



# REVOLUTION HUNGER

Biofortification in a Food Chain  
==== Approach in =====

**WEST AFRICA**



# WEST AFRICA



## Executive Summary

About 800 million people suffer from hunger, but even more suffer from micronutrient malnutrition, also called “hidden hunger.” Deficiencies in essential micronutrients such as iodine, vitamin A, iron, and zinc malnutrition are major concerns. About 2 billion people, mainly women and young children are the most vulnerable. Deficiencies of iron and zinc lead to impaired growth and development, low daily work output, and increased mortality. Iron and zinc levels fall short when people suffer from food shortages, when consumed foods have low micronutrient content, or when absorption of micronutrients is inhibited by factors such as the presence of phytic acid and polyphenols. These chemical compounds, found in some plant-based foods, reduce the body’s ability to absorb iron. The presence of these compounds affects the bioavailability of certain staples in plant-based diets.

In the arid and semi-arid regions of West Africa, more than 300 million people rely on sorghum as their primary source of food. Sorghum is one of the few grain crops that grow well in arid climates, but it is deficient in most essential nutrients and is difficult to digest. In this area, more than 80% of children and up to 66% of women suffer from iron deficiency. Current interventions include diet supplements, dietary diversification, and food fortification. However, interventions have limited success because of poverty, poor local infrastructure and a lack of central food processing. In 2000, biofortification was introduced as a new strategy at the global level.

Biofortification uses the best traditional breeding practices and modern biotechnology to develop micronutrient-dense staple crops. In 2001, Wageningen University integrated a food chain

approach that combines soil science, soil-plant interactions, post harvest handling, food technology and human health and nutrition. The food chain approach to biofortification has shown some success in the West African countries of Benin and Burkina Faso. But there are still many problems to be solved.

### Strategies to Improve Micronutrient Malnutrition

- Dietary diversification is the raising and consumption of a greater variety of foods with high micronutrient content and bioavailability.
- Supplements, tablets, capsules or injections are taken to resolve dietary deficiencies in micronutrients.
- Food processing changes primary food crops through soaking, heating, fermenting, and other processing for food preservation, food safety, improved bioavailability, and to create enjoyable, more nutritious foods.
- Fortified foods are foods regularly consumed by the local population which have had nutrients added to improve health.
- Biofortification is improving the quality of a crop through breeding to add micronutrients.
- Food chain approach employs several of strategies including soil, water and crop management to enhance the uptake of iron and zinc in plants, food processing to increase iron and zinc concentrations and availability, and studies to determine if improved foods lead to improved health.

### YOUR ASSIGNMENT:

Your assignment is to advise national policy makers in Benin or Burkina Faso about which strategy or combination of strategies they should choose to solve iron and zinc deficiencies in rural and urban sorghum-growing and sorghum-consuming areas of West Africa.

### THINKING ABOUT GLOBAL ISSUES:

- What fortified foods do you eat? Which micronutrients are added?
- What is the story behind how specific fortified foods (i.e. fortified with calcium, vitamin D, iron, iodine) were initiated in the United States?
- What other factors of food production and distribution in the United States impact the quality of U.S. population’s health?





## Background

According to the article **Micronutrient Malnutrition Worldwide**, 800 million people are subject to malnutrition, but even more suffer from micronutrient malnutrition (Table 1). Iodine deficiencies are found in soils, surface water, drinking water, and local produce. The distribution of iodized salt, especially in China, has helped to reduce deficiencies from 1.6 billion in 1990 to 1.5 billion in 2000. An estimated 250,000 to 500,000 children become blind every year due to vitamin A deficiencies; half of them die within one year of losing their eyesight. Particularly vulnerable to iron deficiency are pregnant women and growing children. Blood loss caused by malaria, intestinal worms, lice and ticks also contribute to iron deficiencies. In 1989, it was estimated that 60% of pregnant women, 45% of non-pregnant women, 50% of children and adolescents, yet only 24% of men in developing countries were anemic (Demaeyer et al. 1989). Many school-aged children also suffer from iron deficiency anemia.

