BIOFORTIFICATION:
A food-systems solution to help end hidden hunger

HarvestPlus
Better Crops • Better Nutrition

Food and Agriculture Organization of the United Nations

A foreword from Anna Lartey and Arun Baral

Micronutrient deficiency, or hidden hunger, is the most prevalent form of malnutrition, affecting more than two billion people worldwide. Its health impacts—which include stunting, anemia, impaired vision, and even death-are a serious burden for people in low- and middle-income countries (LMICs) who cannot afford, or do not have access to healthy and diversified diets.

Biofortification (nutrient-enriched crops) is part of a food systems approach to address hidden hunger. Biofortification increases the micronutrient content of staple crops for low-resource populations in LMICs who depend on these relatively inexpensive crops for much of their diet.

The Food and Agriculture Organization (FAO) and HarvestPlus are working together to integrate biofortification into national and global food systems. This brief describes our existing areas of collaboration and is intended to inspire FAO staff to develop more opportunities to reach more people with the benefits of biofortification.

Biofortification, diversification of crop and animal production, and dietary diversity, as well as fortification and supplementation, are all essential and complementary elements to tackle hidden hunger—one of the biggest problems our world faces today. FAO and HarvestPlus have a shared goal to contribute toward achievement of the Sustainable Development Goals, particularly those targeting zero hunger and good health and well-being. By combining our respective areas of expertise, we will be able to generate more impact.

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Introduction

Hidden hunger is caused by insufficient intake, absorption, and/or utilization of essential vitamins and minerals. It is a persistent global health problem, and about one quarter of the world's population is deficient in vitamins and minerals (or "micronutrients")[1]. In children and adolescents, these deficiencies increase risk of morbidity and mortality, and lead to irreversible and lifelong deficits in physical and cognitive development[2-3]; in women, they increase the risk of morbidity and mortality, particularly during pregnancy[3-4]; and in people of working age, they reduce productivity[3], thereby impairing both short- and long-term livelihood potential[5].

HarvestPlus leads and coordinates a global effort within the CGIAR network to improve the nutrition and health of smallholder farmer families and consumers of staple crops. The effort focuses on catalyzing the development, production, delivery, and consumption of crops that are rich in at least one of three essential micronutrients identified by the World Health Organization (WHO) as among those most often lacking in diets globally: vitamin A, iron, and zinc.

Biofortification is a cost-effective, food-based, nutrition-sensitive agricultural approach for improving nutrition and is one of a range of complementary strategies, including diversification of various plants and animals in the production system, dietary diversification, supplementation, and commercial food fortification[6]. The ultimate nutrition goal is that everyone has access to an affordable, diversified healthy diet. Biofortification contributes to this goal by ensuring that the staple crop component of this diet is as nutritious as possible. This is particularly important for the rural poor whose diets continue to be dominated by staples and who are as yet unable to access a diversified healthy diet.

The Food and Agriculture Organization of the United Nations (FAO) addresses hunger and all forms of malnutrition using a food systems approach. In line with this, the FAO Conference, the highest decision-making body of the organization, has endorsed "Promoting healthy diets and preventing all forms of malnutrition" as its biennial (2020-2021) theme. In July 2019, FAO and WHO convened an international expert consultation to elaborate guiding principles for sustainable, healthy diets for its member states. These guiding principles were published in October 2019.[i] FAO views biofortification as one of the complementary interventions whose promotion can improve micronutrient intake and can contribute to healthy diets.

In 2016, the WHO, together with FAO, convened a technical consultation to review the scientific evidence, country experiences, and multiple other technical, environmental, and regulatory aspects of biofortified crops. The WHO is currently conducting a Cochrane Systematic Review of published evidence on the nutritional impact of biofortification.

This brief presents the latest evidence from rigorous research and implementation lessons learned on how biofortification can contribute to improving food systems for all. It describes the main achievements and evidence of almost two decades of research and implementation led by the HarvestPlus program and conducted in partnership with over 450 public, private, and civil society partners. Policy options and opportunities to sustain and scale up impact are introduced, and the role of an FAO-HarvestPlus partnership for supporting country-level efforts is highlighted through case studies. The ultimate aim is to encourage the adoption and scaling up of biofortification through national policies and programs, with collaborative support from FAO and HarvestPlus.

i. FAO and WHO. 2019. Sustainable healthy diets – Guiding principles. Rome. Available at: http://www.fao.org/3/ca6640en/ca6640en.pdf

Biofortification: A food-systems solution

Biofortified crop varieties are those which have been nutritionally enhanced using conventional plant breeding or modern biotechnology, (including recombinant DNA techniques). However, by far the most widely adopted biofortified crop varieties have been those developed through conventional crop breeding.

