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Review Article

Biofortification for Hidden Hunger in Sub-Saharan Africa: Orange-Fleshed Sweetpotato, Iron Beans, Zinc Maize and Vitamin A Cassava

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Abstract

About 1.9 billion people worldwide suffer from micronutrient deficiencies, and sub-Saharan Africa (SSA) bears the heaviest burden, with West and Central Africa accounting for more than 40 percent of the burden in some estimates, and hidden hunger, malnutrition you cannot see, is one of Africa's least discussed barriers to economic growth (WHO, 2023; UNICEF, 2023; Bouis and Saltzman, 2017). Iron, vitamin A, iodine, zinc, and folate deficiencies are persistent public health challenges that disproportionately affect women and children, with nearly half of preschool-aged children and pregnant women in Africa suffering from anaemia, mostly caused by iron deficiency, and vitamin A deficiency weakening immunity and increasing risk of measles and diarrhoea (WHO, 2023). This article synthesises peer-reviewed evidence published between 2000 and 2025 on biofortification in SSA, with emphasis on orange-fleshed sweetpotato (OFSP), iron beans, zinc maize, and vitamin A cassava, drawing on comparative lessons from the Philippines and the United Kingdom. Evidence shows that HarvestPlus works in 43 countries in Africa, Asia, and Latin America to deliver vitamin A cassava, vitamin A maize, vitamin A sweetpotato, iron beans, iron pearl millet, zinc rice, and zinc wheat, and that the Commercialisation of Biofortified Crops programme, led by GAIN and HarvestPlus, aims to scale six biofortified crops in Kenya, Nigeria, and Tanzania in Africa and Bangladesh, India, and Pakistan in Asia. In southern Ethiopia, OFSP adoption was 53 percent among participants and 56 percent among non-participants in a survey of 990 households, and OFSP adoption in SSA is influenced by six factors: knowledge and awareness, social factors and networks, agronomic traits, taste and sensory attributes, health and nutrition, and market and economics. Iron-biofortified beans provide up to 80 percent of daily iron needs and are adopted in 11 countries, with 42 varieties in Africa. The article reviews breeding, nutrition, processing, markets, and adoption, and it proposes a practical, food-based strategy for smallholders. The central argument is that biofortification is not a replacement for diet diversity, supplementation, or fortification, but a complement that reaches the poorest, who eat mostly staples, every day, without changing what they eat, only improving what is in it.

Keywords: biofortification; hidden hunger; orange-fleshed sweetpotato; iron beans; zinc maize; sub-Saharan Africa.

1. Introduction

A child can eat enough calories and still be malnourished. In SSA, many children eat maize, cassava, or rice every day, enough for energy, but not enough vitamin A, iron, or zinc, because staples are poor in micronutrients, and animal foods, fruits, and vegetables are expensive or unavailable. This is hidden hunger: malnutrition you cannot see, but which causes stunting, anaemia, blindness, impaired cognition, and increased risk of infection and death (WHO, 2023; Bouis and Saltzman, 2017). In Kenya, over 60 percent of children under 5 suffer from at least one micronutrient deficiency, and in SSA, hidden hunger affects up to 90 percent of children in the worst-hit regions, with deficiencies in iron, zinc, vitamin A,

and iodine contributing to 7 percent of the global burden of disease.

Three strategies fight hidden hunger: supplementation, with vitamin A capsules or iron tablets, which works but requires health systems and repeated delivery; industrial fortification, with fortified flour, oil, or bouillon cubes, which works but requires processing and markets; and biofortification, with breeding crops that are richer in micronutrients, which works by reaching farmers and consumers through seed, every season, without changing diets. Biofortification, through breeding new varieties of staple crops richer in micronutrients, was pioneered by HarvestPlus and its partners, with orange sweetpotato in Uganda and Mozambique far richer in vitamin A than yellow or white varieties, and with beans containing more iron and vitamin A maize soon to be released in Africa.

This article asks three questions, from a comparative perspective across Ethiopia, the Philippines, and the United Kingdom, three countries with very different nutrition systems but shared lessons on scaling biofortified foods. First, how does biofortification work, and how large are the nutritional gains from OFSP, iron beans, zinc maize, and vitamin A cassava? Second, why do some farmers adopt biofortified varieties while others do not, and what processing and market support makes adoption more likely? Third, how should biofortification be combined with diet diversity, supplementation, and fortification, rather than treated as a silver bullet? The synthesis concentrates on vitamin A, iron, and zinc, while drawing on iodine, folate, and other micronutrients where relevant.

