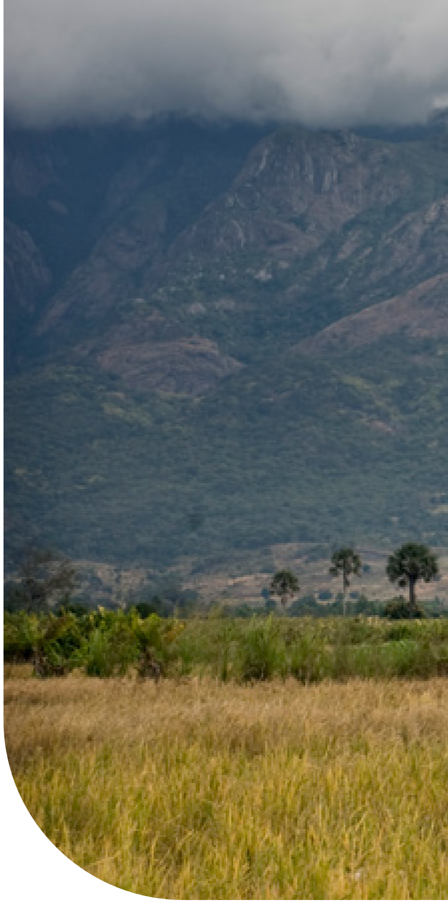
CHAPTER 6



Plant-Source Foods
Leveraging Crops for Nutrition and Healthy Diets

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KEY MESSAGES

- Food crops are key components of sustainable healthy diets. These crops, which include fruits, vegetables, and nutrient-enriched and whole grain staples, deliver energy and high concentrations of health-promoting vitamins, minerals, phytochemicals, and dietary fiber.
- Unhealthy diets are the leading behavioral risk factor for diet-related noncommunicable diseases (NCDs) and a major contributor to globally prevalent micronutrient deficiencies. Dietary improvements can meaningfully reduce NCD-related deaths and help address deficiencies in essential nutrients.
- Consumption of fruits and vegetables remains inadequate among many at-risk populations due to limited availability, affordability, and taste preferences, among other factors.
- Access to affordable and high-quality food crops for the poor in low- and middle-income countries is a global equity, health, and sustainability challenge. Seasonality, perishability, price instability, and household incomes, among other factors, shape the production of and access to non-staple food crops; consumption of staple crops remains relatively stable.
- Proven technologies, such as biofortification and some postharvest food processing techniques, can be scaled up to leverage crops for sustainable healthy diets.

To improve the contribution of plant-source foods to sustainable healthy diets, it is important to:

- Promote policies and accessible technologies that produce and supply more nutritious crops and foods, along with behavioral strategies that shift demand and consumer actions toward a sustainable healthy diet.
- Promote production and consumption of biofortified or fortified staple foods as complementary nutrition strategies where needed. These foods can be an equitable and affordable means of delivering nutrients to especially vulnerable populations, including women and children.
- Prioritize investments in crop diversity that can lead to increased accessibility, affordability, and appeal of safe and healthy diets when carried out alongside upgrades to market infrastructure and nutrition and hygiene education among farmers, value chain actors, and consumers.
- Create an enabling environment, supported by government and financial commitments, for scaling up crop-focused initiatives that can achieve nutrition and climate goals through holistic and context-specific multisectoral interventions that span agriculture, food, trade, and social protection.

Addressing the urgent need for food systems to support sustainable healthy diets will require a major improvement in the availability of and access to affordable, nutritious foods in low- and middle-income countries (LMICs), along with increased consumer demand for healthy diets. Plant-source foods are key components of sustainable healthy diets. This chapter examines food crops that could be leveraged to improve health outcomes; describes production systems and their role in providing populations access to highly nutritious crops; and presents examples of evidence-based technologies that improve the nutritional content of crops, especially for vulnerable populations. Together, these approaches can be leveraged to help vulnerable populations attain healthy diets and support planetary sustainability.