Staple food crops such as wheat, maize, rice, cassava, sweet potato, beans, and pearl millet are primary targets for biofortification because they are consumed widely as a part of everyday diets in low- and middle-income countries (LMICs) but tend to provide low levels of bioavailable micronutrients. Biofortification through conventional plant breeding improves the micronutrient content in these staple food crops through the following process:

1. Varieties that are naturally high in targeted micronutrients are selected;
2. High micronutrient content varieties are crossbred with high-yielding and climate smart/resilient varieties; and
3. Biofortified crops that are high-yielding, climate-smart, and nutrient dense are developed.

About HarvestPlus

HarvestPlus, launched in 2003, is a global research program based at the International Food Policy Research Institute (IFPRI), one of the CGIAR centers. The mission of HarvestPlus is to catalyze the development and scale up of biofortification to improve micronutrient content of staple crops as a complementary, natural, and sustainable solution to hidden hunger.

HarvestPlus has more than 170 staff members based in Washington, D.C.and in 14 countries across Asia, Africa, and Latin America. Their areas of expertise include biofortified crop development, farmer engagement, supply chains for biofortified seed and foods, food science and nutrition research, impact monitoring, policy engagement, and communication. HarvestPlus collaborates with hundreds of partners worldwide to make biofortification an integral part of sustainable, healthy food systems that bridge gaps between agriculture and nutrition.

HarvestPlus promotes the use and delivery of conventionally bred and agronomically-enhanced crops. To date, all of the biofortified crops released through the efforts of HarvestPlus and its partners were developed using conventional plant breeding.

Biofortified crop availability, agronomic and nutritional properties

Over 200 varieties of 11 biofortified crops have been officially released in 30 countries, with support from HarvestPlus (thousands more varietal lines are in testing in these countries and over 30 more). The International Potato Center (CIP), in collaboration with HarvestPlus, has also released over 100 varieties of vitamin A orange-fleshed sweet potatoes (OFSP) in an additional 10 countries. Once released, biofortified crops are continuously improved by selecting varieties with progressively higher levels of micronutrients, that are agronomically competitive (e.g., disease and pest resistant), well adapted to a wide range of agroecological conditions, including being climate-smart (e.g., drought and heat tolerant), and exhibit food quality traits desired by farmers, food processors, and consumers (e.g., fast cooking time and good taste). Biofortified crops are made available as public goods to national governments and small- or medium-size private sector seed companies. These institutions can then perform further tests and develop and release new and improved varieties.

Only varieties with scientifically proven potential to improve micronutrient intakes are disseminated and promoted. Each biofortified crop is rigorously tested to ensure it will improve the nutritional status of the target population groups. When eaten regularly, biofortified foods provide a safe and effective source of key micronutrients. An overview of the numbers of biofortified varieties released, agronomic traits preferred by farmers, target micronutrient levels, and the type and amounts of nutrients delivered, by crop and by region are provided in Table 1.

Table 1. Numbers of biofortified crop varieties released, beneficial agronomic traits*, target nutrient level**, and total amount of nutrient delivered†, by crop and by region

Biofortified crop	Number of releases by region			Total	Agronomic traits	Target nutrient level (ppm)	Percent of the EAR met when consumed as staple
	Africa	Asia	LAC				
VITAMIN A CROPS							
Orange-fleshed sweet potato	7		7	14	High yielding, fast maturing, virus resistant, drought tolerant	32	Up to 100%
Orange maize	54		1	55	High yielding, disease and virus resistant, drought tolerant	15	Up to 50%
Yellow cassava	13		3	16	High yielding, virus resistant	15	Up to 100%
Banana/plantain	10			10	In testing	30	Up to 50%
IRON CROPS							
Common beans	39		21	60	High yielding, virus resistant, heat and drought tolerant	94	Up to 80%
Pearl millet	1	9		10	High yielding, mildew resistant, drought tolerant	77	Up to 80%
Cowpea		5	3	8	Early maturing, disease resistant	98	Up to 25%
Lentils		9		10	High yielding, early maturing	110	In testing
ZINC CROPS							
Wheat		10	1	11	High yielding, disease resistant	37	Up to 50%
Rice		10		10	High yielding, disease and pest resistant	28	Up to 40%
Maize			7	7	High yielding, virus resistant	37	Up to 70%

* Each variety has different competitive advantages (these may be agronomic, tolerance to abiotic stresses, or more desirable consumer traits) compared to other popular local varieties.

** Target total micronutrient concentration (baseline + increase from biofortification), expressed as parts per million (ppm).