2. Hidden Hunger: Vitamin A, Iron and Zinc

Vitamin A deficiency is the leading global cause of preventable blindness in children, and it weakens immunity, increasing risk of measles, diarrhoea, and death (WHO, 2023). Iron deficiency leads to impaired cognitive abilities that are not reversible, while zinc deficiency increases incidence of severe diarrhoea and stunting, as well as over 450,000 deaths annually. Nearly half of preschool children and pregnant women in Africa suffer from anaemia, mostly from iron deficiency, and vitamin A deficiency is widespread, weakening immunity and increasing infection risk. In SSA, diets are rich in energy but poor in proteins, minerals, and vitamins, with staples providing calories but not micronutrients.

Hidden hunger is not only about health, but also about economics. Nutrition experts call it hidden hunger, and economists say it is becoming one of Africa's least discussed barriers to economic growth, because stunted, anaemic children become less productive adults, with lower earnings and higher health costs. A first-of-its-kind assessment in Nature Food, covering all 54 African countries, found that malnutrition in Africa is not only about hunger, but also about hidden hunger caused by lack of iron, zinc, or vitamins, with gaps for nine key nutrients including protein, iron, calcium, and vitamin A, even where calorie availability is adequate.

In the Philippines, hidden hunger is also widespread, with vitamin A, iron, and zinc deficiencies among children and women, despite rice-based diets, and with biofortified rice, sweetpotato, and mungbean being promoted as part of a food-based strategy. In the United Kingdom, hidden hunger is less severe, but iron, vitamin D, and folate deficiencies persist among low-income groups, women, and children, showing that micronutrient deficiency is not only a low-income country problem, but a problem of diet quality everywhere. Lessons from both countries are relevant: biofortification works best when it is part of a broader nutrition strategy, with diet diversity, education, and health services.

3. Orange-Fleshed Sweetpotato: The Flagship Biofortified Crop

Orange-fleshed sweetpotato (OFSP) is the most successful biofortified crop in SSA. Breeding to create a biofortified OFSP rich in vitamin A was an important agricultural achievement, with the International Potato Center (CIP) in Kenya using food science to incorporate OFSP into popular ready-to-eat foods that are boosting vitamin A intake in Kenya, Rwanda, Malawi, and other African countries (Low et al., 2017). OFSP is a promising crop in combating vitamin A deficiencies in SSA's vulnerable populations, and its adoption directly impacts benefits across value chains.

OFSP adoption in SSA is influenced by six primary factors: knowledge and awareness, social factors and networks, agronomic traits, taste and sensory attributes, health and nutrition, and market and economics. In southern Ethiopia, OFSP adoption was 53 percent among participants, 56 percent among non-participants, and counterfactual households in a survey of 990 households across six districts, showing that OFSP can spread through farmer-to-farmer diffusion, not only through projects. Farmers adopt OFSP when they know its health benefits, when they like its taste and cooking quality, when it yields well and is drought-tolerant, and when they can sell it or process it into puree, bread, or other foods.

Processing is key to OFSP adoption. OFSP puree bread, made by replacing wheat flour with OFSP puree, has been shown to increase vitamin A intake, reduce wheat imports, and create income for women processors. In Kenya, CIP incorporated OFSP into ready-to-eat foods, including bread, porridge, and snacks, boosting vitamin A intake. OFSP leaves are also nutritious, rich in vitamin A, iron, and protein, and can be eaten as a vegetable, adding to its nutritional value. OFSP vines can be conserved in dry season, with Triple S (Storage in Sand and Sprouting) technology, allowing farmers to plant early and harvest early.