Sustainable healthy diets are nutritionally adequate, meaning they are health-promoting and disease-preventing, protecting against all forms of malnutrition and noncommunicable diseases (NCDs), and they are environmentally sustainable, meaning they must be produced and consumed within the safe limits of our planet's boundaries. Sustainable healthy diets provide the energy and essential nutrients required for growth and development, and to promote well-being; are accessible, affordable, safe, equitable, and culturally acceptable; and preserve biodiversity and have low impact on the environment.[1]

Diets should provide affordable nutritional adequacy year-round.[2] Crops that deliver energy and high concentrations of vitamins, minerals, phytochemicals, and dietary fiber — such as fruits, vegetables, whole grains, legumes, and roots — are among the principal components of healthy diets essential for well-being[3] (for a discussion of the role that animal-source foods play in sustainable healthy diets, see Chapter 7). The individual foods that make up a healthy diet vary with local food availability, as well as cultural context, which influences acceptability; and with individual characteristics, including age and other factors that determine an individual's particular nutrient requirements (see Chapter 3). The health outcomes associated with diets relate to patterns of eating, rather than to specific foods.[4]

More than a third of the world's population cannot afford to buy a selection of foods that constitute a healthy diet (see Chapter 4).[5] Unhealthy diets underpin all forms of malnutrition and are the leading behavioral risk factor for diet-related NCDs; overall, NCDs are responsible for over 73 percent of deaths.[6] Insidious and largely preventable micronutrient deficiencies alone affect half of all children and two-thirds of women, limiting human potential, especially in LMICs.[7]

Dietary improvements such as increasing fruit and vegetable intake can reduce NCD-related deaths by 20 percent.[8] However, the nutritional content and availability of foods eaten in LMICs are projected to deteriorate because of the effects of climate change and unsustainable resource use, including increasing temperatures and CO_2 levels,[9] soil degradation, freshwater scarcity, and decreasing biodiversity, as well as food price volatility and limited access to high-quality seeds and fertilizers caused by civil and public health crises — thus compromising diet quality.[10]

To deliver sufficient calories to populations experiencing hunger and undernutrition, international and national agricultural research centers have historically focused their efforts on traditional staples, such as white maize, cassava, rice, and wheat. These crops are high in energy (calorie-dense) but lack the nutrient density needed for optimal health, particularly after milling. In many settings, this focus on caloric sufficiency has impeded a shift toward policies and food systems that can also deliver the nutrient-rich or nutrient-enriched food crops required to improve diets. Nevertheless, efforts to leverage crops for sustainable healthy diets are now underway in many LMICs. These include promoting the production (and consumption) of fruits, vegetables, and whole grains, as well as improving the nutrient contribution of plant-source foods through biofortification of staple crops and fortification in postharvest food processing.

CROPS THAT CONTRIBUTE TO SUSTAINABLE HEALTHY DIETS

Fruits, vegetables, and whole grains (as well as other crops not specifically addressed in this chapter) are essential for sustainable healthy diets, but consumption of fruits and vegetables remains low because of limited availability and affordability. Whole grain consumption is also limited due to taste preferences, among other impediments. Addressing these challenges requires expanding supply and increasing demand (see Chapter 3).

AVAILABILITY AND AFFORDABILITY OF FRUITS AND VEGETABLES

Fruits and vegetables are a rich source of vitamins, minerals, fiber, and antioxidants that protect against numerous diseases. They also contribute significantly to agrobiodiversity: 1,097 cultivated vegetable species have been identified worldwide, and 1,250 fruit species have been identified in Latin America alone.[11] Yet, the global availability of fruits and vegetables remains too low to support the level of consumption that populations need to be healthy.

Projections based on forecasted impacts of economic, demographic, and technological change show that no countries in sub-Saharan Africa and few countries in Asia and the Pacific will be able to supply the World Health Organization's minimum recommended daily per capita intake of 400 grams of fruits and vegetables in 2050.[12] Given that national data are sparse or absent in LMICs on common factors that influence food supply and utilization (such as food waste, meals consumed outside of the home, smallholder farmer production, and foods obtained from non-retail or informal markets), this availability gap could be even larger than projected.[13]

Affordability is another obstacle. Purchasing fruits and vegetables from markets is beyond the financial means of many, despite being a relatively cheap source of diverse micronutrients compared with, for example, animal-source foods (see Chapters 4 and 7). Many families' food choices, especially economically disadvantaged households, prioritize calories over nutrients.

