Global Panel on Agriculture and Food Systems for Nutrition

BIOFORTIFICATION:
An Agricultural Investment for Nutrition

This policy brief lays out the technical evidence and arguments for supporting biofortification as one element of a nutrient-sensitive national agricultural research and investment strategy.

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About the Global Panel on Agriculture and Food Systems for Nutrition:
The Global Panel is an independent group of influential experts with a commitment to tackling global challenges in food and nutrition security. The Global Panel is working to ensure that agriculture and food systems support access to nutritious foods at every stage of life.

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Cover image: Eliab Simpungwe, HarvestPlus

Introduction


Image courtesy of Anna-Marie Ball, HarvestPlus

People's deficiencies in key vitamins and minerals continue to pose a very serious constraint to human health and economic development. The Global Nutrition Report (2014) and the Kigali Declaration on Biofortified Nutritious Foods (HarvestPlus 2014a) both highlight the need for multiple complementary strategies to address key micronutritient deficiencies. Combinations of actions are needed because different populations within a country can be reached by different methods and all people need to be reached.

Biofortification represents one promising strategy to enhance the availability of vitamins and minerals for people whose diets are dominated by micronutrient-poor staple food crops. It involves the identification of varieties of a crop that naturally contain high densities of certain micronutrients. Plant breeders use these varieties to develop new, productive and 'biofortified' crop lines for farmers to grow, market and consume.

This policy brief lays out technical evidence and arguments for expanding support for biofortification as an element of nutrition-sensitive national agricultural research and investment strategies. It recommends that policymakers implement biofortification as one of a range of complementary approaches to reducing micronutrient deficiencies, and that they therefore invest in developing nationally appropriate biofortified crop varieties and scale up their adoption and consumption.

The Human Need for Micronutrients

A healthy diet is considered to be one that satisfies human needs for energy and all essential nutrients (FAO 2004). One expert consultation suggested in 2003 that "probably as many as 30 biologically distinct types of foods, with the emphasis on plant foods, are required for healthy diets" (WHO/FAO 2003). Maintaining access to such a diversity of foods is not easy for poor populations. Many are constrained by income level or distance to markets to eating a monotonous nutritionally inadequate diet consisting largely of one staple cereal or root crop (FAO/WHO 2014).

Micronutrient deficiencies are common. Roughly one third of the world's population suffers deficiencies of vitamins (particularly A and C) and minerals (such as zinc, iodine and iron), which result in health effects that range from mild to life-threateningly severe (GNR 2014). Deficiencies in lesser-known but equally important nutrients like selenium, copper, or vitamins E and K, also carry serious health threats. Such needs often go unidentified and unaddressed until a medical condition associated with the deficiency manifests itself. Because of this invisibility, such deficiencies are widely referred to as 'hidden hunger'.

Micronutrient deficiencies particularly affect poor rural populations in low and middle income countries. But, perhaps surprisingly, micronutrient deficiencies are also associated with the growing problems of overweight and obesity, and with non-communicable diseases (Via 2012). This is because a low quality diet tends to be nutrient-poor whether based on highly processed foods from which nutrients have been removed during processing, or on nutrient-poor foods in food insecure environments (Oddo et al. 2012; Aitsi-Selmi 2014).

A number of approaches exist for tackling micronutrient deficiencies. For example, the fortification of staple grain flours or processed foods with vitamins and minerals is an effective approach. The mandatory fortification of wheat flour with folic acid has helped reduce widespread birth defects in many countries, while salt iodisation has proven to be effective globally in addressing the world's most prevalent, yet easily preventable, cause of brain damage (Berry et al. 2010; Zimmerman and Andersson 2012; WHO 2015). The promotion of greater agricultural and diet diversity to reduce micronutrient deficiencies is widely pursued (Brazil 2014; World Bank 2012) as is the delivery of micronutrient supplements through health systems or population-wide campaigns (UNICEF 2013).

How are Crops Biofortified?

There is substantial natural variation of micronutrient content (e.g. iron) in many staple crops, including maize, beans, cassava, rice and millet. In biofortification, conventional crop breeding techniques are used to identify varieties with particularly high concentration of desired nutrients. These are cross-bred with high-yielding varieties to develop biofortified varieties that have high levels of, for instance, zinc or betacarotene, in addition to other productivity traits desired by farmers. The biofortified seeds or cuttings are made available through extension programmes, market mechanisms or by programmes targeting nutritionally vulnerable smallholders.

The roles and responsibilities of men and women in food production and consumption differ: women are often in a key role in making decisions about household food consumption, but have less access to productive resources, assets and services, such as extension. These differences need to be understood and addressed at all stages of a biofortification intervention, from research to marketing and delivery.