† Total amount of micronutrient provided that meets the physiological requirements for young children (1-6 years) and non-pregnant, non-lactating women of reproductive age (15-49 years), expressed as % of estimated average requirement (EAR) met [8-10]. The EAR is the nutrient intake value that is estimated to meet the requirement of half of the healthy individuals in a specific group.

Summary of evidence

Over 16 years of peer-reviewed research has provided strong evidence that biofortified crops are well accepted by farmers and consumers, improve nutritional status and health of vulnerable populations, and are a cost-effective solution to help end hidden hunger. In total, three effectiveness trials, 16 randomized controlled efficacy trials and 13 bioavailability studies have been carried out by HarvestPlus collaborators since 2009. The following section provides an overview of the evidence to date generated by HarvestPlus and its partners.

Farmer adoption and consumer acceptance of biofortified crops

Extensive research, including adoption and consumer acceptance studies, sensory studies, and program evaluations, have been conducted to inform the development of acceptable, effective, and scalable planting materials and food and delivery models for biofortified crops. An overview of these findings is presented in Table 2.

Highlights

- By the end of 2018, over 7.6 million farming households worldwide were growing and consuming biofortified crops, including vitamin A yellow cassava, orange maize, and OFSP; high iron beans and pearl millet; and zinc rice and wheat[32].
- Farmers are willing to grow biofortified crops because of their higher yields, various improved production traits, and overall climate-adaptiveness.
- Consumers enjoy sensory attributes (e.g., appearance, odor, taste, and texture) of biofortified crops. Though introducing new crops varieties, especially if they alter color, may require some adaption, community acceptance (measured in terms of their willingness to pay) increases when consumers are provided with information on the nutritional benefits of biofortified foods.

Nutrition and health benefits of biofortified foods

Biofortified crops are designed to improve the micronutrient intakes of young children (1-6 years) and non-pregnant, non-lactating women of reproductive age (WRA) (15-49 years). However, these crops also provide nutritional benefits to other population groups — anyone who consumes staple foods as a main part of their diet. Table 3 summarizes findings from retention, bioavailability, efficacy, effectiveness, and impact evaluations investigating the nutritional and health effects of biofortified staple foods, by nutrient and crop.

Table 2. Farmer and consumer acceptance of biofortified crops and foods, by nutrient and crop

Biofortified crop	Farmer adoption and consumer acceptance
VITAMIN A CROPS	
Orange-fleshed sweet potato 	- After four growing seasons, over 60 percent of all beneficiaries from two effectiveness trials in Uganda and Mozambique adopted vitamin A OFSP[11]. - Consumers enjoy the appearance, odor, taste, and texture of foods made from vitamin A OFSP (e.g., bread)[12-14]. - Consumers prefer vitamin A OFSP over conventional white sweet potato varieties when nutrition information is provided[15-16].
Vitamin A orange maize 	- Farmers prefer the yield, cob size, and cob-filling characteristics of vitamin A orange maize to conventional white maize[17]. - Nearly all (97 percent) of first-time adopters of vitamin A orange maize said they would grow it again in the next season and that, on average, they were planning to plant four times more seed than they did in the previous season[18]. - Consumers value traditional foods made with vitamin A orange maize more than foods from white and yellow maize varieties, even in the absence of nutrition information[19].
Vitamin A yellow cassava 	- Production of vitamin A yellow cassava in Nigeria is highly profitable[20]. - Women and children prefer the soft texture, sweet taste, and color of vitamin A yellow cassava over traditional white cassava[21-22]. - Foods made from vitamin A yellow cassava are preferred over foods made from conventional white cassava; this preference is even greater when nutrition information is provided[23-24].
IRON CROPS	
High-iron beans 	- In 2018, 20 percent of all bean growers in Rwanda grew high-iron biofortified beans[25]. - Consumers in Rwanda prefer high-iron beans over local common bean varieties[26]. - Consumers enjoy the taste, color and texture of high-iron beans in Colombia and Guatemala[27-29].
Iron pearl millet 	- Consumers enjoy sensory attributes of iron pearl millet, and local foods made from it, over the conventional non-biofortified variety[30]. - Almost three-quarters (73%) of first-time adopters of iron pearl millet said that they would grow it again in the next season[31].

Highlights

- Increased levels of micronutrients in biofortified crops are as bioavailable as those found in conventional varieties and therefore provide higher amounts of absorbed nutrients.
- Young children (1-6 years) and non-pregnant, non-lactating WRA (15-49 years) can get up to 100, 80, and 70 percent of their daily average vitamin A, iron, and zinc requirements, respectively, when biofortified crops are consumed as the main component of their daily diets.
- Biofortified crops improve micronutrient status and functional health outcomes, such as cognitive function and physical activity, and reduce morbidity in non-pregnant, non-lactating WRA and children.