**Table 1: Extent of Micronutrient Malnutrition**

MICRONUTRIENT DEFICIENCY	NUMBER OF PEOPLE AFFECTED (BILLIONS)	REGIONS AFFECTED (IN GENERAL)
Iodine	1.6 (1990); 0.5 (2000)	118 countries
Vitamin A	0.5 of which 0.28 are under age 5 with blindness	118 countries, mainly in Africa and Southeast Asia
Iron	4.0 - 5.0 have iron deficiency; 2.0 have iron deficiency anemia	Worldwide, including Europe and the United States
Zinc	2.0	Worldwide

WHO. 2000. Nutrition

## Consequences

Micronutrient deficiencies generally cause impaired growth, a decrease in work output, and increased mortality of adults and children. Iodine deficiencies cause goiter and cretinism. Vitamin A deficiencies may lead to blindness and reduced resistance to infection.

Iron deficiency affects both industrial and developing countries. In developing countries, the risk of anemia is worsened by other micronutrient deficiencies (folic acid, vitamin A, vitamin B12), parasitic infections such as hookworm and malaria, and chronic infections such as HIV. In infants and children, anemia impairs psychomotor development, coordination, and school performance and in adults, iron deficiency reduces work capacity. In pregnant women, iron deficiencies bring risks of infant retardation, low birth weight and infant mortality (WHO 2000).

Zinc deficiency causes impaired growth and also causes diarrhea, immune deficiencies and skin and eye lesions. Selenium deficiency is associated with Kashin-Beck disease that leads to deformation of the joints affecting children between the ages of 5 and 13 years.

In countries with micronutrient malnutrition, these problems are a heavy burden on the health budget. Moreover, communities with lower work performance are not productive. In pupils with lower IQ, investment in education and training is less effective. Iron deficiency reduces the capacity for heavy manual work by 17% and the capacity for typical "blue collar" work by 5% (Hunt 2001). The total cognitive and physical losses in individuals affected by iron deficiency anemia alone lead to a 1-2% reduction in gross domestic product (GDP). There is evidence that some micronutrient deficiencies can aggravate the beneficial effects of others. For instance, zinc deficiency inhibits the bioconversion of beta-carotene into retinol (Dijkhuizen et al. 2004) causing vision problems.



## Important Concepts

### Micronutrient Malnutrition in Burkina Faso and Benin

Effective supply of micronutrients is determined by three factors: food availability and intake, nutrient content of the food, and the bioefficacy of food nutrients (absorption of nutrients).

Food intake depends on the availability of food and individual access to food. Local food production, markets, and distribution determine availability. Access to available food depends on income and price. Consumption is also determined by attractiveness (such as taste, color, and texture), safety (shelf life, type of spoilage) and by convenience of preparation of food (peeling and frying).

Diet can be improved by selecting foods containing high levels of nutrients or by adding nutrients to specific foods (fortification) or to the diet (supplements). Development of foods with increased nutrients can be done through breeding (biofortification) or by improving processing techniques. Public awareness of the importance of nutrients helps, but still poor food habits may impede behavior change relative to healthy dietary choices.

Bioavailability is the proportion of a nutrient that is available to be absorbed and used. For example, vitamin A needs to be converted to retinol to be used in the body. In cereal and grains, iron and zinc are bound to phytic acid, an anti-nutritional factor, causing up to 95% of these minerals to be unavailable for use in the human body. Food processing can affect the supply of micronutrients. Anti-nutritional factors present in one food item (such as tannins in tea) can negatively influence other nutrients in other food items consumed in the same meal (Hurrell et al. 1999; Hallberg and Rossander 1982). Generally, animal products are better sources of micronutrients than vegetable sources. Some food items promote absorption of micronutrients. For example, vitamin C from fruits and vegetables and proteins from animal products are known to promote micronutrient absorption.

### Socioeconomics in the Sorghum Area of Benin and Burkina Faso

#### *Prevalence of malnutrition*

In sub-Saharan Africa, the number of undernourished people increased from 169 million to 206 million between 1990-1992 and 2001-2003, but the proportion of undernourished fell from 35% to 32% of the population in the same period. In 2001-2003 Benin and Burkina Faso were among the countries doing better than average, with a decrease of 0.1 to 0.2 million in the number of undernourished people between 1990-1992 and 2001-2003 (FAO 2006b). Yet indicators for malnutrition in these two countries are still high, with a difference between the poorest and richest 20% of the population. (Table 2)

**Table 2: Indicators of Hunger and Malnutrition**

INDICATOR	BURKINA FASO	BENIN
Undernourished (% of population)	17	14
Children underweight for age (% under age 5, 1996-2004)	38	23
Children under height for age (% under age 5, 1996-2004)		
Among poorest 20% population	21	17
Among richest 20% population	15	12