Biofortified crops are being developed or adapted by national agricultural programmes in many low and middle income countries (HarvestPlus 2014b).The research and breeding programmes have been pursued in close collaboration with the Consultative Group on International Agricultural Research (CGIAR), mainly through its HarvestPlus programme, and other institutions around the world which together make up a network of 70 research partners working on biofortified crop development (HarvestPlus 2014c).

Some research has also been focused on improving micronutrient levels in crops through using transgenic methods when, for instance, natural variation in micronutrient content does not exist across varieties of a particular staple crop. In such cases, genes can be transplanted across species. This approach can involve considerable time and cost to ensure efficacy and food and environmental safety, and political debates about the use of transgenic crops for human consumption have slowed acceptance of transgenic varieties. Conventional breeding does not face these political and regulatory hurdles associated with transgenic varieties. So conventional breeding ensures a faster route to getting biofortified crops into the hands of farmers. All biofortified crops released to date (and those currently in development by HarvestPlus) are conventionally bred.

An important principle applied in the breeding process is to avoid compromising yield potential of biofortified varieties since this could make them less desirable to producers.

Since biofortification is aimed at the rural poor, who often live in remote marginal environments and consume most of the staple foods they produce, adoption of biofortified varieties increases the chance that their micronutrient needs can be met, even if other interventions are not reaching them. As a result, the potential for nutritional impact on a very large scale at relatively low cost has been cogently argued (Nestel et al. 2006; Stein et al. 2008), and many developing country governments have since invested in promoting biofortified seeds.

Biofortification – Evidence and Uptake



Images courtesy of: thinkstock.co.uk (left); Alamgir Hossain, HarvestPlus (centre); HarvestPlus (right)

The following outline covers a small selection of the many varieties that have so far been biofortified through public research organisations and released for open access in 27 developing countries to date. Reference is made to some of the studies that have confirmed the nutritional value and cost-effectiveness of such crops:

High-iron bean varieties are now being disseminated in Rwanda, Uganda and the Democratic Republic of Congo. In addition to having a higher iron content than traditional varieties, preliminary evidence shows that biofortified beans can improve iron status in Rwandan women (Haas et al. 2014). Acceptability (to taste) and uptake by farmers exposed to the new varieties have been good. In Rwanda, the UN's World Food Programme has purchased these beans for use in refugee camps with a view to improving iron intake among these nutritionally vulnerable consumers (WFP 2014).

Orange flesh sweet potato contains high levels of betacarotene (a building block for vitamin A). Tests show that 75% of the betacarotene is retained in the potato even after boiling in preparation for a meal (HarvestPlus 2014a). Consumer acceptability and nutritional impacts have been widely documented; that is, higher vitamin A status among consumers in some contexts (Hotz et al. 2012), and higher betacarotene concentrations in others (van Jaarsveld et al. 2005; Jamil et al. 2012). Africans have typically eaten white sweet potato which contains no vitamin A. Yields of orange flesh sweet potatoes are as high as those of the white sweet potatoes. Since 2009, eight African countries have released 31 orange flesh sweet potato varieties (HarvestPlus 2014d).

Cassava varieties with high levels of betacarotene are called yellow or golden cassava. These varietals were released in 2013 in Nigeria, where 100 million Nigerians eat cassava daily. Consuming yellow cassava has been shown in one small study to have small but significant improvements in vitamin A status of children (Talsma 2014). Currently, more than 500,000 farmers have received and planted this biofortified cassava (HarvestPlus 2014d). Human studies of nutritional impact are ongoing.

Maize with high betacarotene traits has been shown to be as efficacious as supplements (Gannon et al. 2014). Varieties of this orange maize were released in Zambia in 2012. They yield at least as well as traditional varieties and have been shown to have nutritional impact (de Moura et al. 2014). Biofortification has been highlighted in Zambia's National Food and Nutrition strategy, and has received strong government support, including tastings by members and staff of the Zambian Parliament.

Rice biofortified with zinc was released to farmers in Bangladesh in 2013 (Chowdhury 2014). The country's first biofortified rice varieties have a zinc content that is 30% higher than local varieties (HarvestPlus 2014a). The new rice matures faster than some traditional varieties and contains the zinc in the endosperm rather the outer periphery of the grain, which is usually lost to the consumer when rice is polished. The capacity to scale up high-zinc rice has still to be demonstrated, but if widely planted and consumed in poor households, it could contribute significantly to meeting zinc requirements in countries like Bangladesh, where the poor consume large amounts of rice daily and often sacrifice the consumption of other more nutrient-rich foods as a result.