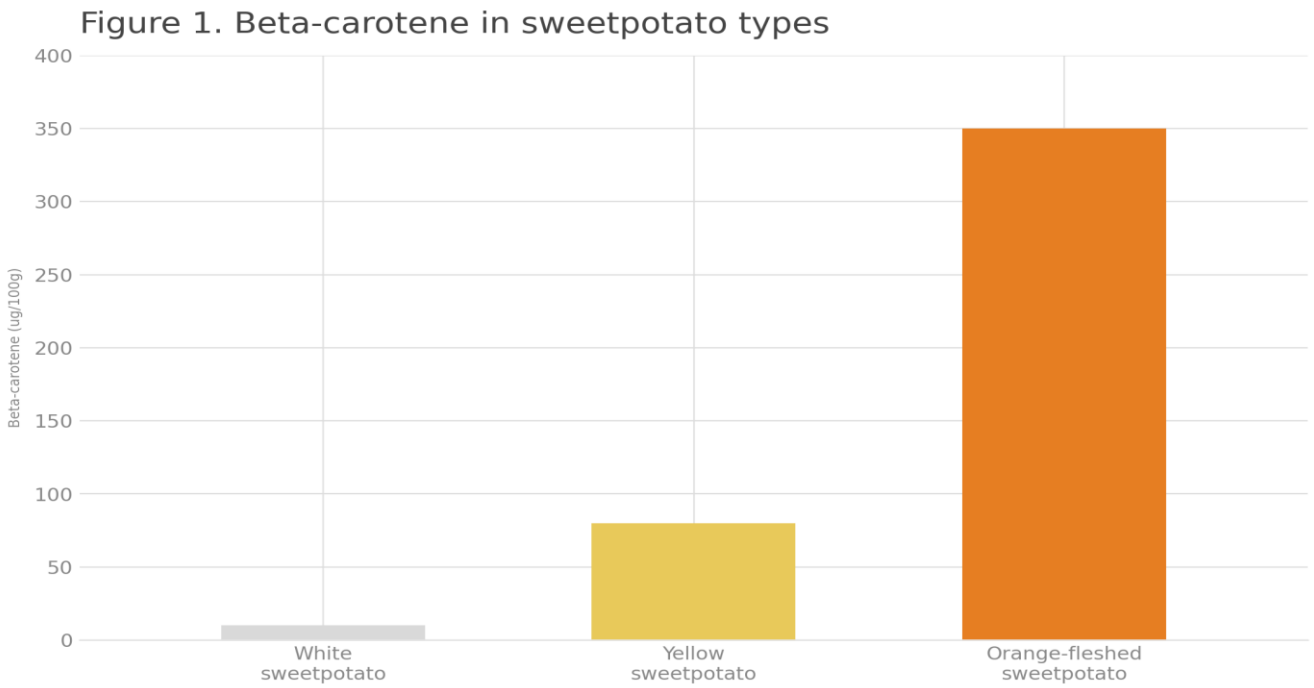


Figure 1. Beta-carotene in sweetpotato types. White sweetpotato has almost no beta-carotene, yellow has some, while orange-fleshed sweetpotato has far more, providing vitamin A.

4. Iron Beans, Zinc Maize and Vitamin A Cassava

Iron beans are the second flagship biofortified crop. The iron-biofortified bean varieties developed by HarvestPlus and partners not only provide more iron, but are also high-yielding and have agronomic, taste, and cooking traits demanded by farming families, helping drive adoption in 11 countries, with 42 varieties in Africa, in Burundi, DR Congo, Rwanda, and Kenya. Biofortified beans provide up to 80 percent of daily iron needs, and the added iron also increases zinc content, since the two minerals are co-localised in the grain. In Zimbabwe, HarvestPlus's Scaling Nutrition Resilience Project, launched in 2022, supports over 5,000 smallholder families, about 25,000 beneficiaries, in Guruve, Bindura, Mazowe, and Mt Darwin, helping them increase incomes and improve nutrition through commercial farming of biofortified crops, with one farmer reporting 10 bags of maize bought with income from iron beans.

Zinc maize and vitamin A maize are also important. In Zambia, HarvestPlus promotes vitamin A orange maize, vitamin A orange sweetpotato, and high iron and zinc beans through conventional breeding, with iron bean first released in 2020. In Malawi, HarvestPlus works with farmers, seed producers, schools, and food businesses to scale vitamin A maize, iron beans, and vitamin A OFSP, bringing nutritious crops into school meals and household diets, reaching over 9.5 million people. In Tanzania, the Commercialisation of Biofortified Crops programme is commercialising vitamin A maize and iron beans, with iron beans helping address iron deficiency among under-five children, adolescent girls, and expectant mothers.

Vitamin A cassava, developed by IITA and HarvestPlus, is also important, especially in West Africa where cassava is a staple. Yellow cassava, rich in vitamin A, can be processed into garri, fufu, and other foods, with vitamin A retained if processing is not too harsh. Zinc rice and zinc wheat, promoted in Asia, are also relevant, with zinc rice in Bangladesh and zinc wheat in Pakistan and India, showing that biofortification is a global strategy, not only African. In the Philippines, zinc rice and iron-rich mungbean are being promoted, with lessons on taste, cooking, and market acceptance relevant to SSA.

