about ten years, the best wheat could be 5 to 10% better than the check variety. So rather than 80% and 70%, those varieties are really only yielding 70% or 60% of the highest yielding modern varieties.

Now that's hardly a high yielding variety, and you get similar results for rice, where the biofortified varieties are 20 to 30% lower than the best varieties. Orange fleshed sweet potato is even worse, with only around half the yield of the variety that they check against, and that variety was released back in 1989, so who knows how much better the modern varieties of biofortified sweet potato really are.

But the real concern — I mean, you know, this is sort of number crunching and nitpicking — but the real concern is that farmers who say, Oh yeah, okay, I'll adopt a biofortified variety, they may not appreciate that their yields overall will drop. And so now in addition to a micronutrient deficiency, you possibly have a macronutrient deficiency where they just don't have enough food.

Host Jeremy: Okay, so you've made a pretty good case against biofortification, but what are the alternatives?

Guest Jeremy: Well, I mean, I think it's absolutely true that biofortification can increase the quality of the food. There's no doubt about that, that you can raise the levels of micronutrients, maybe not as much as they claim, maybe it's not as sustainable as that, but you can do that. But it does reduce the quantity of food. If, on the other hand, breeding staple crops for yield ... I mean, these are the crops that supply supply us with most of the energy we need. If you focus on breeding staple crops for yield, that means supplying the energy we need will need less land. And that land you could then use to grow fruit and vegetables, which if you can get people to eat them, could supply even better nutrition than the one to however many micronutrients you you manage to get into the crops by biofortification. So yeah I mean breeding is great. We need to increase the yield of staples. So let's do that. Let's focus on increasing the yield of staples and looking to other foods to supply the missing micronutrients.

Host Jeremy: Okay. Yeah. But surely, I mean, surely scientists can overcome all the technical objections.

Guest Jeremy: Well, maybe they can, but they haven't so far. And there are other problems. I mentioned genetic uniformity. When you look at conventional breeding, it's time consuming and it's a game of numbers. The more offspring you look at, the better the chances of finding the kind of changes that you're looking for. And there's an approach — it's not that new any more — called marker assisted selection, a really important breeding advance because it allows you to screen rapidly many, many more offspring. Because what you do is you look at the DNA of the offspring and you can do it for a seedling that's just a couple of days old. And you say, okay, has this got the gene that I'm looking for that will increase whatever it is you're looking to increase. And that that, as I say, that's great. It speeds things up

enormously, but it tends to make breeders focus on just a few genes that they know will increase the amount of micronutrients.

And so you've got lots and lots of what look like different varieties offering, say, high iron beans or, or high zinc wheat or high iron wheat. They look different, but actually they only have a few specific genes for whatever the micronutrient is. And that kind of uniformity makes varieties susceptible to pests and diseases. I mean, the classic example of this is southern corn blight. Breeders discovered a variant called cytoplasmic male sterility, which is very useful when you're breeding two different parental lines of maize, corn, to make hybrids, because it means that you don't have to employ teenage kids to go through the rows, removing the male anthers from one of your parents so that you don't get cross fertilization. Anyway, CMS, cytoplasmic male sterility, resulted in all the varieties being susceptible to this disease called southern corn blight, and as a result, in America in the early 70s, corn farmers, maize farmers, lost half of their harvest in some places.

Okay. We don't know that focusing on a few genes for high micronutrient levels will have a bad impact. But is it worth the risk, given all the other problems that biofortification has? I don't think so.

Host Jeremy: Yeah, I take your point. But surely farmers can protect themselves with modern pesticides and fungicides.

Guest Jeremy: Yeah, sure they can if they're wealthy. And that's a really important point. Who are these biofortified varieties for? I mean, who do they benefit? Most of them probably require commercial production. So will the farmers who really need these, who could grow them for themselves, will they be able to afford the seed? Will they able to buy? Will they be able to buy biofortified varieties in the market? And then there's another question, which is will they be able to save their own seed? Smallholder farmers are very dependent on saving their own seed. And if you take a trait like beta carotene, precursor for vitamin A, that's visible, I mean, you know, it's orange-yellow or it isn't. And if it's a darker colour, then it's probably got more of it. But things like iron and zinc, which are also very important, but you can't see whether a bean or a rice grain or a wheat seed, you can't see whether that's got high zinc or high iron. And so maybe farmers thinking that they're saving these more nutritious varieties won't actually be doing that. And, you know,

there's another problem, which is if I go to buy high nutrition varieties in the market, I can't tell there whether I'm getting what I'm supposed to be getting. So there's opportunity for fraud. And we already know that a lot of the food trade is susceptible to fraud of one sort or another.