Table 3. Nutrition and health benefits of biofortification, by nutrient and crop

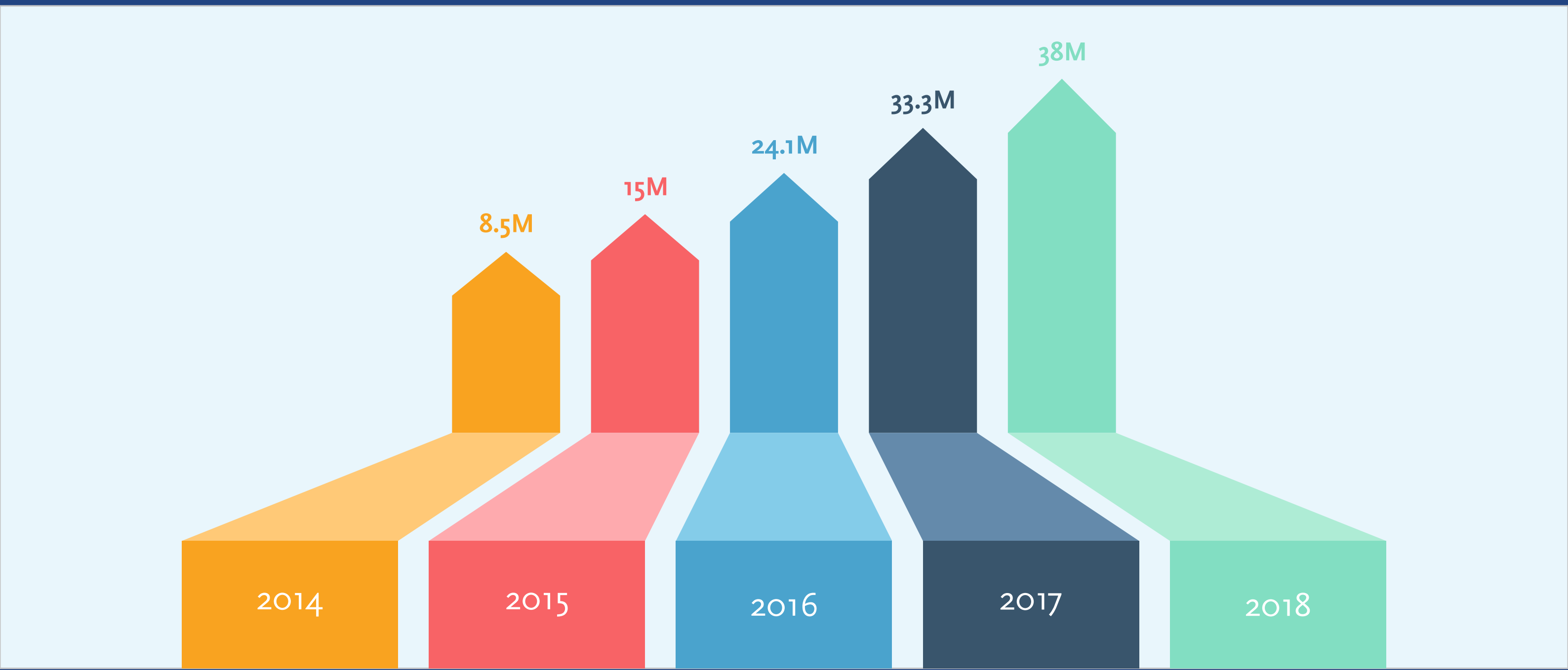
Biofortified crop	Nutrition and health benefits of crops
VITAMIN A CROPS	Provitamin A carotenoids in biofortified vitamin A crops are efficiently converted to the active form of the vitamin (retinol)[33].
Orange-fleshed sweet potato 	- Eating OFSP helps improve children's vitamin A status and dietary vitamin A intake among WRA and children[34-38]. - Regular consumption of OFSP reduces child morbidity: prevalence and duration of diarrheal episodes were significantly reduced in children <5y[39].
Vitamin A orange maize 	- Eating orange maize improves vitamin A status and concentrations of vitamin A precursors (e.g., beta-carotene, alpha-carotene, and beta-cryptoxanthin)[40-42]. - Regular consumption of orange maize significantly improves young children's (4-8 y) ability to see in dim light by improving their pupillary responsiveness[43].
Vitamin A yellow cassava 	- Yellow cassava retains intermediate-to-high levels of provitamin A carotenoids when processed using traditional cooking methods and recipes that involve boiling and frying[45]. - Regular consumption of yellow cassava improves school-aged children's vitamin A status[44].
IRON CROPS	The total iron absorbed from high-iron beans or iron pearl millet is significantly greater than from conventional varieties[46-47].
High-iron beans 	- Eating high-iron beans helps prevent and reverse iron deficiency and increases hemoglobin concentration in WRA[48]. - Regular consumption of high-iron beans reduces time spent in sedentary activities and improves cognitive performance (memory and attention) in young women—key skills for optimal performance at school and work[49-51]
Iron pearl millet 	- Eating iron pearl millet helps reverse iron deficiency and improves iron status in adolescent children[52]. - Regular consumption of iron pearl millet significantly improves cognitive performance (memory and attention) in adolescent children[53].
ZINC CROPS	Zinc absorption from meals based on biofortified staple foods (whole maize meal, polished rice, or whole or refined wheat flour) is 8-25 percent higher than zinc absorption from conventional varieties[54-55].
Zinc wheat 	- Eating zinc wheat helps reduce maternal and child morbidity: when eaten daily, women spend fewer days with fever and children spend fewer days ill with pneumonia and vomiting[56]. - Biofortification improves the amount of zinc absorbed from wheat[54-55].
Zinc rice 	- Zinc from biofortified rice is as well absorbed as zinc provided through industrial fortification and provides more bioavailable zinc than conventional rice[57].