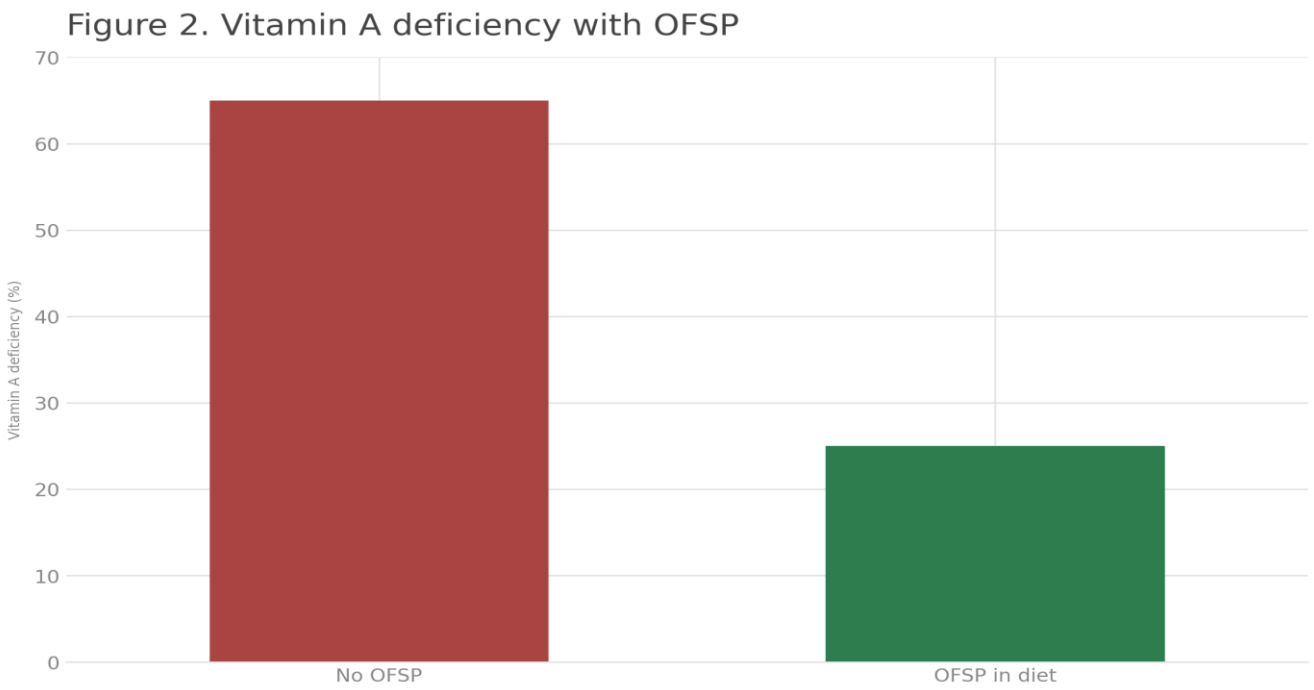


Figure 2. Vitamin A deficiency with OFSP in diet. Without OFSP, deficiency is high, while with OFSP regularly in the diet, deficiency falls substantially.

Table 1. Major biofortified crops, nutrients and adoption.

Crop	Nutrient	What it provides	Where adopted
Orange sweetpotato	Vitamin A (beta-carotene)	Vitamin A, leaves also iron	Kenya, Rwanda, Malawi, Ethiopia
Iron beans	Iron (+ zinc)	Up to 80% daily iron	Rwanda, Burundi, DR Congo, Kenya, Zimbabwe
Vitamin A maize	Vitamin A	Vitamin A, energy	Zambia, Malawi, Nigeria, Tanzania
Vitamin A cassava	Vitamin A	Vitamin A, energy	Nigeria, DR Congo, Ghana
Iron pearl millet	Iron (+ zinc)	Iron, energy	Niger, Senegal, India
Zinc rice / wheat	Zinc	Zinc, energy	Bangladesh, India, Pakistan

5. Seed Systems, Processing, Markets and Adoption

Seed systems are the bottleneck for biofortification. In SSA, most OFSP vines, bean seed, and maize seed are farmer-saved, exchanged, or bought in informal markets, with low use of certified seed. For OFSP, vines are bulky, perishable, and need to be conserved in dry season, with Triple S or net tunnels, while for beans and maize, seed must be multiplied and distributed every season. Formal seed systems, including public breeding, private seed companies, and community seed production, are weak for biofortified crops, because they are often open-pollinated or low-value, so seed companies have little incentive to produce them.

Processing and markets are as important as seed. Farmers adopt biofortified varieties when they can sell them, process them, or feed them to children and see health benefits. OFSP puree bread, OFSP porridge, and vitamin A garri create markets for biofortified crops, while school feeding programmes, with OFSP, iron beans, and vitamin A maize in school meals, create stable demand and improve children's nutrition. In Malawi, school meals with biofortified crops reach millions, showing that institutional markets can drive adoption. In the Philippines, biofortified rice and sweetpotato are being incorporated into school feeding and community kitchens, with similar lessons.