Even when fruits and vegetables are available and affordable, many people do not consume an adequate quantity due to factors such as food safety, taste preferences, convenience, cultural appropriateness, or limited knowledge and awareness of the associated health benefits (see Chapters 3 and 5).[14] Moreover, foodborne diseases caused by biological contamination of food are also an important threat to public health, particularly in LMICs and settings where value chains are long. Fruits and vegetables, as well as livestock and fish products, are among the riskiest foods for biological hazards.[15]

The CGIAR Research Initiative on Fruit and Vegetables for Sustainable Healthy Diets (FRESH) is using end-to-end food systems approaches to address desirability, affordability, accessibility, and availability constraints to increasing fruit and vegetable intake.[16] For example, in northern Tanzania, FRESH partners are implementing an end-to-end approach that includes scaling up good agricultural practices via production hubs, with a focus on training farmers of staple crops to incorporate vegetables through intercropping and other mixed farming systems, and training commercial vegetable producers to improve their resource use efficiency. FRESH is also linking with midstream value chain actors (collectors, traders, wholesalers, and retailers) to reduce postharvest losses and improve food safety. In addition, FRESH researchers are designing and testing food environment and demand-side interventions to address accessibility, affordability, and desirability constraints.

WHOLE GRAIN STAPLES

Whole grains are a "complete package," meaning they provide carbohydrates, a small amount of healthy fat, protein, vitamins, minerals, and dietary fiber. Cereal grains like wheat, maize, and rice constitute more than half of the caloric intake of vulnerable populations globally, but they are frequently eaten in refined form to increase their palatability, functionality, and shelf stability. Compared to refined grains, whole grain cereals offer substantially higher levels of nutrients. Essential nutrients such as zinc and iron can be lost from staple crops during processing. For example, milling can unintentionally strip off the outer parts of the grain that contain essential amino acids, fatty acids, iron, zinc, B vitamins, tocopherols, dietary fiber, and health-promoting phytochemicals.[17]

Investing in more nutritious staple foods, as part of a strategy to improve diets and health, is an equitable way to deliver essential nutrients sustainably. Staple foods are consumed as an everyday source of food by all members of households, including young children, adolescent girls, and women; they can offer a gender-equitable vehicle for enriching diets when these foods are naturally high in nutrients, biofortified, or industrially fortified. In many contexts, social norms dictate unequal food distribution among household members of especially nutrient-dense foods such as animal-source foods.[18] As a result, women and young children, who often eat least and last, suffer the greatest burden of malnutrition. For young children, who have high requirements for nutrients but small stomach capacity for foods, staples can only deliver adequate and safe nutrition when appropriately combined with other nutrient-dense foods and/or foods fortified with multiple micronutrients.[19] Supporting the development and promotion of more productive, resilient, and nutritious varieties of staple crops preferred by smallholder farmers and consumers across LMICs will be a key component of sustainable healthy diets and greater nutrition security.

Plant breeding efforts carried out by CGIAR focus on more than 20 high-priority staple crops — including cereals, legumes, and root and tuber crops — to jointly address the impacts of climate change, environmental degradation, and other challenges to agricultural productivity and nutrition, such as pests and plant diseases, while meeting the varietal preferences of producers and other value chain actors. Food crop technologies developed through CGIAR in collaboration with national agricultural research systems had been adopted on nearly 221 million hectares of land across LMICs as of 2020.[20]

CROP PRODUCTION FOR SUSTAINABLE HEALTHY DIETS

Multiple factors shape the production and utilization of plant-source foods, including seasonality, perishability, price instability, household incomes, and combinations of these factors. Making use of local production and traded food products, increasing production of lesser-known nutritious crops, and increasing the nutrient content of staple crops will all be important for a shift toward sustainable healthy diets.