Reach: Number of people growing and benefitting from biofortified crops

By 2018, an estimated 38 million people worldwide benefited from the production and consumption of biofortified crops and foods (Figure 1). Farming households in LMICs are reached with biofortified crops through a number of different delivery channels, including:

- **A social delivery approach.** Farmers acquire planting material either as free promotional/test packs or pay for the planting material through non-cash means, e.g., swapping grain for seed or giving back to HarvestPlus or to another farmer a prescribed quantity of planting material after the first harvest (i.e., payback or pass on).
- **Commercial delivery.** Farmers acquire seed/planting material on a cash basis directly from the market (subsidized or not).
- **Farmer-to-farmer diffusion.** Farmers voluntarily share their seed with fellow farmers.

Figure 1. Annual number of people growing and consuming biofortified crops.



Source: Catalyzing biofortified food systems: 2018 Annual Report. Washington, DC: HarvestPlus. 2018

Cost-effectiveness of biofortification

Hidden hunger is costly in both health and economic terms. Biofortification is an economical means of adding essential vitamins and minerals to the diet to reduce these costs. In 2008, the Copenhagen Consensus, a global research think tank and policy advisory group, ranked biofortification as a priority intervention for tackling the disease burden associated with micronutrient deficiencies. Based on their assessment, for every 1 USD spent on biofortification, as much as 17 USD in benefits could be generated[6]. The expert panel considered strategies to address micronutrient malnutrition, such as biofortification, supplementation and fortification, as some of the smartest ways to spend money and advance global welfare. In addition, numerous economic evaluations have been conducted to determine the cost-effectiveness of biofortification, using the World Bank criteria of cost (in USD) per disability-adjusted life year (DALY) averted[58]. In all of these evaluations, biofortification interventions have been shown to be highly cost-effective (which the World Bank defines as less than 150 USD per DALY saved)[58]. For example, a cost-effectiveness analysis following a large-scale vitamin A OFSP intervention in Uganda demonstrated that biofortification costs only 15-20 USD per DALY saved[59], and a 2018 review comparing ex ante cost-effectiveness evaluations of biofortification studies concluded that, in most cases, biofortification is highly cost-effective[60].

Integrating biofortification in policies and programs

In order to scale up biofortification sustainably, governments should integrate biofortification into their existing agriculture, health, and social safety net policies and programs, regulations and standards pertaining to seeds and foods, and varietal release protocols. Policy inclusion would enable sustainable mainstreaming (including biofortification in all crop breeding targets and food systems) of biofortification. HarvestPlus has developed tools, such as the Biofortification Priority Index, that can help guide governments' and donors' investments by informing them about which biofortified crops would have the biggest impact in terms of micronutrient deficiency reduction in a given context. Decision makers are guided by the following information:

Analysis and targeting: As noted previously, there is substantial evidence of biofortification's beneficial nutrition, health, and economic impact. Policymakers can target areas and populations that would benefit most from biofortification by using available data on production and consumption of staple food crops, current micronutrient deficiency rates, and effective coverage of other interventions; policymakers can also review existing policies and programs that could feasibly include biofortification. Policies and programs to promote biofortified crops as part of healthy diets and food-systems should also be supported by nutrition education on the importance of eating a diversified diet and empowering consumers to choose nutritious foods.