UNDP 2006

#### *Zinc malnutrition*

A variety of indicators are used to look at malnutrition factors. In a study of three villages in northern Benin, measurements in 80 children between the ages of 6 and 8 years showed the prevalence of stunting at about 30% (Mitchikpe 2007). In a study in 18 villages in northern Burkina Faso, 72% of the 709 study children between 6 and 31 months of age were found to be zinc deficient (Muller et al. 2003). Supplementation with 12.5 milligrams of zinc six days a week for six months did reduce the prevalence of diarrhea (Muller et al. 2001). The estimated share of the population suffering from inadequate zinc intake in Burkina Faso and Benin is relatively low, at 13% and 17% respectively (Hotz and Brown 2004; Brown et al. 2001). However, local areas may differ from the average.



### **Iron malnutrition**

Anemia, generally seen as a sign of iron deficiency, is measured as hemoglobin levels in grams per liter in blood. Recent data report that prevalence of anemia in women between 14 and 49 years of age varies between 48% in Burkina Faso and 65% in Benin (UNICEF 2004).

Recent data also indicates that the prevalence of anemia in children under five years of age in both Benin and Burkina Faso exceeds 80% (UNICEF 2004). Of the reported anemic children in Benin, 9% had a severe form, 51% a moderate form, and 22% a mild form of anemia (EDSB 2001 in Ategbo and Dop 2003). In the study by Mitchkpe (2007) in 80 children between the ages six and eight years in northern Benin, the prevalence of anemia was 33% in the post-harvest season and 70% in the pre-harvest season.

### **Benin and Burkina Faso**

Populations in West Africa are largely agrarian with up to 80% of the population living in rural areas. Households generally produce, process and consume their own food because of poverty, lack of infrastructure (such as roads and markets) and the lack of transportation. In Burkina Faso and northern Benin the staple food is sorghum. At the market, households generally buy only processed products such as salt, sugar, and oil, or when their harvest has failed, they buy nationally produced foods. Micronutrient-rich foods such as meat, milk, and fish are part of meals at ceremonies but rarely enter the diet on ordinary days because they are too expensive.

Daily diets tend to consist largely of staple foods (sorghum, cassava, maize, or yam) and a watery vegetable sauce from tomato, onion, local eggplant, or peanut butter. In northern Benin, sorghum contributes 10-15% of the daily iron requirement and 1-2% of the daily zinc requirement in post-harvest and pre-harvest seasons respectively. But iron and zinc bioavailability is inhibited by the phytic acid and polyphenols present in these sorghum grains. People occasionally harvest fruits and vegetables from the wild to eat as snack foods or to replace food in times of

scarcity. Because these products are consumed irregularly and in very low quantities, their contribution to iron and zinc supply is limited.

Women at the household level process foods for daily meals. Households use a number of different food-processing techniques to prepare sorghum-based foods with different tastes, structures, and shelf lives. Within these processing methods, it is possible to distinguish techniques that are beneficial (fermentation, germination) or detrimental (over-cooking) for iron and zinc content and bioavailability in sorghum-based foods. The impact of local processing on micronutrient supply is still being researched.

### **Sorghum production**

In Burkina Faso and Benin, erratic rainfall conditions and low soil fertility limit food production. Soil and water conservation measures include application of manure, mulch, and compost and construction of stone bunds, all requiring large amounts of labor. The techniques used potentially affect zinc, iron and phytic acid concentrations in sorghum grain. The techniques are used to increase crop yields, but the impact on crop quality is hardly ever measured and is unknown.

Funds for buying fertilizer or building irrigation facilities are lacking except for cash crops such as cotton, for which fertilizers are provided through a loan to be repaid at the sale of the crop.

Several sorghum varieties exist, each with different amounts of iron, zinc, phytic acid and polyphenol. Access to improved sorghum varieties in the countryside is limited because of lack of seeds and agricultural extension assistance. More important, however, farmers rarely take risks in cultivating different varieties.

Public services, including electricity, clean water supply and health and education services, are scarce outside major cities. These factors, combined with a lack of roads and means of transport, make access to health and education service difficult.