GLOBAL OR LOCAL FOOD PRODUCTION

Local food production is increasingly viewed more favorably than national or global food production that requires long-distance trade.[21] This shift has been driven by the COVID-19 pandemic, other global crises, and the unsustainable nature of existing food systems. However, the local versus global debate is misleading. Although it is often assumed that local food systems produce higher-quality, fresher, and more sustainable foods, and that they reduce vulnerability to shocks that disrupt international markets, being (un)sustainable or (un)healthy is not unique to either local or global food systems, and resilience to shocks is not directly related to where food comes from. In each geographical context, efforts should be made to secure access to healthy foods through direct links with local producers where possible and useful, while giving consideration to the efficiency (productivity, price, seasonality, safety, and sustainability) of the whole system. Where efficiency is low, the price of food increases to the detriment of low-income populations. Trade through regional or global markets, therefore, can play a key role in bringing healthy, affordable foods to markets and populations in need.[22] However, globally, there is also an economic incentive to trade commodities that are ultra-processed and/or have a longer shelf life and stability over long distances — qualities lacking in fruits and vegetables.[23]

In some contexts, "orphan crops" — locally produced crops that have been neglected or underused by communities as well as plant breeders and policymakers — and wild edible species can be promoted to help fill nutritional gaps. Within this highly variable pool of plant products are fruits (for example, papaya, pumpkin, and mulberry) and vegetables (kale, okra, and sweet potatoes, among others) with exceptionally high nutritional value.[24] These crops are typically not traded internationally but are important for local and regional food security (including mitigation of shocks), locally available, often produced or harvested by farm households exclusively for home consumption or informal trade, and contribute to year-round healthy diets and agrobiodiversity.[25]

In any context, several challenges and trade-offs exist related to the choice of which crops to produce. First, it is vital to identify and address the challenges and hazards for local farmers, consumers, and the environment[26] entailed by increasing crop production. These challenges can include high water, chemical, and labor requirements, which could be addressed by introducing labor-saving techniques and increasing access to irrigation; and losses of fruits and vegetables due to perishability, which could be addressed with cold-chain technology.[27] Second, especially for underutilized crops, cultivars with enhanced pest and disease resistance must be developed, and postharvest technologies must be improved, for example to lengthen shelf life and increase protein digestibility. Third, promoting orphan crops (for example, through breeding, marketing, subsidies, conditional cash transfers and vouchers, and other strategies) may lead to a rapid expansion of external markets and development of large-scale and intensive production, which increases local incomes. As seen in the case of teff in Ethiopia, however, the growth of external markets can limit availability of these crops for local consumption, if appropriate political and economic protections are not put in place.[28]

CROP DIVERSIFICATION

Crop diversification — the practice of growing more than one crop in an area — can be accomplished by adding a new crop species or a new variety to a farm either spatially (for example, through a shift from monocropping to intercropping) or temporally (for example, by adding more varieties or crops to an existing rotation system).[29]

Crop diversification can improve human nutrition and sustainability through multiple, interlinked pathways.[30] Diverse crop systems such as intercropping and other regenerative agriculture intensification practices improve soil quality,[31] which promotes mineral uptake, crop yields, and better plant and planetary health. Growing a greater array of crop species on-farm through spatial crop diversification can improve dietary diversity and ecosystem resilience. Intercropping (growing more than one crop simultaneously on the same plot) not only enhances resource-use efficiency but also promotes agrobiodiversity. For example, in Guatemala, intercropping combinations, like maize-bean-potato, demonstrated the highest potential for nutrient adequacy per area unit of cultivated land and promoted soil health and cross-pollination.[32]

For smallholder farmers, diversification has been linked with dietary diversity, although other factors, notably good market access and increasing availability of diverse foods at markets, are more strongly associated with improvements in nutrition status.[33] However, the benefits of crop diversification extend beyond diets. Increasing the variety of crops grown can help reduce smallholder vulnerability to production losses and improve household food security, particularly as climate change, and associated extreme heat, floods, and droughts, put unpredictable stress on agriculture. And when crop diversification is linked to markets, it can create income-generating opportunities that improve farmer livelihoods.[34]

The nutritional contributions of diverse agricultural systems could be enhanced further with a combination of modern technologies, scientific progress, and traditional knowledge. For example, fusing available technologies like nutrient-enriched crops (biofortified crops with nutritional qualities that have been enhanced during plant growth)[35] with traditional crop diversification farming systems could address dietary and food security challenges, especially for smallholder farmers.[36] Breeding for improved nutrition also introduces otherwise untapped genetic variation for additional and non-negotiable farmer-preferred traits into new crop varieties, contributing to agricultural diversity.[37] Further research is needed to examine how integrating these diverse knowledge and technology systems along with nutrition education programs can impact diets in target populations (see Chapters 3 and 5).