Suggested policies to target include:

- national development plans
- national agricultural investment plans
- seed policies
- food, nutrition, and fortification policies
- stunting and anemia strategies
- early childhood development and school health policies

Regional, national, and local programs to target include:

- government subsidy and procurement (seed and food)
- agricultural extension
- infant and young child feeding
- school meals
- ante- and post-natal counselling
- nutrition education and other relevant community health programs
- national nutrition surveys
- university and school curricula
- government-funded public service announcements/campaigns

Policy considerations and recommendations:

- Support strengthening of breeding programs, especially for the evaluation of new, potentially adapted, biofortified varieties.
- Facilitate variety registration systems in order to consider biofortified characteristics, and not only yield.
- Facilitate variety adoption by farmers, promoting demo plots and strengthening extension systems.
- Strengthen systems for multiplying and marketing seed and planting material, so that a diverse suite of biofortified varieties can reach farmers, even in remote locations.

Biofortification policies: Key considerations

- **Policy planning:** When existing policies are up for renewal, policymakers can plan to include biofortification in future iterations and can review program budgets to determine what funding could be available. Governments can also incentivize the private sector to increase uptake of biofortification in their product portfolios (e.g., through tax breaks or subsidies for producing biofortified products, offering free/subsidized training on biofortified crops/foods, and raising awareness of micronutrient deficiency and the role of biofortification in reducing it).

Cost of implementing biofortification

Crop development	Initial work on biofortification is generally funded through HarvestPlus and the CG centers using donor funding, with crops targeted to key micronutrient deficiencies in low and lower middle-income countries. Private sectors seed companies also invest private money in product seed development. Some Governments have led national breeding programs (e.g. India), including maintenance breeding programs once adopted, engaging their agricultural universities.
Farmers as growers and home consumers	In noncommercial settings, farmers receive the seeds or stems for free, with "pay it forward" used in some settings. Vines and stems, for which commercial markets are often insignificant, are shared with neighbors after harvest to aid dissemination. Wherever HarvestPlus biofortified seeds are sold in markets, they are competitively priced, given there are no private sector R and D costs to be recouped. Biofortified varieties are agronomically competitive to grow, requiring no more inputs than the varieties they are designed to replace.
Food manufacturers	Given that production costs are no higher, food manufacturers are unlikely to need to pay more for biofortified ingredients. In some cases manufacture can be less expensive, for example partially replacing wheat flour with orange flesh sweet potato flour in bread.
Low income consumers as shoppers	Given the raw materials should cost the same, products such as flour from millers and manufacturers is not more expensive.
Policymakers and government	Once biofortified crop development is complete, only maintenance breeding is required, as with all crops to ensure ongoing agronomic competitiveness. This makes ongoing costs relatively small compared to supplementation and fortification, which have little reduction in ongoing costs, and the market reach of the crops is extensive. Biofortification is a key recommendation for governments and policymakers where micronutrient malnutrition is a public health problem.

- **Monitoring and evaluation:** For biofortification to be effective, it is essential that farmers and consumers have access to choose biofortified crops and foods. Monitoring efforts should track the availability, quality and nutrient content of biofortified crops and foods along the supply chain in order to ensure significant coverage of these crops/foods and that their micronutrient content remains at levels sufficient enough to have a measurable nutritional impact in individuals. Evaluations can shed light onto whether government programs are being implemented effectively, are delivering intended outcomes, and are contributing to the overall impact of reducing micronutrient deficiencies.

- **Scaling up and sustaining:** Given that biofortification targets the main staple crop(s) produced and consumed within a country, there is potential to reach significant scale in adoption, and by extension, a significant reduction in micronutrient deficiency.

Biofortification in public policy

Biofortification has been endorsed by several heads of state in Africa and by the African Development Bank as a tool to achieve the African Union's Malabo Declaration commitment to reduce or eliminate child undernutrition. Numerous reports have been published that champion biofortification technology, including FAQ's 2017 policy guideline, *Nutrition-Sensitive Agriculture and Food-systems in Practice: Options for Intervention*[61]; the Malabo-Montpellier Panel Report, *Nourished: How Africa Can Build a Future Free from Hunger and Malnutrition*[62]; the World Bank's Agriculture Global Practice Report, *An Overview of Links Between Obesity and Food-Systems Implications for the Agriculture Agenda*[63]; and the African Development Bank's Multi-Sectoral Nutrition Strategy, *Harnessing "Grey Matter Infrastructure" to Unlock the Human and Economic Potential of Africa: Catalyzing Nutrition Smart Investments to Support a 40% Stunting Reduction in Africa by 2025*[64]

To date, 24 countries have included biofortification in their national agriculture, nutrition, and/or health policies and plans (e.g., Bangladesh's Second National Plan of Action for Nutrition, India's Varietal Release Protocol and Public Distribution Scheme, and Rwanda's Nutrition Action Plan).