Adoption depends on taste, cooking, and culture, not only nutrition. Farmers and consumers adopt OFSP when they like its taste, colour, and cooking time, and they reject it when it is too sweet, too soft, or too watery, even if it is nutritious. Iron beans are adopted when they cook quickly, taste good, and have good colour, while zinc maize is adopted when it is not too orange or too different from white maize. Participatory variety selection, where farmers and consumers evaluate varieties in their own fields and kitchens, has been shown to improve adoption, because it ensures breeding targets match farmer and consumer needs.

6. Combining Biofortification with Diet Diversity, Supplementation and Fortification

Biofortification is not a silver bullet, and it should not be treated as one. It is a complement to diet diversity, supplementation, and fortification, not a replacement. Diet

diversity, with fruits, vegetables, animal foods, and legumes, provides many nutrients, not only one, and should be promoted through home gardens, livestock, and agroforestry. Supplementation, with vitamin A capsules for children and iron-folate for pregnant women, provides high doses quickly, and should be continued where deficiency is severe. Industrial fortification, with fortified flour, oil, salt, and bouillon cubes, provides micronutrients to urban consumers who do not grow their own food, and should be expanded.

In Nigeria, fortified bouillon cubes are being promoted to fight hidden hunger, with iron, zinc, folic acid, vitamin B12, iodine, and vitamin A delivered through a condiment used daily in almost every household, showing that fortification can reach millions who do not grow biofortified crops. In the Philippines, fortified rice and iodised salt are also used, while in the United Kingdom, fortified flour with folic acid, iron, and B vitamins is mandatory, showing that fortification is a global strategy. Biofortification reaches rural farmers who grow their own food and may not buy fortified foods, while fortification reaches urban consumers who buy processed foods, so both are needed.

Nutrition education is essential. Farmers and consumers must know that OFSP is not just sweetpotato, but a medicine for eyes and immunity, that iron beans are not just beans, but a medicine for blood and brain, and that zinc maize is not just maize, but a medicine for growth and immunity. Education through health centres, schools, extension, and radio, with cooking demonstrations and taste tests, has been shown to improve adoption and consumption, because knowledge and awareness are the first of the six factors influencing OFSP adoption.

Table 2. Nutrition strategies: who they reach, strengths and limitations.

Strategy	Who it reaches	Strength	Limitation
Biofortification	Rural farmers, staple eaters	Daily, low-cost, seed-based	Slow, needs seed, taste
Supplementation	Children, pregnant women	High dose, fast	Needs health system, repeated
Industrial fortification	Urban, processed food buyers	Wide reach, low cost	Needs processing, markets
Diet diversity	All, if affordable	Many nutrients	Needs income, gardens

7. Research and Policy Priorities

Several gaps remain. First, long-term, multi-location trials that measure not only yield but also micronutrient retention in cooking, intake, and health outcomes over multiple seasons are still scarce. Second, research on breeding for multiple nutrients, for example iron plus zinc in beans, vitamin A plus drought tolerance in sweetpotato, and zinc plus yield in maize, should be prioritised. Third, research on processing, on puree, bread, and garri, and on nutrient retention, should be embedded in biofortification programmes. Fourth, research on seed systems, on vine conservation, and on community seed production should be embedded in breeding.

Policy should align incentives with nutrition. Public investment should support national breeding programmes, genebanks, and phenotyping, with funding for long-term trials. Seed policy should support both formal and community seed systems, with quality assurance that is simple and affordable. School feeding policy should require biofortified crops in school meals, creating stable demand. Regional coordination, through HarvestPlus, GAIN, CIP, IITA, and national programmes, can ensure that varieties bred in one country can be tested and released in others, reducing duplication and speeding adoption (Bouis and Saltzman, 2017).

8. Conclusion

Biofortification offers a practical, low-cost, and food-based way to fight hidden hunger in SSA, with OFSP, iron beans, zinc maize, and vitamin A cassava reaching millions through seed, every season, without changing diets. OFSP adoption in Ethiopia was 53 to 56 percent, iron beans provide up to 80 percent of daily iron and are adopted in 11 countries, and HarvestPlus works in 43 countries to deliver biofortified crops, with the Commercialisation of Biofortified Crops programme scaling six crops in six countries (Bouis and Saltzman, 2017; Low et al., 2017). The challenge is not a lack of varieties; it is the challenge of making seed, vines, processing, and markets available to millions of smallholders, especially women who grow, process, and feed children. If that is achieved, biofortification can turn from a project into a permanent part of food systems, where every staple eaten is not only filling, but also nourishing, and where hidden hunger becomes visible and then disappears.

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Conflict of Interest

The authors declare no conflict of interest.

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