Challenges to improving diet quality through crop diversification include farmers' reluctance to embrace the complexity of growing additional crops, limited market demand for new crops due to the absence of supportive government policies, and insufficient access to inputs, suitable equipment, technical expertise, and storage and transportation infrastructure.[38]

TECHNOLOGIES TO IMPROVE SUSTAINABLE HEALTHY DIETS

Food fortification and biofortification are well-established, proven strategies to address micronutrient deficiencies in vulnerable populations. These technologies can be further scaled up to improve access to critical nutrients.

BIOFORTIFICATION

Biofortification improves diet quality by enhancing the micronutrient density of widely consumed staple food crops through plant breeding, modern biotechnology, or agronomic practices such as fertilizers or foliar sprays.[39] Plant scientists screen for genetic variation in global plant gene banks to develop nutrient-dense cultivars and, through breeding, develop nutrient-dense cultivars of a particular food crop. Biofortified seeds are bred to also be high-yielding and with farmer-preferred traits that help offset climate-induced declines in agricultural productivity and nutrition. Once added nutrients are incorporated into a variety, they remain year-on-year as seeds are replanted. Hybrid seeds of any crop, biofortified or not, are not as productive if replanted from a previous harvest, so common practice is to purchase new hybrid seed every year.

Biofortified crops can be sustainably and readily integrated into existing cropping systems and programs that support healthy food systems. Therefore, plant breeding is a continuous forward-looking process that requires alignment of nutritional, climate-resilient, and pest-resistant traits with sufficient investment to maintain a healthy food supply.

More than 450 varieties of 13 nutrient-enriched biofortified crops have been released as public goods in more than 40 countries, where they are being eaten by more than 100 million people in LMIC farming households and millions more who purchase them through markets. These efforts have been led by HarvestPlus (IFPRI) and other CGIAR Centers in collaboration with national agricultural research systems and public and private sector partners in host countries, with strong evidence of positive impacts on nutrition (Box 1).

Increasing consumption of biofortified crops and foods is a highly cost-effective public health intervention, and among the highest value-for-money investments for economic development,[40] based on the World Bank criteria of cost per disability-adjusted life years (DALYs) saved.[41] Socioeconomic and sensory

BOX 1 PROVEN BENEFITS OF BIOFORTIFICATION

Randomized controlled studies consistently show positive effects of eating biofortified crops on nutrition and health across age groups and diverse geographies.

- Children in India who ate zinc-enriched wheat daily experienced a significant reduction in the number of days they spent with common infections.[a]
- Women in Rwanda and schoolchildren in India experienced improvements in iron status, cognition, and physical activity after regularly eating beans and pearl millet enriched with iron.[b]
- Children under five years of age in Kenya, Mozambique, Uganda, and Zambia had improved vitamin A status after eating vitamin A-enriched cassava, orange-fleshed sweet potato, or vitamin A-enriched maize, respectively, as main components of their diets.[c]
- Menus incorporating nutrient-rich biofortified foods were highly acceptable among Indian children attending childcare centers and schools and provided a significant portion of their daily nutrient requirements.[d]
- Consumers are highly accepting of biofortified varieties.[e]

Source: HarvestPlus, https://www.harvestplus.org/wp-content/uploads/2021/12/Biofortification_The-Evidence.pdf

evaluation studies examining farmers' and consumers' acceptance of biofortified crops show that farmers like their various agronomic and consumption attributes, are willing to buy them, and sustain adoption of nutrient-enriched varieties.[42]

CGIAR has committed to mainstreaming biofortification to scale up its impact and integrate breeding for improved micronutrient density across all its programs. Doing so takes investment and time (it takes 6 to 10 years to breed, test, and release a new biofortified variety of a crop), and scaling requires more than safeguarding seed supply and building consumer demand. Key market constraints need to be addressed with relevant stakeholders to enhance the competitiveness of biofortified value chains; businesses require support with tools for commercialization; and an enabling environment needs to be established through policies, standards, and regulations to increase consumer access. Adoption of seed standards is essential for identifying and aggregating biofortified seed along the supply chain, and certification provides official assurance of the genetic purity and quality of nutrient-enriched seeds produced.[43]