FAO-HarvestPlus collaboration and case studies

FAO’s commitment to support countries to improve nutrition is enshrined in the preamble to its constitution—it is a fundamental cornerstone of the work of the organization. FAO takes a food systems approach to address nutritional challenges globally and works across a range of program and policy areas aimed at increasing availability, accessibility, affordability, and acceptance of sustainable and healthy diets. FAO is working with HarvestPlus on a number of initiatives in biofortification, which are aligned with its goals of supporting nutrition through a food system approach. For example, FAO and HarvestPlus are working together in Zimbabwe to leverage and strengthen existing national policy and private industry to improve smallholder farmers’ livelihoods and nutrition through scaling up the delivery of vitamin A orange maize and high-iron beans. In Uganda HarvestPlus and its partners helped improve women’s earning potential and access to markets through women-led farmer groups. In Brazil, the Maranhão state government is working to ensure school meals are healthy and linked to the direct purchase of biofortified crops from smallholder farmers. In an upcoming project in the Democratic Republic of the Congo (DRC), supported by HarvestPlus, FAO will include high-iron beans in seed packets distributed to households to support government implementation of a World Bank-funded multisectoral nutrition loan.

FAO and HarvestPlus partnership

In 2015, FAO, with financial support from the Government of the United Kingdom through the Department for International Development (DFID), established the Livelihoods and Food Security Program (LFSP) in Zimbabwe to improve food security and reduce poverty among rural populations through the production and consumption of biofortified vitamin A orange maize and high iron beans. HarvestPlus is a strategic partner in the program and provides capacity building, technical assistance, specialized product knowledge, and is also responsible for introducing and scaling up biofortified crop cultivation. To date, more than 250,000 households in 12 districts of Zimbabwe have been reached with a total of 250MT of vitamin A orange maize and 200MT of high iron beans, both directly and through market-led interventions. In 2019, additional funding was secured to help facilitate scaling up and to ensure sustainable uptake of biofortified crops in Zimbabwe.

Vitamin A OFSP program in Uganda improved women's access to markets

In Uganda, 27 percent of households are headed by women. Although women have primary control over food choices, men and women have complex and shifting roles in crop choice and on-farm labor supply in smallholder agriculture. In the vitamin A OFSP project in Uganda, HarvestPlus recognized the importance of ensuring that gender-focused activities were an ongoing part of program development, monitoring, and adjustment, resulting in a high degree of gender sensitivity. The project used existing community structures to address gender issues through community dialogues, which helped to improve uptake of vitamin A OFSP. The membership of farmers' groups targeted for adoption of vitamin A OFSP were predominantly women—some farmers' groups had only female members, while others had both genders represented. Women played a vital role in the diffusion of food-based agricultural technologies.

Biofortified crops incorporated into Maranhão State (Brazil) policy for food and nutritional security

In 2009, Brazil enacted a decentralized national public policy, the Programa de Compra da Agricultura Familiar, which guarantees that at least 30 percent of produce purchased for school-feeding programs is supplied by smallholder family farms (“Agricultura Familiar”). In 2016, the Maranhão state government recognized biofortified crops as a priority food and nutrition security policy. Building on the successes of the national school-feeding legislation, the Maranhão state government invested the equivalent of over 2.5 million USD in biofortified crops and established an agreement to incentivize smallholder farmers to grow and sell biofortified crops such as yellow cassava, OFSP, orange maize, beans, and cowpeas to the state school-feeding programs. The pilot project has already reached over 3,600 farm families in over 15 municipalities and has served as an innovative model to improve the nutrition of school-aged children by incorporating biofortified foods into school lunches.

FAO and HarvestPlus help diversify agriculture production in the DRC

In the DRC, FAO promotes biofortified crop varieties in its work to strengthen farmers' access to seed and planting materials. For example, a four-year, EUR 50 million project funded by Germany, implemented jointly by FAO, WFP, and UNICEF, features biofortified varieties of high-iron beans and OFSP. In 2020, FAO and HarvestPlus will work together under a five-year World Bank loan to the DRC Ministry of Health to implement a multi-sectoral nutrition program. HarvestPlus will supply high-iron bean seeds for inclusion in seed packets to be distributed by FAO as part of a diversification of agricultural production.