Because of its significance to poor consumers in Asia and parts of Africa, and because rice shows low natural variation or complete absence in some micronutrients, rice has been a particular target of transgenic approaches to micronutrient enhancement. Transgenic research has focused on improving betacarotene and iron levels, but transgenic varieties have not yet been released.

Biofortified pearl millet, with higher iron and zinc content, is already being grown widely in Maharashtra, India. Studies showed that porridges or breads made with this new pearl millet provide a significant amount of iron and zinc (HarvestPlus 2014d). Iron biofortified millet has been shown to improve the iron status of school-aged children (Beer et al. 2014).

The Case for Biofortification

Agriculture has enormous potential to support improvements in nutrition (Global Panel 2014). In the past, much agricultural policy has focused successfully on increasing the productivity of staple crops, and this has supported increased supply as well as affordability by driving down prices for consumers. Biofortification of widely-grown staple crops carries another benefit: once higher levels of nutrients have been bred into staple crops, they remain present in the plants' seeds or cuttings for many years. Adopting varieties of these crops bred for high levels of micronutrients delivers nutritional benefits generation after generation, and can reach particularly the rural poor who grow the food staples which they consume. Once biofortified crops are part of national food systems, recurrent costs are low and production is sustainable.

When combined with interventions that promote dietary diversification, commercial fortification through food processing and targeted supplementation to specific population groups, widely produced, biofortifed crops can contribute to resolving nutrient deficiencies at a significant scale. Examples of substantive government encouragement of biofortification already exist. Nigeria has explicitly included biofortified crops in its national dietary guidelines and in its newly revised National Policy on Food and Nutrition (see case study), while Uganda has mounted large-scale public consumer education campaigns around orange flesh sweet potato.

Biofortification should always be regarded as one component of a suite of complementary strategies to reduce micronutrient deficiencies. Biofortified crops are relatively easy to incorporate into national programmes for improving food production and nutrition security. That is an advantage. However, biofortified crops should not be seen by governments and the private sector as an alternative to other nutrition-enhancing agricultural and food-related interventions, such as increasing the production, availability or affordability of nutrient dense foods like vegetables, fruit, milk, fish and meat, or intervening in food systems to preserve nutrient levels, fortify foods or encourage consumer demand and consumption. Further, the value of biofortification is enhanced by good agronomic practices, such as soil management and fertiliser use that improves levels of micronutrients in soils.

CASE STUDY

NIGERIA: Mainstreaming Nutrition within Agricultural Transformation

Image courtesy of Yassir Islam, HarvestPlus

The government of Nigeria has identified biofortification as a priority initiative in its efforts to support nutrition through agriculture. The National Council on Health approved the approach as a key activity to tackle micronutrient deficiencies, and enshrined it in the recently revised National Policy on Food and Nutrition. Initial efforts have focused on disseminating biofortified cassava stems and orange flesh sweet potato vines to farmers, while simultaneously promoting private sector involvement in the production, processing and marketing of these crops. Nigerian universities and National Agricultural Research Institutions are receiving funds specifically to support multiplication and expanded use of these two crops from 2011 onwards, while promoting research on additional staples, such as maize and small grains. With the newly-strengthened regulatory and legal framework and infrastructural support for the seed industry, multiplication programmes are expected to allow 80 million Nigerians to have access to more nutritious diets in the coming 4 years.

> "The challenge is no longer the science of biofortification – we know it works; our challenge as policy-makers is to scale up biofortified crops to reach millions of households through institutional, regulatory and financial policy.* "

Dr. Akinwumi Adesina
Global Panel member*; and Federal Minister of Agriculture and Rural Development, Nigeria*

* The Second Global Conference on Biofortification. Getting Nutritious Foods to People. March 2014.

Recommendations to Policymakers

Images courtesy of: Neil Palmer, CIAT (left); Alina Paul Bossuet, ICRISAT (right)

There are diverse policy opportunities in agriculture and food systems to improve diet quality and nutrition, as illustrated in the Global Panel's Technical Brief How can Agriculture and Food System Policies improve Nutrition? (Global Panel 2014). Among these, biofortification offers a potential win-win: it can improve nutrient quality of crops while also delivering high yields and good agronomic performance. Enhancing the nutrient content of staple foods represents a novel approach that is principally based on conventional crop breeding strategies. Biofortification is not a stand-alone solution, however. The most cost-effective combination of options is always context-specific, since micronutrient deficiencies vary by population and national capacities for different approaches are mixed.