Successfully leveraging biofortified crops for sustainable healthy diets comes with challenges. National financial and political commitments are required to ensure the prioritization of nutrition traits within agricultural systems and a continual pipeline of nutrient-enriched seeds. Smallholder farmers need ready access to affordable high-quality biofortified crops, as well as training on how to grow and process biofortified crops after harvest. Additional evaluations of biofortification's impact, investment in biofortification businesses by the private sector, and timely implementation of policy frameworks and regulatory guidance are needed to enable this technology to deliver on its full potential to improve the quality of diets.

POSTHARVEST FOOD PROCESSING

Most foods are processed after harvest to reduce losses caused by pests (such as drying cereals, parboiling rice), remove toxic compounds to make foods edible (grating and heat treatment of cassava), preserve or enhance the flavor or texture of foods (refining cereals into flour or fermenting milk), remove pathogens (pasteurizing milk and fruit juices), and increase shelf life (decorticating and degerming cereals). Processing can improve the nutrition contribution of crops to healthy diets, but it can also do the opposite. Most notably, industrialized milling has led to the widespread removal of the most nutritious parts of grains, largely to prolong shelf life and improve palatability.

Large-scale food fortification (LSFF) is a proven and cost-effective nutrition strategy that adds vitamins and minerals during processing at industrial facilities to commonly consumed foods and suitable condiments. LSFF provides nutrient-dense, sustainable options to increase the diet quality of staple crops, particularly for populations that may not be able to access or afford a diverse diet, or where nutrients need to be restored due to processing losses. Because fortification can provide key minerals, such as iron and zinc, that have lower bioavailability in plant-based diets than in animal-based diets,[44] LSFF will remain an important technology even if global consumption of plant-based food increases.

When mandated by law and when coverage is high, LSFF has proven effective in significantly reducing the prevalence of micronutrient deficiencies, with greater impact among adults than in younger children, likely due to the larger amounts of the fortified food consumed.[45] Many countries have adopted mandatory fortification strategies, especially for maize, wheat, rice, oil, and salt, yet compliance varies. In LMICs, processing is mostly handled by small and medium enterprises.[46] Thus, developing enabling environments to increase the involvement of these enterprises in food fortification could enhance competition and increase the number, quality, and affordability of healthy diet components accessible to marginalized populations, including smallholder farmers.[47]

In addition, prioritizing the use of less-refined flours for cereal flour fortification could better leverage LSFF to enrich the quality of diets and protect against obesity and diet-related NCDs.[48] Shifting a significant portion of global grain consumption toward whole grains using both supply- and demand-side approaches would be a pivotal and achievable enhancement for diets and global food systems.

RECOMMENDATIONS

Diet quality is deteriorating and projected to worsen, with widespread implications for human and planetary health. Sustainable healthy diets should remain the global aspiration of food systems transformation, and nutritious crops are the fundamental currency of food systems that deliver sustainable healthy diets. Access to affordable and high-quality crops such as fruits, vegetables, and nutrient-enriched staples and other whole grains for the poor in LMICs is a global equity, health, and sustainability challenge.

To leverage crops for sustainable healthy diets, policymakers should:

- Combine policies and accessible technologies — intercropping, biofortification, and postharvest processing techniques such as LSFF — to produce and supply more nutritious crops and foods along with behavioral strategies to shift demand and behaviors toward sustainable healthy diets (see Chapters 3 and 5).
- Promote production and consumption of biofortified or fortified staple foods where needed. These foods are a major component of diets of all household members, including women and children, and thus can be an equitable and affordable means of delivering nutrients.
- Prioritize investments in crop diversity, including nutrient-rich crops such as fruits and vegetables, that in combination with upgrades to urban market infrastructure and nutrition and hygiene education among farmers, value chain actors, and consumers could lead to increased accessibility, affordability, and appeal of safe and healthy diets.
- Create an enabling environment, supported by government and financial commitments, for scaling up crop-focused initiatives that can achieve nutrition and climate goals through holistic and context-specific multisectoral interventions that span agriculture, food, trade, and social protection (see Chapter 8).