Frequently asked questions about biofortification

Are biofortified crops genetically modified (GM)?

Biofortified crops are food crops that have been nutritionally enhanced using conventional crop breeding or transgenic technology. However, the vast majority of biofortified crops currently available have been developed through conventional crop breeding. These crop varieties are released by national partners in compliance with existing laws and regulations.

Are biofortified crops safe to consume?

Yes. The risk of excessive consumption of micronutrients from biofortified foods is minimal because 1) the maximum amounts possibly ingested from biofortified foods are well below any upper tolerable limit for vitamin A, iron, or zinc; and 2) the amount of micronutrients absorbed are tightly regulated by the body and influenced by the food matrix. Biofortified crops enriched with iron increase body iron levels slowly. They provide a safe, practical, and efficacious approach to reduce nutritional iron deficiency and improve iron intake. Additionally, all plant-based foods, like biofortified vitamin A orange maize or yellow cassava, provide precursors to vitamin A (e.g., beta carotene and beta-cryptoxanthin) that require conversion in the body to the active form of vitamin A (retinol). This process is downregulated when there is already enough vitamin A within the body, minimizing the risk of toxicity from retinol. Carotenoids are not known to be toxic at the maximum levels achieved by biofortification. While not without any risk to specific population groups (e.g., individuals with thalassemia or hemochromatosis, in the case of iron), the risk of biofortification is far outweighed by the potential benefit of reduced burden from micronutrient deficiencies.

It is recommended that, when available, data on population dietary intake of vitamin A and iron, markers of status, and coverage of control programs are used to determine the severity of deficiency and identify the populations or geographic regions most likely to benefit from biofortification programs, as recommended for commercial fortification interventions. HarvestPlus uses multiple strategies to ensure risk is minimized, including conducting background nutrition surveys in areas of implementation to determine usual intakes, prioritizing crop delivery by country using the Biofortification Priority Index, and documenting the coverage of other micronutrient interventions.

Do biofortified crops deplete the soil of nutrients?

No. The additional quantity of minerals taken from the soil by biofortified crops is insignificant. Provitamin A carotenoid synthesis by plants does not require additional nutrients from the soil.

Does biofortification reduce yield and/or other agronomic properties of crops?

No. Plants, just like people, need micronutrients to grow and be healthy. Micronutrient-rich seeds show greater seedling vigor, and the resulting crops are more productive. The nutrient trait is added to the breeding program at the CGIAR center and National Agricultural Research Extension Systems (NARES) that are already using high-yielding lines of these crops. All released biofortified varieties are agronomically competitive in the agroecological zone(s) for which they were developed, relative to the varieties farmers already grow.

Do biofortified seeds need to be repeatedly purchased by farmers?

In most cases, no. Most food crops in the developing world are not hybrids crops (i.e., they do not need to be purchased annually). Biofortified crops that are non-hybrids include zinc wheat, rice, and open pollinated maize; iron pearl millet and common beans; and vitamin A OFSP (roots and vines) and yellow cassava (cuttings). These biofortified crops can be saved, shared, and replanted, though regular replacement of seed/clean planting material is encouraged to sustain yield advantages.

Are biofortified crops equitable?

Yes. In the case of staple foods, differential food allocation within a household does not usually happen. Biofortified staple crops are specifically developed to benefit everyone in a household–everyone who consumes staple crops as their primary, everyday source of food get to benefit from them.

Does biofortification undermine biodiversity?

No. Biofortified crops are the result of genetic diversity conserved in seed banks around the world. The process leverages the natural variation in micronutrient content across the spectrum of varieties of a crop, often utilizing varieties that are no longer grown in conjunction with varieties that are well-adapted for a given location. When a biofortified crop is bred, multiple varieties are released over time, recognizing that different farmers have different preferences. Biofortification is not a substitute for diversification of crop production; rather it is part of such a strategy that includes the use of species and crop varieties that are well adapted to changing environments and market demands and that have improved nutritional content.

Does biofortification help mitigate challenges of climate change?

Yes. Prior to release, biofortified varieties are tested under various stress conditions (e.g., biotic and abiotic or exposure to virus, fungi, heat, drought, etc.) to make sure that their nutritious and agronomic benefits remain, even in adverse climates. Rising carbon dioxide levels will increase the carbohydrate content and simultaneously decrease the iron, zinc, and protein content of the edible portions of plants, reducing nutritional value by 3-17 percent compared with current conditions. Biofortification helps offset this by increasing the level of micronutrients in the crops. Given genotypic differences within species in their extent of vulnerability to decreases in zinc and iron from enhanced carbon dioxide supply, it should also be possible to breed against this risk through biofortification.

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