## **THINKING ABOUT GLOBAL ISSUES**

- How can micronutrient malnutrition impact the economy of a developing country?  
A local community?
- Describe the similarities and differences of “hunger” and “hidden hunger.”



## Stakeholders

### *Children and Women*

Children and women have been identified as the groups most vulnerable to micronutrient malnutrition. They are also the stakeholders with the least amount of influence and power. These stakeholders should be reached with programs aimed at improving their situation. Programs result from policy decisions at different levels: local, national and international.

### *Local Civil Servants*

At the local level, civil servants at regional, provincial, and village levels implement policies. Local clinics for maternal care reach women at different stages of pregnancy and childcare. Children and their parents can also be reached through schools, and women can be reached through informal or formal women's groups. Some nongovernmental agencies (NGO's) work directly at the local level with churches and civil society groups, bypassing national decision makers. These programs tend to reach only a few stakeholders.

### *National Officials*

National agricultural research centers such as l'Institut de l'Environnement et Recherches Agricoles (NERA) in Burkina Faso and l'Institut National de Recherches Agricoles de Benin (NRAB) are important for agricultural research that can help improve nutrition through breeding and cultivation programs that contribute to the micronutrient supply in daily diets. The decision makers in developing countries such as Benin and Burkina Faso are responsible for direct execution of programs at the local and national level. Many of these programs depend heavily on international donors based in their countries to implement policies.

### *UN Organizations*

#### *WHO*

The World Health Organization is addressing micronutrient issues including iron deficiency and anemia using three methods:

1. Dietary diversification including iron-rich foods, food fortification, improving iron absorption, and iron supplementation.
2. Immunization programs for malaria and hookworm to control infection.
3. Prevention and control of other nutritional deficiencies, such as vitamin B12 folic acid, and vitamin A.

#### *UNICEF*

Has supported child health and nutrition by reducing the prevalence of anemia (including iron deficiency) by one third by 2010. They support educational campaigns to teach the important role of iron in the diet. But for people who cannot afford or do not have access to iron-rich foods (liver, red meats, eggs, fish, whole-grain bread and legumes), this is not a solution. Another approach is to fortify staples such as flour. The program can also supply supplements during pregnancy to help prevent anemia in mothers and their babies. In malaria-endemic countries, bed nets are provided because malaria is often the major factor underlying anemia. The UNICEF child health program in Burkina Faso provides immunization and micronutrient supplementation. Women receive training in health, nutrition, and hygiene. Collaboration between UNICEF and the WHO has led to a 40% reduction in guinea-worm cases, contributing to reduced body-iron losses.

### *International and National NGOs*

An NGO, a nongovernmental organization, is an independent group that pursues activities to relieve suffering, protect the environment, or provide basic social services.

#### *Helen Keller International (HKI)*

Is an organization that treats preventable blindness by distributing vitamin A twice a year to 9 million preschool children in Africa, including Burkina Faso. HKI helps communities address long-term health by establishing community gardens and cultivating foods rich in vitamin A: fruits and vegetables. Surplus foods can be sold for additional income. One intervention was aimed at replacing a white-fleshed sweet potato with an orange-fleshed sweet potato high in vitamin A.

#### *The Micronutrient Initiative (MI)*

Established in 1992, after the World Summit for Children. The MI has been working to protect the world's children from micronutrient malnutrition. They partnered with UNICEF and HKI to reach 16 million children with vitamin A capsules as part of the delivery of regular health services. They are also working with government and industry in the fortification of cereal flour, cooking oil, salt and condiments.



## Stakeholders

### *Harvest Plus*

This program seeks to reduce micronutrient malnutrition among the poor by combining agriculture and nutrition research to breed nutrient-dense foods (biofortification). Coordinated research is being done in plant breeding, human nutrition and crops at both national and international universities. Biofortification efforts are focused on six crops: beans, cassava, maize, rice, sweet potatoes and wheat. Additional studies have begun to examine other crops that are also important to those facing micronutrient deficiencies: bananas/plantains, barley, cowpeas, groundnuts, lentils, millet, pigeon peas, potatoes, sorghum and yams. Harvest Plus recognizes that conventional breeding techniques take time and therefore they promote the research on genetically modified organisms (GMOs) to increase the speed of improvements.