Host Jeremy: Well, all right then clever clogs. What's the answer?

Guest Jeremy: Well, I mean, dietary diversity. We know it can work. The more different foods you can eat, the much more likely you are to be well nourished, to get all the micronutrients and macronutrients that you need. But there are ... I mean, I freely admit there are problems with dietary diversity. I mean, we know it ought to be able to work, but a bit like biofortification, there hasn't been much measurement of the actual effects of dietary diversity. It's just assumed to be axiomatically that, you know, a diverse diet is going to be good for you. But we don't really know that. I mean, we know it. We know that dietary diversity protects against a lot of the diseases, so-called diseases of civilisation, things like obesity and cardiovascular problems and diabetes and things like that. But most of those studies have been done in the rich world where there's probably probably not such a great amount of micronutrient deficiency. So, we don't know how much it'll work in poor countries, but a priori I would expect it to, I really would.

But then the other, the other kind of problem with dietary diversity is that because food is such an important part of culture and because it has so many different social values, dietary diversity has this problem that throws some researchers into a spin, which is that it doesn't scale. In other words, you can't take something that works for poorer households in Rwanda and assume that if you take the same procedures to a poor family in Bangladesh or Peru or wherever, that it'll work. So, I mean, a lot of these big programs are kind of based on the idea that, well, if we try a fortified something, we can get people to eat it wherever they are. Because, I mean, you know, any rice eating culture is going to eat high iron rice. With dietary diversity, it takes real work.

Host Jeremy: Okay. It takes real work. Why hasn't that work been done?

Guest Jeremy: I don't ... I really don't know. I mean, you'd think it would be important. My suspicion is that biofortification is really just

very attractive as what looks like a simple solution to a very difficult and complex problem. I mean, we know ... In our paper we kind of go through as much as we can how much money has been spent on biofortification and it's at least $500 million over the past 20 years or so. And that's almost certainly an underestimate. And agricultural research, especially for developing countries, for poorer farmers and for poverty, it gets little enough money as it is. So it's quite probable in our view that the money that went to biofortification probably prevented money going to the kinds of studies that would really prove that a more diverse diet would have definite beneficial effects. And again, as I said before, what works in one culture to promote dietary diversity wouldn't necessarily work in another. So you then need to do the studies in every different culture.

But there's a kind of a circular problem here because the people who dole out the money want evidence that things work, and without funding, it's hard to get the evidence. Now, I've said that biofortification hasn't actually produced much evidence that it works, but the thing is, it's shiny, it's modern. It's a very simple thing to understand. We put more in the food, of course it's going to be good for people. It catches the attention and I think it captures the funding in the same way.

Host Jeremy: Micronutrient deficiency clearly is something we really ought to be able to tackle. But are you hopeful for the future?

Guest Jeremy: Maybe a little. I mean, funding for one of the main biofortification programs has been dropping. There does seem to be some recognition that the claims that have been made for biofortification might not stand up to tough scrutiny. The question is whether funding for alternatives like dietary diversity is rising, whether more effort is being put into that. And I don't think it is.

The thing is that good nutrition is a really, really difficult problem because of the cultural role of food and how that differs from one society to another. And because, especially for micronutrients, they're invisible and you don't feel the effects, you don't see the effects, for a long time. And that's why micronutrient deficiency is often called hidden hunger, because you can have perfectly adequate amounts of of carbohydrates and fats and proteins and still suffer from micronutrient deficiency. But it's absolutely essential that we solve it. People ... I guess we need to educate people, in developed countries

just as much as in developing countries, that they should be consuming a diverse diet. And all of the campaigns today have singularly failed to do that. Five a day and food pyramids and all that, they just don't work. We don't know what does work. We don't know what does work in any society, really.

I'm impressed by things like the charity that Bee Wilson set up in the UK called TasteEd to educate small children about food, about diet. And there are similar programmes in Scandinavia, in France. But the whole question of, well, how do you help people to choose a more nutritious diet is one that I think we really ... People really need to work harder at. And I don't think biofortification even begins to be an answer to that problem.