The steps required for scaling up of biofortified crops involve the following:

1. **Identify national opportunities** for improving micronutrient provision and determine whether biofortified crops can make a valuable contribution, in concert with other interventions;

2. **Invest in national agricultural research** to generate or adapt crop varieties to have high content of essential vitamins and minerals while, at the same time, providing higher yields that will be attractive to producers. Opportunities for conventional breeding approaches should be identified and governments may wish to consider as well the pros and cons of transgenic approaches;

3. **Facilitate the registration, certification and production** of biofortified seeds or cuttings to allow for private and public sector multiplication and distribution;

4. **Invest in effective delivery strategies** to provide poor smallholder producers, both women and men, knowledge of, and access to biofortified crops, and promote their adoption and in-home consumption;

5. **Promote uptake** by farmers and consumption by targeting nutritionally-vulnerable populations through active social marketing, gender-sensitive extension guidance and potentially also via public sector procurement that supports institutional feeding programmes (such as in school feeding);

6. **Support the growing but critical evidence-base** on costs and effectiveness of biofortification strategies, and widely share success stories and best practices. Biofortification has the potential to reach large numbers of nutritionally vulnerable people, but measuring and tracking is important to understanding whether this potential is being achieved. Governments should invest in the data gathering and reporting systems to evaluate the effectiveness of all interventions aimed at improving agriculture, health and nutrition.

“We can see that after years of scientific research, we are just at the point where the research is no longer being argued or debated, where we can start taking the product of all of that work into the world at scale.* ”

Rachel Kyte

Global Panel member; and Vice President and Special Envoy, Climate Change Group, World Bank Group; and Chair of CGIAR Fund Council

* The Second Global Conference on Biofortification. Getting Nutritious Foods to People. March 2014.

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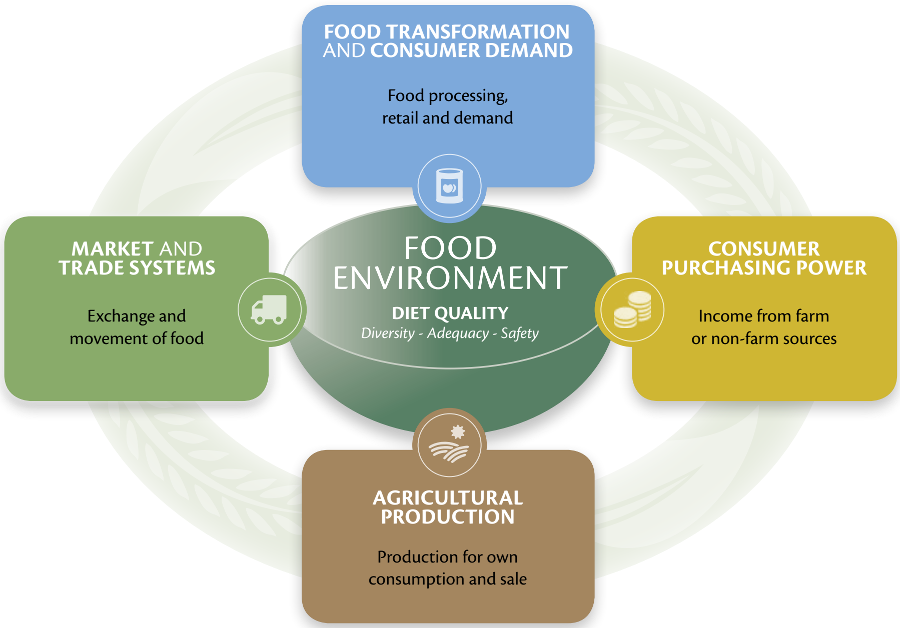
How can Agriculture and Food System Policies improve Nutrition?

The multiple burdens on health created today for low and middle income countries by food-related nutrition problems include not only persistent undernutrition and stunting, but also widespread vitamin and mineral deficiencies and growing prevalence of overweight, obesity and non-communicable diseases. These different forms of malnutrition limit people's opportunity to live healthy and productive lives and impede the growth of economies and whole societies.

The food environment from which consumers should be able to create healthy diets is influenced by four domains of economic activity:



In each of these domains, there is a range of policies that can have enormous influence on nutritional outcomes. In the Global Panel's technical brief, we explain how these policies can influence nutrition, positively and negatively. We make an argument for an integrated approach, drawing on policies from across these domains, and the need for more empirical evidence to identify successful approaches.

Find out more here: www.glopan.org/technical-brief

Biofortification is an example of a policy in the **AGRICULTURAL PRODUCTION** domain that can have a positive influence on nutritional outcomes.

Visit **www.glopan.org** to download the *Biofortification: An Agricultural Investment for Nutrition* policy and summary brief.

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