### *Grand Challenges in Global Health*

The Grand Challenges in Global Health projects focus on 14 major global health challenges with the aim of engaging creative minds to work on solutions that could lead to breakthrough advances for the developing world. The approach is to use transgenesis, biochemistry, selective breeding of plants, and other appropriate technologies to provide combinations of micronutrients, vitamins, and essential amino acids in a bioavailable form in local crops, such as rice, wheat, sorghum, millets, cassava, potatoes, maize, bananas and others, or to enhance energy density and improve protein quality in such foods, in a socially and culturally acceptable way. Nutritionally Enhanced Sorghum for Arid and Semi Arid Tropical Ardas of Africa is one of four projects currently underway.

### *African Biofortified Sorghum Project*

The ABS project seeks to develop a more nutritious and easily digestible sorghum variety that contains increased levels of essential amino acids, especially lysine, increased levels of Vitamins A and more available iron and zinc. The success of the project could improve the health of 300 million people who depend on sorghum as a staple food in Africa. The ABS consortium is a strategic alliance that leverages the best of public, private and academic sectors to deliver an effective product that fights malnutrition in Africa. The consortium contributes to the advancement of science on the continent, building valuable knowledge in sorghum research, establishing scientific infrastructure, training African scientists and contributing to a better understanding of biotechnology issues in Africa.

### *Wageningen University (WU)*

WU started an international research program on sorghum in Benin and Burkina Faso using a food chain approach. They looked at soils and plant and food processing to enhance iron and zinc concentration in foods. Research showed that the use of phosphorous in the fertilization practices of a grain crop would increase yields and enhance micronutrients uptake levels. Research scientists also looked at current food processing methods that deactivate or remove phytic acid and polyphenols. In addition to improved fertilizing practices, several food-processing activities have been found to reduce phytic acid levels in the sorghum-based foods, potentially increasing iron and zinc bioavailability. (Kayode et al. 2007, and Kayode, Nout, et al. 2006). Studies have shown the processing and milling techniques of grains affect the bioavailability of iron and zinc. Work at WU indicates that both approaches, biofortification (breeding) and food chain (genotype, environmental factors and food processing) work together to improve nutrition.



## THINKING ABOUT GLOBAL ISSUES

- How does collaboration play an essential role for the international stakeholder programs working on this problem?
- Compare and contrast the goals of each of the stakeholders.



## Strategies/Policy Options

Six policy options present themselves as possible strategies: dietary diversification, supplements, food processing, fortified foods, biofortification and a food chain approach.

### **Dietary Diversification**

One action is to identify foods with high micronutrients and promote their consumption. By encouraging the cultivation of a variety of crops or raising livestock, people are more likely to consume local food. This also creates income—another way of improving the diet. Changing behavior through education and communication, especially for women, can also help to diversify diets.

### **Supplements**

This intervention focuses on the use of tablets, capsules or injections for groups experiencing micronutrient malnutrition. This would mean daily consumption of iron pills. Vitamin A and iodine can be stored in the body, which means larger single doses could be used. For children, studies have shown that 2 single-doses of vitamin A per year can be effective. This intervention is successful when it is made a part of the health habits of a targeted group, for example during regular immunizations for children.

### **Food Processing**

Processing can turn crops into enjoyable, nutritious dishes. In addition, processing helps to preserve foods for storage and distribution. Unfortunately, some processing removes micronutrients.

### **Fortified Foods**

Fortification is the addition of nutrients to popular foods. Examples are iodized salt and vitamin A, and D enriched margarine. These food items need to be ones that are affordable, accessible and regularly consumed by a targeted group. In order to make this initiative successful, traditional, non-fortified foods need to be taken out of the market.

### **Biofortification**

Breeding (both conventional and GMO techniques) can be used to increase the micronutrients in a food crop. Examples are golden rice and orange-fleshed sweet potato (both-beta carotene rich), high protein maize and low-phytic acid barley. Seeds must perform well in different soils and environmental conditions.

### **Food Chain Approach**

This approach aims to increase the supply of cereal-based foods rich in zinc and iron by improving many factors: biofortification, processing, and dietary diversity. Research focuses on soil, water and crop management as well as processing techniques and ways to improve food choices of targeted groups. Studies also determine whether improved foods lead to better health. This interdisciplinary approach helps to decide whether slight modifications at different levels can produce adequate health benefits.



## THINKING ABOUT GLOBAL ISSUES

- What other crops have been successfully biofortified for malnourished populations?
- What other “food challenges” might be solved using biofortification?

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